ATTACHMENT 3 - PROJECT JUSTIFICATION

3.1 Project Summary Table

Table 4 – 2014 Drought Solicitation Project Summary

Drought Project Element		Interregional Landscape Water Demand Reduction Program
D.1	Provide immediate regional drought preparedness	X
D.2	Increase local water supply reliability and the delivery of safe drinking water	X
D.3	Assist water suppliers and regions to implement conservation programs and measures that are not locally cost effective	X
D.4	Reduce water quality conflicts or ecosystem conflicts created by the drought	X
IRWM Project Element		
IR.1	Water supply reliability, water conservation, and water use efficiency	X
IR.2	Stormwater capture, storage, cleanup, treatment, and management	
IR.3	Removal of invasive non-native species; creation and enhancement of wetlands; and acquisition, protection, and restoration of open space and watershed lands	
IR.4	Non-point source pollution reduction, management, and monitoring	X
IR.5	Groundwater recharge and management projects	
IR.6	Contaminant and salt removal through reclamation, desalting, and other treatment technologies and conveyance of reclaimed water for distribution to users	
IR.7	Water banking, exchange, reclamation, and improvement of water quality	
IR.8	Planning and implementation of multipurpose flood management programs	
IR.9	Watershed protection and management	X
IR.10	Drinking water treatment and distribution	
IR.11	Ecosystem and fisheries restoration and protection	

3.2 Project Description

3.2.1 Brief Description (25 words or less):

SAWPA-implemented interregional program for sustainable water-use conservation through a suite of measures: turf removal, technology-based information system, and conservation-based rate structures.

3.2.2 Implementing Agency/Organization

The Santa Ana Watershed Project Authority (SAWPA) is the applicant and will establish a process for implementation and expenditure of the grant funding.

SAWPA is composed of the funding partners Eastern Municipal Water District (EMWD), Inland Empire Utilities Agency (IEUA), Orange County Water District (OCWD), San Bernardino Valley Municipal Water District

(SBVMWD), and Western Municipal Water District (WMWD), which will assist with the Program's implementation.

SAWPA will collaborate with the Upper Santa Margarita Watershed (USMW) IRWM to assist with the implementation of the Program in their region.

3.2.3 How Project Will Address Drought Impacts, How It Is an Eligible Project Type, and Why Expedited Funding Is Needed (One page, min. 10 pt font):

This Program inherently includes the following eligibility attributes:

- Drought preparedness:
  - The Program is entirely a water conservation program.
  - The Program improves landscaping efficiencies by replacing turf with water efficient landscaping.
  - The Program achieves long term, permanent water conservation.
- Reliability of the local water supply will be increased by promotion of reasonable water use, reducing wasteful demands.
- The Program is not locally cost effective. Funding will be used to implement a conservation program that cannot be justified on financial characteristics alone; however, it is exceptionally beneficial for immediate and long-term conservation.
- The Program will reduce water quality conflicts by reducing poor-quality urban runoff, which contributes to polluting creeks and the ocean with fertilizers and pesticides.

Immediate and sustainable water conservation will be achieved by removing turf, providing feedback to customers with water budgets, performing retail customer comparison, and/or implementation of conservation-based rate structures. Aerial imagery is an integral component to all the Program tasks identified within this application. It is essential for locating turf, increasing accuracy of technology-based conservation, and as a foundation for water budget rates. These immediate conservation measures will reduce dependence on State Water Project (SWP) supplies, extraction from declining groundwater basins, and dependence on Colorado River supplies. Furthermore, this is a collaborative and interregional effort by agencies throughout the Santa Ana River Watershed and portions of the USMW, emphasizing the transformational, behavioral change in water use, including the following elements:

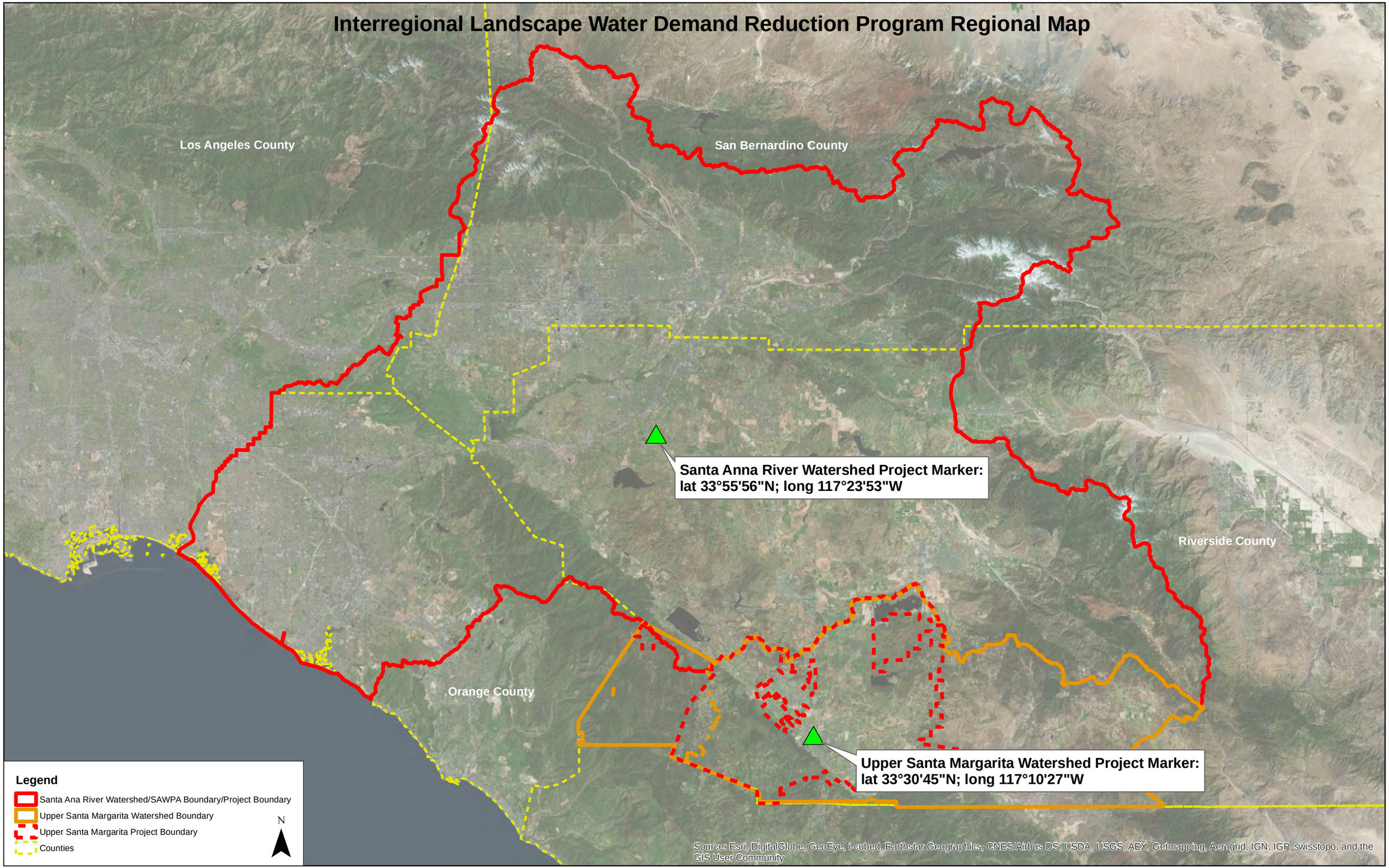
- ***Turf Removal.*** This element will integrate with local agencies' turf removal programs to target Commercial/ Institutional/Homeowners Association customers. Turf will be removed and replaced with more water-efficient landscaping, permanently reducing wasteful irrigation. "Funding Need" is justified because turf replacement is not locally cost effective, as cost savings do not outweigh the initial cost of replacement; however, water savings are significant. Additionally, turf irrigation is a significant contributor to poor-quality urban runoff, as it is typically overwatered and over fertilized. "Institutional" use includes schools, parks, etc.

- ***Technology-Based Information System.*** This element is an effective and rapid educational tool to change water use behavior. This system will transform the customers' view of the nexus between water's value and its reasonable use and result in permanent conservation. With more accurate landscape data provided through the aerial imaging measurement technology, data and outreach are significantly enhanced for accuracy to each customer. Should the drought persist, this can be a rapid updating tool for agencies to sort and rank accounts that waste water and provide feedback into the customer outreach campaign. "Funding Need" is due to the reduced budgets of agencies to expend funds during financially constrained times.

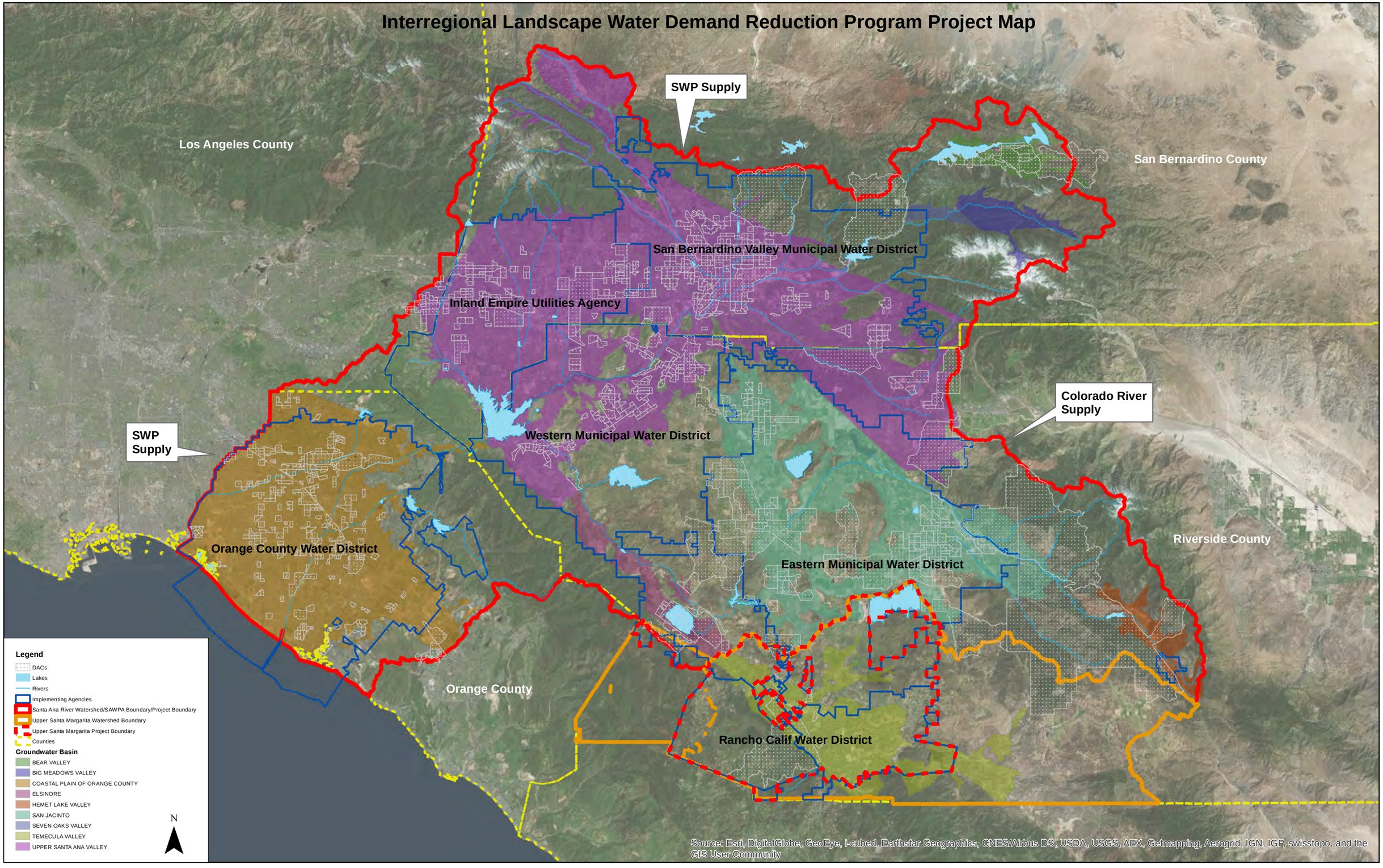
- ***Conservation-based Rate Structures.*** Early initiators of conservation-based rate structures have demonstrated significant water demand reduction, which assists in improving water supply reliability. Whether full implementation of budget-based rates or other conservation-based rates are used, this will provide steps toward transformational acceptance of rate structures' implementation to create permanent water conservation. This is a system change to permanently reduce water demands and the impacts noted above. "Funding Need" is due to the reduced budgets of agencies as noted above.

The adverse financial impact of the 6 years of recession coupled with the current drought have impacted water purveyors severely, greatly limiting their financial ability to implement new initiatives. The requested funding is needed to more effectively initiate more robust conservation programs that otherwise would not be implemented.

Interregional Landscape Water Demand Reduction Program Regional Map



Interregional Landscape Water Demand Reduction Program Project Map



3.3 Project Physical Benefits

Table 5. Annual Project Physical Benefits

Project Name: Interregional Landscape Water Demand Reduction Program
Type of Benefit Claimed: Water Supply Saved
Units of the Benefit Claimed: AF/year
Additional Information about this Benefit: N/A.

(a)	(b)	(c)	(d)
	PHYSICAL BENEFITS		
Year	Without Project	With Project	Change Resulting from Project (c) – (b)
2015	0	2,841	2,841
2016	0	5,945	5,945
2017	0	7,841	7,841
Etc.	0	7,841	7,841
Last Year of Project Life: 2037	0	7,841	7,841

Comments:

This water conservation program targets new water conservation and behavioral change; therefore, it is assumed that "Without Project" estimates are zero for presentation purposes.

Project Name: Interregional Landscape Water Demand Reduction Program
Type of Benefit Claimed: Energy Saved
Units of the Benefit Claimed: kWh
Additional Information about this Benefit: See comments for conversion of water saved to energy saved.

(a)	(b)	(c)	(d)
	Physical Benefits		
Year	Without Project	With Project	Change Resulting from Project (c) – (b)
2015	0	6,961,248	6,961,248
2016	0	14,565,145	14,565,145
2017	0	19,209,385	19,209,385
Etc.	0	19,209,385	19,209,385
Last Year of Project Life: 2037	0	19,209,385	19,209,385

Comments:

According to the California Energy Commission's 2005 report California's Water-Energy Relationship, the amount of energy required to pump 1 AF to Southern California is on the order of 2,450 kilowatt-hours (average of East Branch and West Branch pumping to serve IEUA, Figure 2-2, pg 23).

Project Name: Interregional Landscape Water Demand Reduction Program
Type of Benefit Claimed: Carbon Emissions Saved
Units of the Benefit Claimed: MT CO_2
Additional Information about this Benefit: See comments for conversion of water saved to energy saved.

(a)	(b)	(c)	(d)
	Physical Benefits		
Year	Without Project	With Project	Change Resulting from Project (c) – (b)
2015	0	4,800	4,800
2016	0	10,043	10,043
2017	0	13,246	13,246
Etc.	0	13,246	13,246
Last Year of Project Life: 2037	0	13,246	13,246

Comments:

According to the US Environmental Protection Agency, the emission rate of CO_2 per kWh is 6.89551 × 10-4 metric tons CO2 per kWh (http://www.epa.gov/cleanenergy/energy-resources/refs.html)

3.4 Technical Analysis of Physical Benefits Claimed

The Interregional Landscape Water Demand Reduction Program (Program) is being proposed as a result of the 2014 statewide drought and future water supply reliability. The Program has four key physical benefits:

- Reduction of dependence on imported water supply (SWP and Colorado River supplies) (water supply savings);
- Energy savings;
- Reduction of carbon emissions; and
- Reduction of deleterious urban runoff water quality.

Savings in imported water supply is the primary physical benefit, with energy savings, carbon emissions savings and reduction of poor quality, urban runoff being secondary benefits. The Program will result in the implementation of water conservation tools and measures that will reduce the both the Santa Ana River Watershed's and USMW's need for imported water and improve water supply reliability. The savings in imported water supply lead to savings in energy and carbon emissions for the pumping and related facilities used to transport water to Southern California from the Bay–Delta via the California Aqueduct. Although approximately 60% of that energy used for conveying Bay–Delta supply is from hydroelectric power generation, it is assumed that reduction of this electrical demand will indirectly reduce reliance on fossil-fuel electrical generation.

3.4.1 Reduction of Imported Water Reliance

The Program will reduce water demands, and therefore reduce reliance on imported water, by over 7,841 AF/year by implementing turf removal, technology-based conservation outreach, and conservation-based water rates. This water conservation is critically needed, as the recent drought has caused elimination of the SWP as a supply source and significant reduction in groundwater recharge, resulting in severe depletion of groundwater storage and reduction of groundwater to critical levels as discussed in Attachment 2. The following elements of the Program will achieve these savings.

3.4.1.1 Turf Removal

Using estimates from data the Municipal Water District of Orange County (MWDOC) presented in 2013 (Reference: Baum-Haley, Melissa, *Get a CLWUE! The Comprehensive Landscape Water Use Efficiency Program* PowerPoint Presentation, MWDOC, October 3, 2013), we assume turf removal will provide a reduction in water demand of 44 gallons/SF of turf removal and replacement with less irrigation demanding landscape. For this element, the project will create the permanent reduction of 668 AF/year reliance on imported water (as presented in Table A, by removing approximately 4,950,000 SF of turf over a 3-year period.

Table A. Projected Turf Removal and Incremental Water Savings by Year

Year	Turf Removed in SAR Watershed (SF)	Turf Removed in USMW (SF)	Total Turf Removed (SF)	Water Savings[1] (gallons/SF removed)	Annual Water Savings (million gallons)	Annual Water Savings (AF/year)
1	2,000,000	500,000	2,500,000	44	110	338
2	1,300,000	400,000	1,700,000	44	75	230
3	700,000	50,000	750,000	44	33	101
Totals:	4,000,000	950,000	4,950,000	--	218	668

Notes:

[1] Value based on 2013 MWD presentation (Source: Baum-Haley, Melissa, *Get a CLWUE! The Comprehensive Landscape Water Use Efficiency Program* PowerPoint Presentation, MWDOC, October 3, 2013, slide #11 entitled "Turf Removal Rebate Program")

It is recognized that significant "unnecessary" turf exists as a legacy throughout the watersheds, and the drought and increased incentives to remove turf provides an opportunity to save more water immediately, particularly compared to other areas of California that receive more annual precipitation (i.e., turf removal in arid Southern California saves more water than the same turf removal in wetter areas of the State, all other things being equal).

MWD has reported that each incentive increase of their turf removal program has increased the participation by over 50% (MWD May 14, 2014 News Release, page 1). In May 2014, MWD further increased the rebate incentive from $1/SF to $2/SF and Santa Ana River Watershed and USMW water agencies have immediately seen a significant increase in residential applications, although only minor interest by non-residential customers, who could produce substantial water savings through this Program.

Overall, existing incentive programs for turf removal have resulted in participation heavily weighted by residential projects. MWDOC analysis of existing program data (actual cost accounting of turf removal and landscape replacement receipts) identifies that non-residential turf replacement projects are more costly ($6–$9/SF, $7.50/SF average) compared to residential projects at about $3/SF actual total cost. This is likely due to homeowners providing labor themselves in many cases and landscape designs with less planted density. MWDOC turf removal program participation over the last 4 years by non-residential customers was only 15% of participation; however, it averaged significantly higher square footage per project by a factor of 10, averaging removal of 11,700 SF/project compared to residential projects averaging 1,160 SF/project.

For this Program, the actual cost of removing 4,950,000 SF and replacing with lower water demand landscaping at an average $7.50/SF plus $883,333 for share of aerial imagery cost and $300,000 for implementation outreach cost, for a total of $38,308,333

This Program will integrate with MWD's and other local agency (such as MWDOC and WMWD; SBVMWD is planning to duplicate MWD's program in their service area) turf removal programs by targeting commercial/institutional/HOA large turf parcels with an additional $1/SF funding (total up to $3/SF, or approximately 40% of actual cost) to better incentivize implementation by non-residential parcels. Therefore, the program will emphasize non-residential customers to achieve additional water supply reduction in this land use classification not expected to participate in the lower incentive rebate program.

High resolution aerial images developed across the watersheds will provide the high-tech ability to locate high-turf percentage accounts to participate in turf removal rebate programs. This will enhance turf rebate effectiveness by identifying and directing outreach to the highest-yield customers. Landscape conversion is estimated to range from $6/SF to $9/SF. The program will enhance local funding from $2/SF to $3/SF for customers to remove 4,950,000 SF of turf.

This water conservation program targets new water conservation and behavioral change; therefore, it is assumed that "Without Project" estimates are zero for presentation purposes.

No new facilities or policies are needed to implement this element of the Program, nor are there any potential adverse physical effects due to turf replacement.

3.4.1.2 Technology-Based Information System

This element of the Program will result in estimated conservation and cumulative reduction of imported water need by 3,236 AF/year in 3 years (as presented in Table B) by reaching an estimated 150,600 customers with technology-based information systems. Note that assuming Program implementation will take 6 months, only one-half of the Year 3 value will be included in the total savings within the Program period.

Table B. Projected Water Use Reduction Due to Technology-Based Conservation by Year

Year	Savings Rate[1,2]	Usage/Customer[3] (AF/year)	Number of Customers[4]	Annual Water Savings[5] (AF/year)
1	5%	0.665	150,600	5,007
2	3%	0.632	150,600	2,855
3	2%	0.613	150,600	1,846
			Total Average Year 3 Projected Savings (AF/year)	3,236

Notes:

[1] Year 1 savings based on findings at EBMUD for implementation of WaterSmart Software (Source: Mitchell, D. and Chesnutt, T. *Evaluation of East Bay Municipal Utility District's Pilot of WaterSmart Home Water Reports*. California Water Foundation and East Bay Municipal Utility District. December 2013, specific pages iv, 34, 56 and 60.) Year 1 savings coincides with the last 6 months of 2015 and first 6 months of 2016 (assumes 6 months to implement).

[2] Year 2 and 3 savings based on findings from longer-term persistence analysis of behavioral nudges (Source: Bernedo, M., Ferraro, P. and Price, M. *The Persistent Impacts of Norm-based Messaging and their Implications for Water Conservation*. Journal of Consumer Policy, Table 3 page 10.) Savings are on top of previous year. Year 2 savings coincide with July 2016-June 2017. Year 3 savings occur July 2017 to Dec 2017 (6 months only).

[3] Annual average household water usage calculated for Year 1 based on 180 gpd/capita (Source: http://www.sawpa.org/wp-content/uploads/2014/01/8-Per-Capita-Water-Use.pdf) and assuming 3.3 persons/EDU. Subsequent years' usage reduced by the savings rates listed in column two.

[4] Of the total number of customers, 600 are in the USMW. The remaining 150,000 are in the Santa Ana River Watershed

[5] Year 3 water savings reported for project will only occur for last 6 months of 2017; therefore, only half of this value will be used in the water savings benefits (see Table 5).

The Technology-Based Information System tool will be an effective and rapid educational tool to use to immediately obtain water conservation. With accurate landscape area data provided through the aerial imaging/square footage measurement technology, the data and outreach are significantly enhanced for accuracy to each customer. In addition, should the drought persist, the water efficiency calculator mentioned above can be a rapid updating tool for agencies to sort and rank accounts that waste water and feed back into the Technology-Based Conservation customer outreach campaign. Implementation of this approach may include agency development of the tool, a collaborative approach between agencies to develop the tool, or third-party vendors such as WaterSmart.

For the Program, we are conservatively basing our analysis on the application of 1 year's funding of the Technology-based Conservation outreach, and include the documented water conservation effects over a 3-year duration. This approach intends to obtain water savings and demonstrate the potential savings to water purveyors. Ultimately, this will provide agencies the ability to document the water savings success both individually and watershed-wide to support whether continued funding locally after Year 1 is cost effective.

Continuation or Durability effects (i.e., the ongoing effect if the reports continue over time, past 1 year) as opposed to the Persistence effects (i.e., the effect if the reports stop) have been studied for this new approach. These studies indicate that reasonable expectation of water savings include 5% in the first year, 3% in the second year, and 2% in the third year if the reports are only provided for the first year (therefore, the conservation effect declines in subsequent years) (References: Results showing 5% for EBMUD: Mitchell, D. and T. Chesnutt, *Evaluation of East Bay Municipal Utility District's Pilot of WaterSmart Home Water Reports*, California Water Foundation and East Bay Municipal Utility District, December 2013, specific pages iv, 34, 56 and 60; Results showing persistence of one time message: Bernedo, M., P. Ferraro, and M. Price, "The Persistent Impacts of Norm-Based Messaging and Their Implications for Water Conservation," *Journal of Consumer Policy*, May 25, 2014, Table 3, page 10). It should be noted that the Continuation or Durability effects of continued use illustrate increased savings.

Actual local cost for participation of 150,600 customers is $1,504,950 plus $883,333 for share of aerial imagery cost and $248,160 for implementation outreach cost, for a total of $2,636,443/year.

No new facilities or policies are needed to implement this element of the Program, nor are there any potential adverse physical effects due to turf replacement.

3.4.1.3 Conservation-Based Water Rates

Conservation-based water rates influence and can reduce any and all water use, particularly wasted water. Using the state efficiency standards, this task can help agencies meet long-term conservation legislation and hold water efficiency gains during drought restriction times.

Per Proposition 26 and 218, water rates must be structured based on "cost of service." While this requirement may somewhat hinder utilizing higher prices to incentivize water use reduction, water rates can be developed meeting these requirements while also providing a level of conservation. Water rates can be developed in creative structures that accurately fund fixed costs, variable costs, differing water supplies' costs, and water conservation programs while also financially conveying to the rate payers the value of their individual water use. Some forms of conservation rate programs can also provide a new "local" funding source for conservation, enabling local agencies to conduct more aggressive conservation efforts in the future.

Conservation-based rate structures have, when fully implemented, resulted in sustained water demand reduction of up to 17% for budget-based rates (University of California, Riverside/Baerenklau et al. study "Residential Water Demand Effect of Increasing Block Rate Water Budgets", specific page #1). Other approaches to conservation-based rate structures may also provide lower water savings by providing the initial steps of a transformational rate structure. For these other approaches, a water savings of 5% will be assumed in the initial 3-year project implementation, with anticipated increasing water savings subsequently into the future.

Implementation of this Program will include educating policy makers on the effectiveness of conservation-based rate structures, creating outdoor water budgets, consulting, and developing rate structures for conservation-based rates. The Program would outline procedures, software, training, and outreach necessary to cost-effectively implement a program in their agency. There are 73 water purveyors in the Santa Ana River Watershed that do not have a water budget by connection (the three agencies in the USMW participating in the Program each have budget-based rate structures), of which we estimate up to 30 would be interested in developing outdoor water budgets, up to 20 interested in preparation of a cost/benefit analysis of conservation rate structure, and finally, up to 10 water agencies committing to implementation of conservation-based water rates that provide a pricing mechanism to alter behavior. Assuming a resulting minimum 5% reduction in water use (different rate structures

will have varying effectiveness on conservation) for a targeted 10 agencies with an average of 14,500 customers, average annual water demand will decrease by approximately 4,800 AF/year in 3 years, as shown in Table C.

Table C. Projected Water Savings from Conservation-Based Rates by Year

Year	No. Agencies Implementing[1]	Usage/Customer[2] (AF/year)	Reduction in Water Use[3]	Annual Water Savings (AF/year)
1	0	0.665	5%	0
2	3	0.665	5%	1446
3	7 additional	0.665	5%	3375
			Total 3 Year Projected Savings (AF/year)	4,821

Notes:

[1] Per Raftelis Financial estimate given their experience in the region, 30 agencies will explore converting to conservation based rates and 10 of those will actually convert. Anticipated that explorative period will take about 1 year, with the first three agencies completing implementation in Year 2 and the remaining in Year 3. Assumes each agency has 14,500 connections, which is median value of SAWPA retail agencies being targeted. USMW agencies are not participating in this element as they have already implemented conservation-based rates.

[2] Annual average household water usage calculated for Year 1 based on 180 GPCD (Source: http://www.sawpa.org/wp-content/uploads/2014/01/8-Per-Capita-Water-Use.pdf) and assuming 3.3 persons/EDU.

[3] Estimated water savings rates range from 5 to 17%. For the purposes of this analysis, we are using the most conservative estimate of 5% (Source: Raftelis Financial).

The implementation cost of soliciting and implementing water conservation-based rates for 10 agencies, including $833,333 for aerial imagery and $200,000 for outreach coordination, is estimated to be $3,165,333

The Conservation-Based Water Rate element of the Program will be implemented in the following approach:

1. Workshops – To create initial momentum of interest, four workshops in each of the three counties of the Santa Ana River Watershed (total of 12 workshops) will be held targeting the 73 water purveyors. Workshops would be tailored to both elected officials and staff members. These workshops will review various factors to determine outdoor water budgets, conservation-based rate structures, billing system requirements, and other general issues that would need to be addressed in implementing conservation-based water rates. These workshops are intended to educate and elicit interest in these rate structures.
2. Outdoor Water Budget Development – Up to 30 water purveyors will be targeted from interest expressed at the workshops or other communication to develop outdoor water budgets. The outdoor water budgets are the amount of water a parcel needs to maintain a healthy landscape. This budget would be calculated for each parcel using aerial mapping and local weather conditions. Based on this information, water agencies can compare actual usage with the water budget to determine which accounts are efficient or wasteful with their water use. The information can then be used to target water conservation programs, which would complement other programs within the Program and can educate individual accounts on how efficiently they use water.
3. Cost/Benefit Analysis of Conservation Rate Structure – Based on the Outdoor Water Budget study, the benefit from reducing wasteful water and the cost of implementing conservation rate structures will be determined for up to 20 water purveyors. The benefits that will be examined include the avoided cost of purchased water, lower Capital Improvement Program expenditures and increased watershed quality from lower urban runoff. The cost of the conservation structure will include billing system assessment, potential increase in staff, and public outreach.
4. Conservation Rate Pricing – From the Outdoor Water Efficiency and Cost/Benefit Analysis studies above, up to 10 water purveyors committing to implement conservation-based rates will be provided further study and development of customized conservation-based rate structures, consistent with requirements of Propositions 26 and 218, for implementation. Pricing would be the main tool in this element of the program to transform customers' view of the nexus between the value of water and its reasonable use.

This analysis will also take into account revenue shortfall so that as the agency reduces demand, the financial condition of the utility is not jeopardized. These water purveyors are targeted for implementation of the rate structures.

No new facilities or policies are needed to implement this element of the Program, nor are there any potential adverse physical effects due to implementation of water conservation-based rates.

3.4.1.4 Supporting Water Use Efficiency Tools

Economies of scale will be utilized to provide tools that will be used in the implementation of the Program elements described above as well as other uses by water agencies in the water use efficiency programs. While these tools are integral to the implementation of the Program described herein and water savings are presented, it should be noted that these tools will facilitate unquantified water use savings with these other, unidentified uses.

Aerial Imagery – High resolution aerial imagery at six inches/pixel resolution, including infrared and Lidar, will be produced for the urbanized area of the Santa Ana River Watershed and portions of the USMW and provided to all water purveyors. Economies of scale will reduce the cost of this mapping, and also provide this tool to water agencies that might not otherwise utilize this technology due to cost. This high resolution remote sensing information with measurement of irrigated area and percentage of turf grass will be provided for both residential customers and for commercial sites in the watersheds. The aerial images developed across the watersheds will provide agencies the ability to locate high-turf-percentage accounts to target for local agency outreach to participate in turf removal rebate programs. This will return more savings by identifying and directing outreach to the highest-using customers. This imagery and modeling will also provide cost-effective information to be used in the Technology-Based Information Outreach and Conservation-Based Water Rate Structure implementation. Aerial imagery will have multiple uses as a basis for both short-term and long-term water savings for this Program.

Implementation of Watershed Coordination – To maximize the financial resources among the participating agencies, the coordination and outreach throughout the watersheds needs to be regional and robust. The challenge will be to connect the public, and all stakeholder audiences, to direct calls to action that encourage significant behavior change.

Initial implementation steps will include an analysis of existing data and a newly generated survey to test attitudes, knowledge and appetite for change in water use. This information, along with extensive assessments of existing agency outreach efforts and materials and evaluation of regional earned media, advertising, event, and partnership landscape, will lead to the development of a comprehensive regional outreach plan.

The survey data and market analysis will assist in identifying key messages, campaign brand elements, and targeting methodologies for outreach plan implementation. Primary focus areas for implementation include comprehensive message development, branding and campaign launch design, sophisticated and interactive web platform development, earned and social media engagement, advertising, sponsorship and strategic partnership development, and special event planning. Further, all elements will include provisions for customizable campaign elements, budgeting detail, and specialized spokesperson training for both individual staff and elected leaders at each agency.

3.4.2 Water Savings Summary

Projected water savings are summarized in Table D.

Table D. Projected Water Supply Savings Benefit by Year

Year	Turf Replacement	Tech-Based Information System	Conservation-Based Water Rates	Totals (AF/year)
2015	338	2,504	0	2,841
2016	567	3,931	1,446	5,945
2017	668	2,351	4,821	7,841

Notes:
Note that Year 1 of the Tech-Based Conservation Program from Table B occurs from July 2015 to June 2016, Year 2 from July 2016 to June 2017 and Year 3 from July 2017 to December 2017. Hence the values on Table B were input here accordingly.

3.4.3 Energy Saved

According to the California Energy Commission's 2005 report California's Water-Energy Relationship, the amount of energy required to pump 1 AF to Southern California is approximately 2,450 kilowatt-hours (kWh) (average of East Branch and West Branch pumping to serve IEUA, Figure 2-2). This results in savings of 6,964,248 kWh in 2015, 14,564,145 kWh in 2016, and 19,209,385 kWh in 2017 through 2037 (20-year project life).

3.4.4 Carbon Emissions Saved

According to the U.S. Environmental Protection Agency, the emission rate of carbon dioxide (CO_2) per kWh is 6.89551×10^{-4} metric tons CO_2 per kWh (http://www.epa.gov/cleanenergy/energy-resources/refs.html). Using this conversion rate, the amount of carbon emissions saved with the program are: 4,800 MH CO_2 in 2015, 10,043 MT CO_2 in 2016, and 13,246 MT CO_2 in 2017 through 2037 (20-year project life).

3.4.5 Water Quality – Reduction of Urban Runoff

Recent Salt and Nutrient Management Plans have demonstrated that the highest contributor to TDS loading is from turfgrass return flows (Rancho California Water District, Temecula Valley Basin Salt and Nutrient Management Plan, March 2014). Permanent water conservation produced from the program will result from the reduction in turfgrass overwatering, which creates the majority of urban runoff. Over fertilization, pet waste, pesticides, etc. get carried along with this overwater into the urban runoff tributary to creeks, the groundwater basins, and the ocean. Removing turf and incentivizing effective reduction of outside irrigation will reduce this runoff and improve water quality in creeks, in groundwater, and at the beaches, benefiting human health and welfare as well as wildlife.

3.5 Cost-Effectiveness Analysis

The proposed program is the least cost alternative (see Table 6, Cost Effective Analysis), and can be immediately implemented to mitigate drought reduction of water supply with water savings commencing in the first year and fully implemented with 7,841 AF/year water savings within 3 years. Comparable alternatives, to create new water supply as opposed to reducing demand, include recycled water expansion where implementation would be 5–10 years, and ocean desalination, which would not be implemented for over 10 years, if at all, depending on environmental and cost limitations.

Table 6 – Cost Effective Analysis

Project Name: Interregional Landscape Water Demand Reduction Program	
Question 1	Types of benefits shown in Table 5 include: 7,841 AF/year of Imported Water Supply Saved, 19,209,385 kWh Energy Saved and 13,246 MT CO_2 Carbon Emissions Saved for 20 years.
Question 2	Yes, alternative methods have been considered for achieving the same types and amounts of physical benefits as the proposed project, including expansion of recycled water facilities throughout the region and ocean desalination. These alternatives are new sources of supply that would also offset reliance on imported water. The following are the estimated costs of the Subject Project compared to the alternatives: • Interregional Landscape Water Demand Reduction Program (Subject Project): $254/AF ($22.9M, 7,841 AF/year, (A/P, 6%, 20)=0.0872) • Recycled water development: $887/AF (reference: *http://www.gwrsystem.com/index.php?option=com_content&view=article&id=9&Itemid=27* for OCWD GWRS project costs) • Ocean Desalination: $2,014/AF (reference: *http://www.sdcwa.org/seawater-desalination* for SDCWA Carlsbad Ocean Desal Plant)
Question 3	The proposed program project is the least cost alternative.
Comments: The proposed program is the least cost alternative, in addition can be immediately implemented to mitigate drought reduction of water supply with water savings commencing in the first year and fully implemented in 3 years. Recycled water expansion implementation would be 5–10 years, with Ocean Desalination >10 years, if at all, depending on environmental and cost limitations.	

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CALIFORNIA
ENERGY
COMMISSION

California's Water – Energy Relationship

FINAL STAFF REPORT

Prepared in Support of the 2005 Integrated Energy Policy Report Proceeding (04-IEPR-01E)

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EXECUTIVE SUMMARY

As California continues to struggle with its many critical energy supply and infrastructure challenges, the state must identify and address the points of highest stress. At the top of this list is California's water-energy relationship: water-related energy use consumes 19 percent of the state's electricity, 30 percent of its natural gas, and 88 billion gallons of diesel fuel every year – and this demand is growing.

As water demand grows, so grows energy demand. Since population growth drives demand for both resources, water and energy demand are growing at about the same rates and, importantly, in many of the same geographic areas. This dynamic is exacerbated by the fact that Northern California has two-thirds of the state's precipitation while two-thirds of the population resides in Southern California. Water demand and electricity demand are growing rapidly in many of the same parts of the state stressing already constrained electricity delivery systems. When electric infrastructure fails, water system reliability quickly plummets and threatens the public health and safety.

The state water plan concludes that the largest single new supply available for meeting this expected growth in water demand over the next 25 years is water use efficiency. The remainder must be provided by the development of new water supplies including water recycling, and desalination of both brackish and seawater[1], all of which will increase energy demand over current levels.

Worse, the times when the highest energy intensity water supply options will be most needed are most likely to occur during multi-year drought periods when surface water supplies are low and groundwater levels drop, requiring even more energy for pumping each gallon of water. To compound the problem, reduced surface water supplies and snowpack in high elevations are likely to reduce the availability of valuable hydroelectric supplies. Yet, these are also the times when the most aggressive water conservation efforts are implemented, reducing overall water use, which helps reduce the total impact on energy demand. Although the net effects of this dynamic are not fully understood, this report presents current knowledge to assist with further analysis.

This is an urgent time of both challenge and opportunity. The primary finding of this paper is that a major portion of the solution is closer coordination between the water and energy sectors. A meaningful solution cannot be reached in the current regulatory environment where water utilities value only the cost of acquisition, conveyance, treatment, and delivery; wastewater utilities value only the cost of collection, treatment, and disposal; electric utilities value only saved electricity; and natural gas utilities value only saved natural gas. The state must both develop and expand best practices and existing programs to realize the substantial incremental benefits of joint water and energy resources and infrastructure management.

1 State Water Plan, B160-05.

While many nuances of this complex statewide problem are still unclear, staff's analysis shows that significant energy benefits can be reaped through the twin goals of the efficient use of water by end users and the efficient use of energy by water systems. It is also clear that not nearly enough has been done to ensure that California's water supply strategies are synchronized, hand-in-hand, with its energy strategies. Nor has enough been done to forge partnerships between the water and energy sectors so that their natural synergies, joint resources, and assets can be effectively leveraged for the benefit of all Californians.

The state has the opportunity now to reap near-term energy benefits by helping California's water and wastewater utilities become more energy self-sufficient, which will ease pressures on California's already stressed electric system. By adjusting existing policies, programs, and resources, water and wastewater utilities could be converted from high energy users to net renewable energy producers.

California's water and energy policymakers need to commit today to the joint planning and management of these critical resources. The state's water plan and resource strategies are being reviewed with all key stakeholders, and implementation plans are already on the drawing table. At the same time, the California Public Utilities Commission has approved substantial utility ratepayer expenditures in energy efficiency programs for the 2006-2008 program cycle. The state must waste no time in taking advantage of these rapidly evolving events.

The state can meet energy and demand-reduction goals comparable to those already planned by the state's investor-owned energy utilities for the 2006-2008 program period by simply recognizing the value of the energy saved for each unit of water saved. If allowed to invest in these cold water energy savings, energy utilities could co-invest in water use efficiency programs, which would in turn supplement water utilities' efforts to meet as much load growth as possible through water efficiency. Remarkably, staff's initial assessment indicates that this benefit could be realized at less than half the cost to electric ratepayers of traditional energy efficiency measures.

This staff report examines how energy is used – and how it can be saved – in the water use cycle. The strategies and goals for a comprehensive statewide water-energy program would achieve incremental energy benefits for water and energy utilities. The overarching goal of establishing a comprehensive statewide water-energy program would create a dynamic, living process where key stakeholders have incentives to continuously identify and implement strategies optimizing the state's water and energy resources and assets on an integrated, coordinated, and collaborative basis. This opportunity must not be lost since the need is so great. Because of all these factors, staff recommends that an action-oriented approach structured to achieve near-term results be developed immediately.

INTRODUCTION

The California Energy Commission's (Energy Commission) *California's Water Energy Relationship* staff report is part of the *Integrated Energy Policy Report* (*Energy Report*) proceeding. It was prepared to promote greater understanding of the critical symbiotic relationship between the water and energy sectors, especially electricity. In its scoping order, the Energy Commission stated that:

- "(f)or 2005, the Committee will continue the emphasis from the *2003 Energy Report* on increasing the level of energy efficiency and diversity in the state's energy systems and understanding the limitations of the state's electricity, natural gas, and transportation fuel infrastructure." [2]
- "The need for new water supplies in California and the West due to population growth and potential changes in the state's hydrological cycle has important implications for the state's energy system that are not yet fully understood. The *2005 Energy Report* will need to evaluate this issue as part of pursuing the broader goal of sustainability.[3]
- "To meet the challenge of sustainability, California's energy and environmental agencies, along with key private and public stakeholders, must work together to address critical issues that include:

    > Impacts of water demand and supply strategies, including the need for increased pumping to provide reliable water supplies, increased need for water treatment, and possible development of desalination facilities..."[4]

This report examines the dynamic give-and-take relationship between California's water and energy resources. Among many other issues, this staff report examines the state's water sector and its energy use, along with changes likely to occur in the future. The staff considered various components of the system and the energy implications, or characteristics of these components, for both energy use and generation. With the participation of a broad base of key stakeholders, the staff evaluated actions and methods that can boost the synergistic efficiencies of both the energy and water sectors. This report is meant to inform and provide technical support for decision makers, water and energy industry professionals, and the general public about critical energy supply and demand issues plaguing the state's water sector today.

[2] California Energy Commission, Integrated Energy Policy Report Committee Scoping Order, dated September 3, 2004, p. 2.
[3] Ibid.
[4] Ibid, p.7.

This study presents the best, most updated available information on linkages between California's energy and water sectors. The process to develop this report included two public workshops, several meetings of an ad hoc working group[5] formed for the study, and interviews with scores of water professionals. This outreach included two meetings with members of the Association of California Water Agencies, which represents about 90 percent of the state's water agencies (many of which also operate wastewater treatment facilities), members of the California Municipal Utilities Association, and participation in the annual plenary of the California Urban Water Conservation Council.

The following key concepts form the basis of the analysis in this paper:

- ***Water and energy relationship:*** Refers to the types and magnitude of water and energy interdependencies requiring documentation and evaluation for various types of water resources, end uses, systems, and processes in order to fully understand the water-energy tradeoffs under different resource planning scenarios. In this report staff uses ***water and energy utilities*** when encompassing all water, wastewater, electricity, natural gas, and diesel fuel suppliers, utilities, and districts, both public and private.

- ***Water use cycle:*** Refers to the overall process of collecting, developing, conveying, treating, and delivering water to end users; using the water; and collecting, treating, and disposing of wastewater.

- ***Energy intensity:*** Energy intensity is defined as the amount of energy consumed per unit of water to perform water management-related actions such as desalting, pumping, pressurizing, groundwater extraction, conveyance, and treatment - for example, the number of kilowatt-hours consumed per million gallons (kWh/MG) of water. This concept is applied to water supplies, to components of the water use cycle, and to the total energy intensity of a unit of water throughout the entire water use cycle.

- ***Energy self-sufficiency:*** Refers to an entity that supplies its own energy requirements. This would typically be done through a combination of energy efficiency and self-provision of power, whether purchased or produced.

- ***Integrated water and energy resource management:*** Refers to the comprehensive body of policies, practices, methods, tools, and procedures

[5] The Water-Energy Relationship Working Group consists of representatives from state water and energy-related government agencies, local and regional water agencies, industry organizations, environmental and citizen groups, and other key water professionals. It was established to help guide and critique this Staff Paper, but its life is expected to extend beyond the WER study process to work on other planning efforts, such as DWR's Water Plan process, and perhaps a planning effort related to optimization of pumped-storage opportunities in the state. The transcripts of all Water-Energy Relationship Working Group meetings on pumped-storage will be made available to the public and will become part of the record of evidence for the 2005 Energy Report.

that collectively comprise “statewide integrated water and energy resource planning and management.” Appendix A summarizes most of the existing organizations, programs, and research. Optimal integration is presently beyond the reach of both water and energy resource management best practices.

Chapter 1 describes California’s water-energy relationship – what it is and what it means within the context of California’s current energy circumstances. Chapters 2, 3, and 4 examine the primary components of the entire water cycle and address their energy intensity. Chapter 5 discusses the potential development of new renewable energy resources by water and wastewater utilities. Chapter 6 explores different types of future changes likely to affect the energy intensity of water supplies; water treatment and distribution; water end use; and wastewater treatment and disposal. Findings and recommendations are contained in Chapter 7. Appendices appearing at the end of the report provide additional detail, and a glossary of terms is included.

CHAPTER 1 - WHAT IS THE WATER-ENERGY RELATIONSHIP?

The nation's water and energy resources are inextricably entwined. Energy is needed to pump, treat, transport, heat, cool, and recycle water. On the flip side, the force of falling water turns the turbines that generate hydroelectric electricity, and most thermal power plants are dependent on water for cooling. In California, an elaborate system of manmade storage, treatment and conveyance structures exist to augment natural hydrologic features. This system not only helps produce needed electricity supplies but requires large amounts of energy to deliver quality water where Californians need and want it.

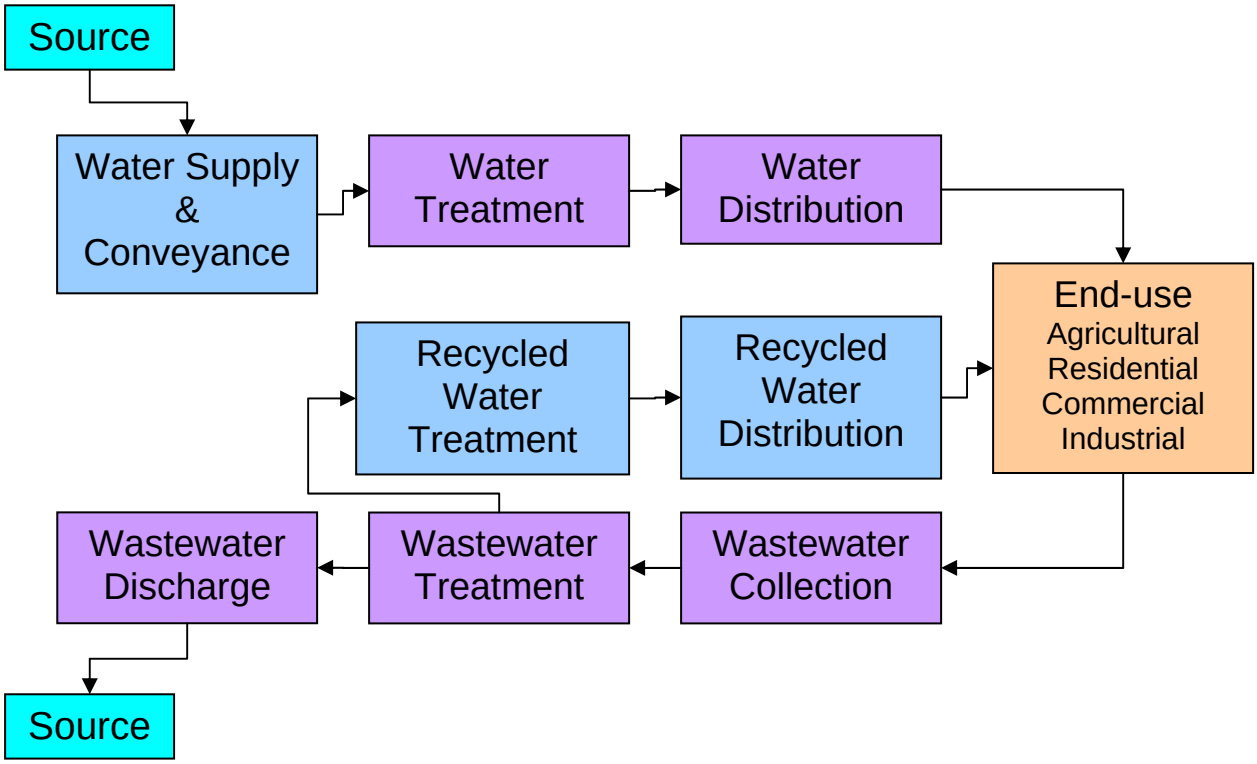
This chapter describes the overall water use cycle and introduces the concept of energy intensity. The energy intensity framework in the water use cycle helps identify opportunities for changing the pattern and magnitude of water-related energy consumption in California.

The Water Use Cycle

The Water-Energy Relationship Working Group discussed the state's water use cycle at length. While there are exceptions, Figure 1-1 illustrates the state's typical cycle.[6] Turquoise blue represents sources of water, water supplies are shown in light blue, water and wastewater treatment are shown in purple, and end use is shown in beige.

[6] This schematic is based on work by Dr. Robert Wilkinson (Wilkinson, Robert C., 2000. *Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures*, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency) and on Wilkinson and Gary Wolff in current work on the energy intensity of water in California with additions by Energy Commission staff.

Figure 1-1: California's Water Use Cycle



Water is first diverted, collected, or extracted from a source. It is then transported to water treatment facilities and distributed to end users. What happens during end use depends primarily on whether the water is for agricultural or urban use. Wastewater from urban uses is collected, treated, and discharged back to the environment, where it becomes a source for someone else. In general, wastewater from agricultural uses does not get treated (except for holding periods to degrade chemical contaminants) before being discharged directly back to the environment, either as runoff to natural waterways or into groundwater basins. There is a growing trend to recycle some portion of the wastewater stream – recycled water – and redistributing it for non-potable end uses like landscape irrigation or industrial process cooling.

Water-Related Energy Use

Energy is required at all stages of the water use cycle. It is difficult to measure the amount of water-related energy that is actually consumed. Better information is available about energy consumption by water and wastewater utilities. However,

energy consumption by water users is harder to determine since electric and gas meters do not separately measure water-related uses.[7]

The data presented in Table 1-1, with supporting details in Appendix B: 2001 California Energy Consumption by End Use, are based on information provided by the state's energy utilities to the Energy Commission for use in demand forecasting.[8] The Water-Energy Relationship Working Group and other stakeholders participated in extensive discussions to help staff estimate the magnitude of water-related energy consumption by water and wastewater utilities, and agricultural and urban water end users. As shown in Table 1-1, these estimates indicate that total water-related consumption is large – 19 percent of all electricity used in California, approximately 30 percent of all natural gas, and more than 80 million gallons of diesel fuel. The Energy Commission is funding a research project to refine the numbers, and results are expected in early 2006.

Table 1-1: Water-Related Energy Use in California in 2001

	Electricity (GWh)	Natural Gas (Million Therms)	Diesel (Million Gallons)
Water Supply and Treatment			
Urban	7,554	19	?
Agricultural	3,188		
End Uses			
Agricultural	7,372	18	88
Residential	27,887	4,220	?
Commercial			
Industrial			
Wastewater Treatment	2,012	27	?
Total Water Related Energy Use	**48,012**	**4,284**	**88**
Total California Energy Use	**250,494**	**13,571**	?
Percent	**19%**	**32%**	?

Source: California Energy Commission

The data in this table have been organized to align with the water use cycle in Figure 1-1. Water supply and treatment corresponds to the part of the water use

[7]Meters are typically installed to record all the electricity or natural gas use by an entire household, building or other type of facility.
[8] Agricultural data in this table is taken from Tables 1-4 and 1-5 in this chapter.

cycle between the source and end-user. Water supply and treatment account for 22 percent of water-related electricity consumption; 70 percent is required by urban water users and 30 percent by agriculture. On-farm agricultural water use consumes additional energy, estimated at 15 percent of water-related electricity demand. Residential, commercial, and industrial end uses combined represent 58 percent of the electricity consumed. Wastewater treatment accounts for 4 percent. The vast majority of water-related natural gas consumption is by residential, commercial, and industrial customers, primarily for heating water. Natural gas consumption in the agricultural sector is primarily for irrigation pumping. Agriculture is the only sector where diesel fuel consumption, which is also used for water pumping, is quantified. Question marks in the table indicate areas where additional information is needed.

The Energy Intensity of the Water Use Cycle

Each element of the water use cycle has unique energy intensities (kilowatt hours/million gallons (kWh/MG)). Table 1-2 illustrates the considerable variability in both the range of intensities for each segment and the components of the water use cycle. End use energy demand was excluded since the focus is on the energy requirements in the remaining conveyance, treatment, distribution, and wastewater treatment processes. Details supporting this table are in Appendix C: Energy Impact Analysis of Existing Water Management Practices.

Table 1-2: Range of Energy Intensities for Water Use Cycle Segments

	Range of Energy Intensity kWh/MG	
Water-Use Cycle Segments	**Low**	**High**
Water Supply and Conveyance	0	14,000
Water Treatment	100	16,000
Water Distribution	700	1,200
Wastewater Collection and Treatment	1,100	4,600
Wastewater Discharge	0	400
Recycled Water Treatment and Distribution	400	1,200

<u>Water Supply and Conveyance</u>

Energy intensity for this portion of the water use cycle is determined primarily by the volume of water that is transported, the distance, and the changes in topography along its route. California's water supply varies significantly with annual and seasonal hydrologic conditions, and with climate, geography, and topography. Nearly 70 percent of the state's total stream runoff is north of Sacramento, but 80

percent of the water demand is south of Sacramento. This creates challenges that policymakers have struggled to resolve for nearly a century.

The energy intensity of collection, extraction, and conveyance of raw water supplies can be near zero for gravity-fed systems from the Sierra to both urban areas in Northern California and agricultural districts in the Central Valley. However, other systems use very large pumps to transport large volumes of water hundreds of miles from points of collection to points of need. As a consequence, the energy intensity of water supplies in Central and Southern California is typically much higher than in Northern California, with Southern California the highest due to the need to transport water more than 3,000 feet up over the Tehachapi Mountains.

Water Treatment

Some sources of water need very little treatment, so their energy intensity is low. Other sources, such as brackish groundwater or seawater desalination, require much more treatment so their energy intensity is significantly higher. The energy intensity also varies depending on the intended end user. For example, most agricultural and some industrial end users can use water that requires little or no treatment, while most residential and commercial users need water treated to potable standards.

Energy use for water treatment will increase as more stringent water quality rules are implemented under the Safe Drinking Water Act and the Clean Water Act. These new rules require multi-stage disinfection - including treating potable water more than once to ensure the removal of harmful organisms that may grow during storage and transport - and improved disinfection technologies that reduce risk of carcinogens and other potentially harmful disinfection by-products. These improved disinfection technologies – principally, ultraviolet treatment and ozonation – are much more energy intensive than prior chemical methods.[9]

Water Distribution

Some fresh water distribution systems are gravity fed, but most require some pumping. The primary driver of increased energy for water distribution is urban growth.

Wastewater Collection

Some wastewater collection systems use gravity to bring the wastewater to a treatment plant. Others need energy to lift or transfer the wastewater.

Wastewater Treatment

All wastewater treatment systems require energy, though some require more than others depending on the quality of the waste stream, the level of treatment required, and the treatment technologies used. Energy use for wastewater treatment is expected to increase with adoption of more stringent water quality rules under the

[9] There may be some energy savings that are not considered here due to the reduction in needed chemicals for treatment.

Clean Water Act. However, by increasing the quality of wastewater effluent, more recycled water can be added to the state's water supply portfolio.

Wastewater Discharge
Some wastewater discharge systems use gravity to return wastewater to the environment. Others need energy to lift or transfer the wastewater.

Recycled Water and Distribution
Depending upon the level of wastewater treatment in existing facilities, the effluent may be recyclable without requiring additional treatment to displace potable water sources used for non-potable applications. More energy is needed if additional treatment is required. Most recycled water distribution systems require additional energy to pump water uphill to intended users.

As noted previously, since there are so few options to make new water, the increased use of recycled water is a major strategy in the state's water plan.

Energy Intensity in Northern and Southern California

Due to significant variations in energy used to convey bulk water supplies from one place to another, the average energy intensity of the water use cycle in Southern California is much higher than in Northern California. This is due to the fact that Southern California imports about 50 percent of its water supplies from the Colorado River and from the State Water Project (SWP) – each of which is more energy intensive than any single source of water supply used in Northern California.

Table 1-3 shows the combined energy intensity of the water use cycle for typical urban communities in Northern and Southern California. Details supporting this table can be found in Appendix C.

Table 1-3: Electricity Use in Typical Urban Water Systems

	Northern California	Southern California
	kWh/MG	kWh/MG
Water Supply and Conveyance	150	8,900
Water Treatment	100	100
Water Distribution	1,200	1,200
Wastewater Treatment	2,500	2,500
Total	3,950	12,700
Values used in this report	4,000	12,700

Staff recognizes that no two water treatment, distribution, or wastewater treatment systems are identical, so the relative energy intensities reflected above are prototypical. However, within these processes, variability is lower in magnitude than with conveyance and is not linked to a north/south differentiation. The primary north/south regional variation that causes the state's unique and important water energy dynamic is linked to the magnitude of energy required to convey Northern California water supplies to Southern California.

On average, water conveyance requires more than 50 times the energy for Southern California than it does for Northern California. This is also five times the national average. Southern California depends heavily on water imports from the Colorado River and from Northern California. This water travels hundreds of miles through pipelines and aqueducts and, in some places, must be pumped over mountain ranges before reaching its destination. Conversely, 40 percent of Northern California's population is served by gravity-fed systems, with the balance supplied by surface supplies or relatively shallow wells. Recognizing that the actual energy intensity in each component of the water use cycle will vary by utility, the energy values reflected above appear to be reasonable and conservative. This paper assumes that 4,000 and 12,700 kWh per million gallons are consumed for water that is supplied, treated, consumed, treated again, and disposed of in Northern and Southern California, respectively.

Water End Use Energy

California uses about 14 trillion gallons of water in a normal year, with about 79 percent used for agriculture and the remainder in the urban sector. Once water is delivered, customers use it in a variety of applications. Combined agricultural, residential, commercial, and industrial water-related end uses account for 58 percent of all water-related electricity and 99 percent of water-related natural gas use.

Agriculture

Agricultural water use can be both energy intensive, requiring extensive pumping and, in some cases, treatment; but it can also be essentially energy-free, using gravity alone to flow raw surface water onto fields. Each year, California's agricultural sector uses roughly 34 million acre-feet of water to grow food and fiber commodities. It takes more than 10,000 GWh of electrical power to pump and move this water. The energy is used by large state and federal water projects, by irrigation districts, and by on-farm requirements, as outlined in Table1- 4 below.

Table 1-4: Energy Consumed in Agriculture for Water

Category	Energy Consumption (GWh)[1]
Conveyance to Irrigation Districts by the State and Federal water projects[2]	1,720
Conveyance to Irrigation Districts by the Western Area Power Administration	400
Irrigation District surface water pumping	822
Irrigation District ground water pumping	246
On-farm ground water pumping	4,499
On-farm booster pumping[3]	2,873
Subtotal	10,560
Electric equivalent for diesel and natural gas engine driven water pumping[4]	1,231
Total	11,791

[1]Values shown in this table only include agricultural water pumping to meet crop applied water demands. Other agricultural water uses not included in this table include water used for livestock and food processing that is not considered to be commercial. Source: California Agricultural Water Electrical Energy Requirements, ITRC Report No. R 03-006, Irrigation Training and Research Center, 2003 http://www.itrc.org/reports/cec/energyreq.html

[2] Energy used to pump surface water through state and federal water projects to supply irrigation and water districts.

[3]This includes groundwater and surface water pumping to supply pressurized irrigation systems such as sprinkler, drip, and micro spray.

[4]Diesel and natural gas are the second and third most prevalent energy sources used to pump agricultural water. These sources are used to run engines that directly run the water pumps, typically for on-farm groundwater and booster pumping. Emissions requirements typically prevent the use of diesel for pumping in irrigation districts.

The numbers in Table 1-4 represent energy consumption for a typical weather or water year. These numbers will change with different water year scenarios. For example, during a wetter-than-average year with larger surface water deliveries, the energy used for groundwater pumping will decrease. During a period of several back-to-back dry years, a significant amount of additional energy will be used because of increased on-farm groundwater pumping.

In general terms, the electricity used for water represents more than 90 percent of the total electricity used for crop production in the agricultural sector. This applies mostly to field crops, but also to the state's fruit and nut trees and vineyards.

Dairy farms use electricity and other fuels for pumping water for crops, heating water for cleaning and disinfecting barns, and transporting wastewater for lagoon disposal and aerators. Most of the remaining electricity is used for milking equipment and refrigeration. Fans are also used for animal cooling. Greenhouses and nurseries use electricity and other fuels for watering crops, ventilation, and heating. Other agricultural on-farm electricity use goes to food processing including washing, packaging, and refrigeration. However the majority of food processing is in large-scale processing facilities typically classified as industrial. Their energy requirements are discussed in the section describing industrial water users.

Although most agricultural electricity use is during the summer months, there are many year-round operations including dairies, nurseries and greenhouses, feedlots, and other animal production farms.

As shown in the previous table, diesel and natural gas are also used to pump water. Table 1-5 provides an estimate of the breakdown between diesel and natural gas used for agricultural water use in California (Cal Poly 2003).

Table 1-5: Estimates for Diesel and Natural Gas Engine Driven Water Pumping in California Agriculture

Type	Number of Engines[1]	Fuel Required	Conversion to kWh[2]	Equivalent Electricity (GWh)
Natural Gas	1,932	17.5 Million Therms	6.76 kWh/Therm	118
Diesel	12,535	88 Million Gallons	12.8 kWh/gallon	1,113
Totals	14,467			1,231

[1] These data were generated by Cal Poly ITRC during the analysis for the *California Agricultural Water Electrical Energy Requirements Report* (2003). However, it was not published in that report (Cal Poly ITRC unpublished data, 2005). It was subsequently submitted as testimony in the June 21, 2005, IEPR workshop.
[2] The total number of diesel-and natural gas-engine-driven water pumps was obtained from the 2003 USDA Farm and Ranch Irrigation Survey. In comparison, the estimate used for the 2005, AG-ICE proceeding with the CPUC (A.04-11-007/008) provided by the California Air Resources Board (CARB) reported about 8200 diesel driven irrigation pumps. The estimate from CARB is low compared to the USDA survey. We chose the USDA data because they survey more farms throughout California [http://www.nass.usda.gov/census/census02/fris/tables/fris03_20.pdf].
[3] The conversion from kWh to therms and gallons of diesel is based on the Nebraska Performance Standards for Irrigation Energy Sources (Source: Dorn, T.W., P.E. Fishbach, D.F. Eisenhauer, J.R. Gilley, and L.E. Stateson, *It Pays to Test Your Irrigation Pumping Plant*. Publication EC-713. Lincoln: University of Nebraska, Cooperative Extension Service).

Changes to air quality regulations in agricultural regions will likely lead to conversion of many of these pumps, primarily the diesel-powered ones, to electric pumps. If they were all converted to electric, this would increase the electric requirements of

the agricultural sector by more than 10 percent. Although the total number of potential conversions is limited by regulation and available program incentives, the state's planners and electric utilities will need to account for and supply the additional peaking capacity and electricity needed for these pumps. This is discussed in more detail in Chapter 4.

Residential, Commercial and Industrial

Staff has only recently focused on water-related energy consumption in the residential, commercial, and industrial sectors, collectively referred to as urban water users. Table 1-6 presents the aggregated data for each sector. Detailed information can be found in Appendix B.

Table 1-6: End-Use Energy Associated with Urban Water Users

Sector	Electricity (GWh)	Natural Gas (Million Therms)
Residential	13,528	2,055
Commercial	8,341	250
Industrial	6,017	1,914
Total	**27,887**	**4,220**

Source: California Energy Commission

The residential sector accounts for 48 percent of both the electricity and natural gas consumption associated with urban water use. Residential water uses include personal hygiene (shower, bath, sink), dish and clothes washing, toilets, landscape irrigation, chilled water and ice in refrigerators, and swimming pools and spas. Residential energy uses related to these activities include water treatment (filtering and softening), heating (natural gas or electric water heaters), hot water circulation loops, cooling (icemakers and chilled water systems for HVAC and chilled drinking water), circulation (spa pumps, as one example), and, in some cases, the groundwater pumping of private wells.

Commercial water-related energy use represents 30 percent of the electricity and 6 percent of the natural gas use. Industrial water-related energy use represents 22 percent of the electricity and 45 percent of the natural gas. Commercial and industrial water uses include all those found in residences, plus hundreds more. Some of the more energy-intensive applications related to commercial or industrial water use include high-rise supplemental pressurization to serve upper floors, steam ovens and tables, car and truck washes, process hot water and steam, process chilling, equipment cooling (x-ray machines, for example), and cooling towers. In the commercial sector, the major water-related end uses that use electricity are cooling and water heating. Cooling towers for air conditioning are large water users. In the industrial sector, water-related energy use is very dependent upon specific processes. Except for oil and gas extraction, no single industrial category stands out

as a major user of electricity or natural gas. Water heating and process heating are the largest users of natural gas.

In general, urban water use in California is more energy intensive than agricultural water use. This is because every urban water system requires energy for water and wastewater treatment, both of which are not generally required for agriculture. The vast majority of urban water systems also require energy for distribution.

Hydropower Production, Energy Recovery, and Renewable Resources

Hydropower

The most widely recognized aspect of the water-energy relationship is hydropower production. As discussed in Chapter 2, California is served by a vast system of reservoirs and dams, pumped storage, and run-of-river facilities. These facilities are operated by investor-owned utilities (IOU), publicly owned utilities (POU), state and federal agencies, irrigation districts, and other entities, mostly to serve multiple purposes including power generation, water supply, recreation, and flood control. California's hydropower system provides valuable peaking reserve capacity, spinning reserve capacity, load following capacity, and transmission support, all at low production costs.[10] California's combined total hydroelectric capacity is more than 14,000 megawatts (MW)[11] or about one-quarter of the in-state generation capacity. Hydro-generated energy was about 29,000 GWh, or 13 percent of the in-state generation in 2004.[12] The state has conducted extensive studies on traditional hydropower, both in the contexts of its value to the California electric system and issues relating to environmental impacts. Staff refers the reader to these existing reports reference herein, all of which are available on the Energy Commission's Web site.

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[10] California Energy Commission Staff Report, *California Hydropower System: Energy and Environment*, Appendix D, *2003 Environmental Performance Report*; prepared in support of the Electricity and Natural Gas Report under the Integrated Energy Policy Report Proceeding (02-IEP-01), October 2003 [Publication 100-03-018].

[11] California Energy Commission, *2003 Environmental Performance Report*. Appendix D, *California Hydropower System: Energy and Environment*, Sacramento, CA. 100-03-018, March 2003, p. D-6.

[12] California Energy Commission, *Potential Changes in Hydropower Production from Global Climate Change in California and the Western United States*, June 2005, consultant report, Prepared in support of the *2005 Integrated Energy Policy Report*, Publication No. CEC 700-2005-010.

Energy Recovery from the Water Use Cycle

In-Conduit Hydropower

The state's large water conveyance projects already take advantage of the energy in the water flowing through their pipelines. Wherever there is flowing water, there exist both energy and the potential to capture and utilize that energy. Pipelines that convey water supplies by gravity have energy that could be captured, but care must be taken to make sure that sufficient 'head', or force, remains to carry the water to its final destination. Wherever pressure-reducing valves or stations are used to reduce the energy in moving water, there is an opportunity for energy production. At any point in a water or wastewater system where influent is delivered for treatment or wastewater effluent is discharged, there may be further opportunities for power production. Barriers and challenges to additional development of in-conduit hydropower that recovers energy from the water delivery and conveyance process are discussed in more detail in Chapter 5.

Biogas

Another option for developing generation in the water sector is to increase beneficial use of digester gas produced by the sewage wastewater, dairy manure, and food processing wastes/wastewater. Biogas, composed primarily of methane, can be used for combined heat and power (CHP) production.

California has 311 sewage wastewater treatment facilities, 2,300 dairy operations, and 3,000 food processing establishments. Currently, about 50 percent of sewage sludge, 2 percent of dairy manure, and less then 1 percent of food processing wastes/wastewater generated in the state are used to produce biogas. Converting these wastes into energy can help operating facilities offset the purchase of electricity and provide environmental benefits by reducing discharged air and ground water pollutants.

The Energy Commission is working with Commerce Energy Inc. and Inland Empire Utility Agency (IEUA) to develop technologies that will address the lack of knowledge of the relationship between various co-digestion feedstocks (sewage sludge, food processing wastes, and dairy manure) and gas production.

Other Renewable Energy Resources

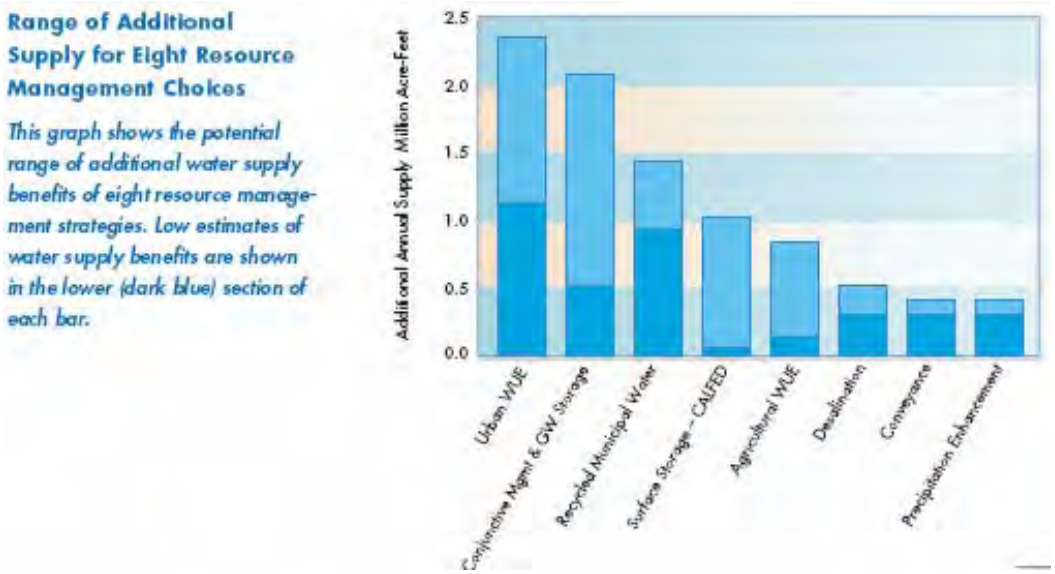
Water and wastewater agencies typically have very large landholdings with characteristics that readily lend themselves to the development of renewable resources, especially wind and solar. These resources could be used to help California meet its aggressive Renewable Portfolio Standard (RPS) goals. For example, regional water and wastewater agencies have hundreds of miles of rights-

of-way, often in areas suitable for solar production. These agencies also have watershed lands that collect water for end-use applications, either potable or for agricultural or industrial use. In order to protect the water quality, large portions of these watershed lands are inaccessible to public recreational use. Many are remotely located, which make their visual impact of little public concern. Watershed lands are also at higher elevations, where wind resources are typically of fairly good quality. Some wastewater utilities also have extensive lands, which are used to dispose of treated effluent and are inaccessible to the public. Municipal or governmental control over these lands could accelerate their use as sites for renewable energy generation

A Loading Order for Water Resources

The *California Water Plan Update 2005,* prepared by the Department of Water Resources (DWR), established a strategic plan that prioritized resource measures to meet new load growth and other water supply challenges. As shown in Figure 1-2, first among the strategies is increased urban water efficiency. Appendix D provides an excerpt of the plan from the Water Plan Update. Thereafter, the plan depends upon increased reliance on conjunctive management and groundwater, followed by recycled water. Agricultural water use efficiency is also an important strategy.

Figure 1-2: New Water Supplies for California



Source: *2005 State Water Plan Update*, DWR.

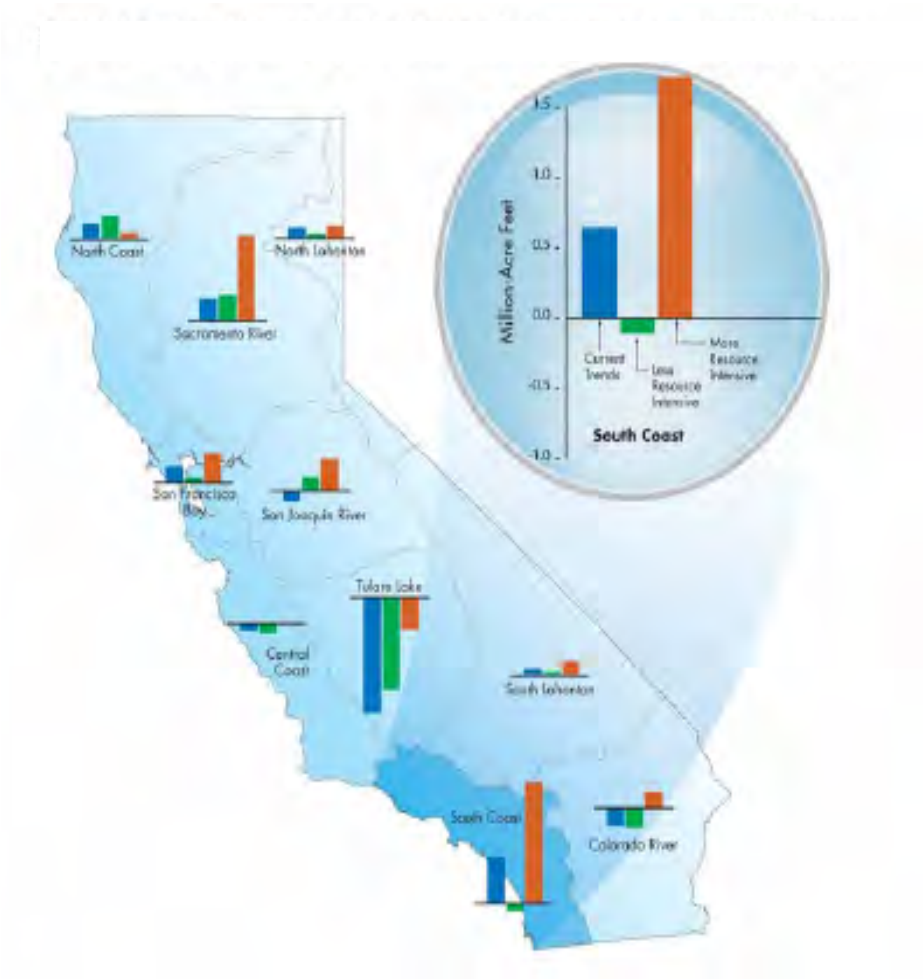
In many respects, the *2005 Water Plan Update* mirrors the state's adopted loading order for electricity resources described in the Energy Commission's *Integrated Energy Policy Report 2005* and the multi-agency *Energy Action Plan*. The first three

strategies all concern the efficient use of existing resources. These strategies encompass efficient use, efficient operations and management, and efficient reuse. Including agricultural water use efficiency, the state's water resources strategy targets will meet 70 percent of future growth in water demand through efficiency measures.

This is a very important concept. Specifically, like energy utilities, water utilities already apply integrated resource planning tools and techniques in their future plans. Similar to energy utilities, they also already apply strategies of "least-cost, best-fit." Thus, in order to optimize the state's water and energy resources on an integrated basis, the primary concept that needs to be integrated into California's water planning on the supply side is the energy intensity of various water supply options. On the demand side, the primary concept is recognition of the energy embedded in various types of water end use throughout the entire water use cycle. Just as energy efficiency increases available supplies and avoids incremental infrastructure costs and environmental impacts, every unit of water not consumed can displace a more energy-intensive water source.

In many cases, the areas of the state that are most stressed with respect to water supplies are also areas with transmission congestion and shortages of local energy supplies. Not surprisingly, since load growth is largely driven by population growth, the geographic areas most resource constrained are the same for both water and for energy. Figure 1-3 shows the projected water demand as estimated by DWR for three different future scenarios and demonstrates the sizable gap between the less and more water-resource-intensive projections. This makes a compelling case for close coordination between water and energy planning and synchronization of both resources and infrastructure goals.

Figure 1-3: Net Change in Average-Year Water Demand for 3 Scenarios by Region, 2000-2030

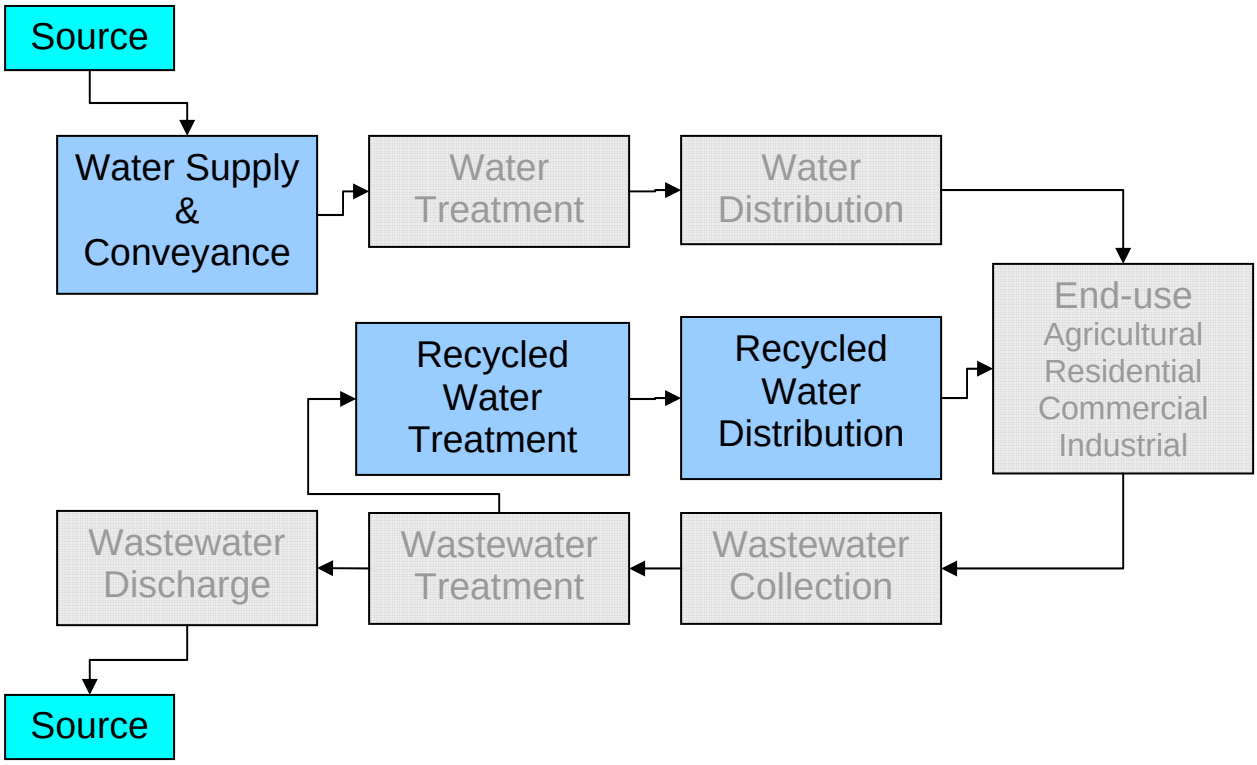


Source: *2005 State Water Plan Update*, DWR.

CHAPTER 2 – WATER SUPPLY AND CONVEYANCE

This section discusses the energy intensity of different water supply sources, all the way through the cycle to conveyance for water treatment. Recycled water, a by-product of wastewater treatment, is also discussed here as an additional source of supply.

Figure 2-1: Water Use Cycle - Supply Source



Primary Sources of California Water

Californians collectively use about 43 million acre-feet (about 14 trillion gallons) of developed water for urban and agricultural use in a normal year. Of this total, 34 million acre-feet go to agriculture (about 11 trillion gallons and 79 percent) and 9 million acre-feet (about 3 trillion gallons and 21 percent) go to the urban sector.[13]

Understanding the energy implications of water use in California requires a basic knowledge of the various water systems that collect, store, and transport water

[13] DWR *2005 Water Plan Update* Volume 1, Table 3-1.

supplies. These supplies can be roughly categorized as surface water, groundwater, desalted water, and recycled water.

- Surface water comes from precipitation, rain and snow, captured and stored in natural lakes and streams, and manmade reservoirs, canals or aqueducts. Most surface water storage is fed from runoff coming from the state's large mountain ranges. The greatest source of surface water supplies is the Sierra snowpack, which holds more water than all of the state's lakes and reservoirs put together, and conveniently melts during the warmer and drier months when California most needs water.

- Groundwater is precisely that – water stored in the ground. Rain directly irrigates farms and gardens but also feeds groundwater basins and aquifers.[14]

- Recycled water, also known as "reclaimed" water or "reuse", is water produced from wastewater effluent. Water quality regulations specify approved uses for recycled water. The level of use depends upon the level of wastewater treatment applied.

- Ocean or brackish water is used for some industrial purposes but must be treated to remove salts and dissolved solids (desalted) for agricultural and urban purposes.

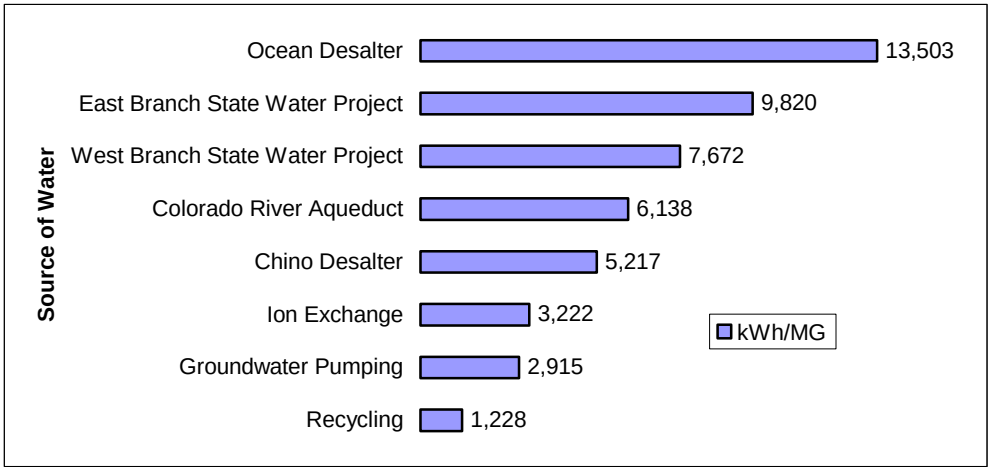
According to DWR's *2005 Water Plan Update*, surface water accounts for more than 60 percent of the state's water use in a typical hydrology year. Groundwater accounts for about 30 percent, although this is highly variable since groundwater makes up most of the state's water supply shortages in dry years. Use of desalted and recycled water, while still a very small percentage of California's total water supply portfolio, is increasing -- both as a means to supplement limited water supplies and provide a hedge against drought risk.

The Energy Intensity of Water Supplies

Every source of water has a different energy intensity. Figure 2-2 shows the relative energy intensity of water supply options for one Southern California regional water and wastewater utility, the Inland Empire Utilities Agency (IEUA).

[14] An aquifer is a body of permeable rock that can contain or transmit water.

Figure 2-2 Energy Intensity of IEUA Water Supply Options



Source: Dr. Robert Wilkinson, Environmental Studies Program, University of California, Santa Barbara, and Martha Davis, IEUA.

Of the above IEUA options, the East Branch State Water Project source is second only to ocean desalination in energy intensity. Recycled water is the least energy-intensive supply option. The relative energy intensity of supply options varies for each water utility, depending upon the nature and characteristics of its water supplies.

The sections below describe the relative energy intensities of various water supply sources. This concept is important to the discussions in the following chapters since the energy intensity of supply is the most significant sector in which near-term action can positively affect the state's energy circumstances.

Surface Water

The energy intensity of surface water supplies is mainly in the conveyance of raw water for either agricultural and some industrial uses or to treatment facilities for potable urban water use.

California's water supply varies significantly with annual and seasonal hydrological conditions, as well as geography and topography. The major water sources are in Northern California, while the major urban centers and agricultural lands are in the Northern Bay Area, Central Valley, and Southern California. Surface water conveyance systems were built to balance statewide water supplies with demands. These conveyance systems were designed to move water to areas of need outside the basin in which water is collected. This process – known as "interbasin transfers" – accounts for most of the energy embedded in California's surface water supplies. The energy intensity of various interbasin transfers depends on the distance and elevation over which the water must travel. The map in Figure 2-3 shows the state's interbasin transfer systems.

Figure 2-3 Interbasin Transfer Systems in California

Source: *2005 State Water Plan Update*, DWR.

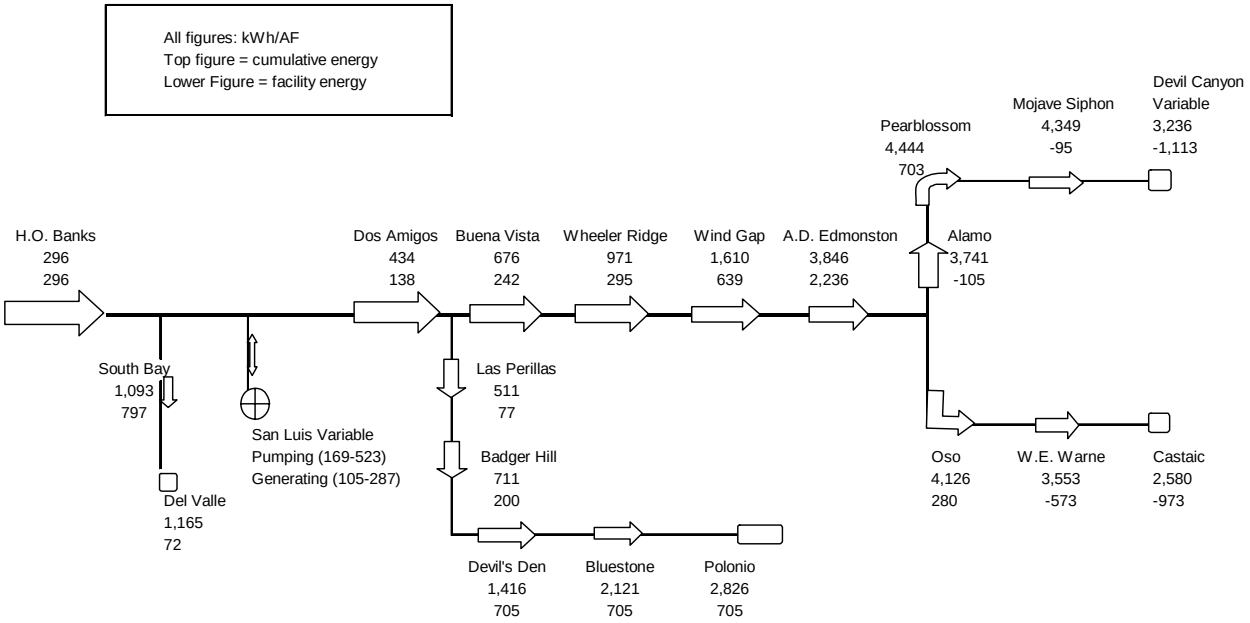
It is the pumping of this water that accounts for the relative energy intensities of different surface water sources. Note that some systems originate in mountain ranges and use gravity to naturally deliver water to points of need. These systems use very little energy. Other systems must transport water long distances on relatively flat valley floors. The State Water Project must also pump water more than 3,000 feet over the Tehachapi range to reach end users in Southern California.

SWP, the largest state-built multipurpose water project in the U.S., was planned, designed, built, and is now operated and maintained by the DWR. The SWP was constructed for the primary purpose of transporting water from Northern California to arid areas, both agricultural and urban, in Central and Southern California. The SWP delivers water to 29 water agencies and irrigation districts, which then distribute the

water to 20 million people and 900,000 acres of crops. SWP water is distributed about 50/50 to agricultural and urban water uses.[15]

The elevation diagram below (Figure 2-4) illustrates the relative energy intensity of delivered SWP water at various points along the California aqueduct. The numbers are shown in kilowatt-hours per acre-foot (kWh/AF). They include transmission losses and, where applicable, energy recovery.

Figure 2-4: State Water Project Pumping Energy



Source: Dr. Robert Wilkinson, PhD, University of California, Santa Barbara, based on DWR data.

Depending on the point at which SWP water is delivered, the embedded energy may range from a low of 676 kWh/AF (676 x 1,000,000 gallons/325,851 gallons/AF = 1,330 kWh/MG) at Dos Amigos, to a high of 3,236kwh/AF (9,930 kWh/MG) at Devil Canyon.

Many of the state's interbasin transfer systems also have significant hydroelectric generation. The Central Valley Project, the East Bay Municipal Utility District's (EBMUD) Mokelumne Aqueduct, and San Francisco's Hetch Hetchy Regional Water System, are all net energy producers. Despite its significant hydroelectric capacity, the State Water Project is a net energy consumer. The Colorado River Aqueduct is also a net energy consumer in California, although the project itself includes significant federal hydroelectric projects on the Colorado River.

[15] Presentation by Bill Forsythe, DWR, to Committee Workshop January 14, 2005.

Groundwater Sources

Groundwater supplies about 30 percent of the state's water needs on average but as much as 60 percent during times of severe drought.

Several hundred million acre-feet of water are stored in 450 groundwater aquifers in the state, compared with approximately 45 million acre-feet in California's 1,200 surface water reservoirs.[16] These aquifers are recharged either naturally or artificially. Natural recharge generally consists of runoff that percolates into the soil, or migration of surface water through a lake or streambed. Almost all of the 450 groundwater aquifers in the state are in decline or overdrafted, forcing users of that water to pump from greater and greater depths, requiring greater amounts of energy in the process.

The process of artificially storing groundwater for future withdrawal is known as aquifer storage and recovery (ASR). Closely related to ASR are "conjunctive use" and "artificial recharge," terms that are often used interchangeably. Water agencies around the state store water in aquifers for both daily and seasonal use and for emergency drought supplies. In general, surplus water is pumped into wells or allowed to percolate into aquifers from ponds and lakes, then pumped from wells when needed.[17]

Less is known about groundwater than about any other water source. This is because each groundwater basin is unique and production characteristics of wells are often interlinked. Since groundwater use is largely unregulated, the actual quantity of energy used for groundwater pumping statewide is also not readily determinable.[18]

In a 2003 study, the Electric Power Research Institute (EPRI) estimated national averages ranging from 700 to 1,800 kWh/MG, depending on use and customer sector.[19] Dr. Robert Wilkinson, director of Water Policy Program at the Bren School of Environmental Science and Management, University of California, Santa Barbara, estimated 2,915 kWh/MG, for groundwater pumping in the Chino Basin.[20] This number reflects the fact that the groundwater aquifers in Southern California, where the Chino Basin is located, are relatively deep compared to those in the northern and central part of the state.

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[16] ACWA Water Facts website.
[17] USGS 2005, Introduction to Aquifer Storage and Recovery, [http://ca.water.usgs.gov/issues/6.html].
[18] Hundreds of thousands of groundwater wells are privately owned, and serve residences, farms, businesses, and small water systems. The electricity used for pumping from private wells is often not separately metered and is not captured in the Energy Commission's and electric utilities' energy use data.
[19] "Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century", EPRI Topical Report, March 2002.
[20] Dr. Robert Wilkinson's presentation to the January 14, 2005 *Energy Report* Committee workshop.

It is reasonable to expect wide variability in the energy intensity of different groundwater sources, depending upon both the depth at which the groundwater resides and the efficiency of the pumps and motors used to pump it. In the context of energy intensity and benefits to the state, the primary benefit of groundwater is its ability to offset the high energy intensity of SWP deliveries in the fall. In Southern California, some water agencies already pump groundwater during the summer and recharge aquifers with SWP imports during the non-summer months. Even at the upper end of energy intensity, using local groundwater supplies to defer summer deliveries of SWP water to Southern California results in significant energy and reliability impacts for the state overall.

Ocean and Brackish Water

Treating ocean or brackish water -- desalination -- began in California in 1965. In 1999, there were 30 desalting plants operating in California for municipal purposes, with total capacity of 80,000 acre-feet per year. Table 2-1 illustrates the expected growth in desalination in California.[21] If all of the planned new capacity is built, total production of desalination will increase from about 80,000 acre-feet per year to nearly 600,000 acre-feet.

Table 2-1: Desalting in California for New Water Supply

	Plants in Operation		Plants in Design & Construction		Plants Planned or Projected	
Feedwater Source	No. Of Plants	Annual Capacity	No. Of Plants	Annual Capacity	No. Of Plants	Annual Capacity
Groundwater	16	79,100	6	29,500	6	61,700
Seawater	7	1,500	1	300	13	415,100
Total	23	80,600	7	29,800	19	476,800
Cumulative			30	110,400	49	587,200

1. Capacity in Acre-feet per year. No. of Plants is the number of new plants.
2. Design & Construction – Construction underway or preparation of plans and specifications has begun for new plants or plant expansions.
3. Planned – Planning studies underway for new plants or plant expansions.
4. Projected – Projected new plants or plant expansions.
5. Sources: "Water Desalination Report" and Worldwide Desalting Plants Inventory series by International Desalination Association as cited in the DWR Bulleting 160-05.

Source: 2005 State Water Plan Update, DWR

[21] *California Water Plan Update 2005* Volume 2, Resource Management Strategies, Chapter 6 Desalination.

Recycled Water

The fastest growing new source of water in the state is not a new source at all; it's recycled water from wastewater systems, commonly referred to as reclaimed water or reuse. Californians have used recycled water since the late 1800s. Faced with increasingly stringent requirements governing disposal of wastewater and limited water supplies, many agencies are installing additional treatment facilities that can purify wastewater to the point where it can be substituted for fresh water in many applications, including power plant cooling and landscape irrigation.

The primary benefit of increasing the use of recycled water, from an energy perspective, is the displacement of other, more energy-intensive water supplies.

- By using local recycled water to recharge depleted groundwater aquifers in Southern California, the amounts of energy-intensive seawater desalination and SWP imports could be reduced.

- When recycled water is distributed to local end users for landscape irrigation, significant energy savings accrue:

  - First, from displacing the energy intensity of the highest marginal water source.

  - Second, from avoiding the energy used to treat the water unnecessarily to potable water standards.

Since recycled water is often a by-product of existing secondary and tertiary wastewater treatment processes, it is the least energy-intensive source in the state's water supply. While incremental energy is typically required to pump recycled water uphill to redistribute it to end users, this incremental energy is offset in part or in whole by displacing higher energy intensity water supplies, as well as reducing potable water treatment and distribution.

The actual net energy benefit of any proposed project also needs to consider the incremental energy that might be needed to treat the wastewater to higher standards than normal, such as targeted end use water quality requirements. Table 2-2 describes the level of treatment needed for different types of reuse.

Table 2-2: Demand Sectors and Minimum Treatment Levels

Demand Sectors and Examples of Minimum Treatment Levels for Specific Uses to Protect Public Health

Types of Use	*Treatment Level*		
	Disinfected Tertiary	*Disinfected Secondary*	*Undisinfected Secondary*
Urban Uses and Landscape Irrigation			
Fire protection	☑		
Toilet & urinal flushing	☑		
Irrigation of parks, schoolyards, residential landscaping	☑		
Irrigation of cemeteries, highway landscaping		☑	
Irrigation of nurseries		☑	
Landscape impoundment	☑	☑*	
Agricultural Irrigation			
Pasture for milk animals		☑	
Fodder and fiber crops			☑
Orchards (no contact between fruit and recycled water)			☑
Vineyards (no contact between fruit and recycled water)			☑
Non-food bearing trees			☑
Food crops eaten after processing		☑	
Food crops eaten raw	☑		
Commercial/Industrial			
Cooling & air conditioning - w/cooling towers	☑	☑*	
Structural fire fighting	☑		
Commercial car washes	☑		
Commercial laundries	☑		
Artificial snow making	☑		
Soil compaction, concrete mixing		☑	
Environmental and Other Uses			
Recreational ponds with body contact (swimming)	☑		
Wildlife habitat/wetland		☑	
Aquaculture	☑	☑*	
Groundwater Recharge			
Seawater intrusion barrier	☑*		
Replenishment of potable aquifers	☑*		

**Restrictions may apply*

Source: DWR's Water Facts 23 issued October 2004.

In most circumstances, from an energy perspective, recycled water made as a by-product of the wastewater treatment process is the most preferred option. Primary barriers to increasing the use of recycled water include the incremental cost of dual piping systems to deliver this source of non-potable but usable water and public apprehension about using water recovered from the sewage treatment process.

The Energy Intensity of the Water Resource Portfolio

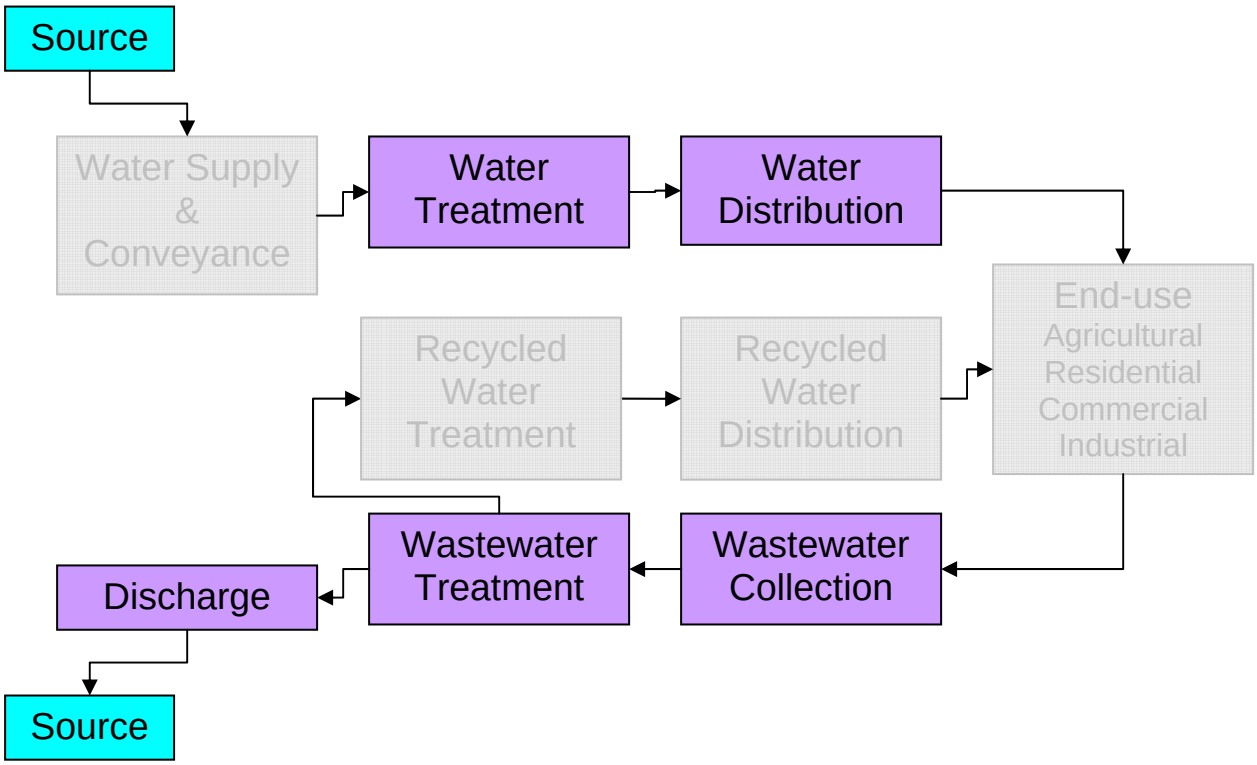
Ultimately, all of these resource choices come together in a water utility's water resource portfolio. Similar to energy utilities, water utilities conduct integrated resource planning (IRP) on a "least cost/best fit" basis. Since energy is typically the highest cost of water supply resources, embedded energy in delivered water supplies is generally reflected in the preferred loading order of water resources in the state's *2005 Water Plan Update.* Using water more efficiently frees up current resources to meet some of the future demand growth.

This is particularly critical in Southern California, where its water mix is roughly half from local sources, and half from imported sources. While water utilities are working hard to develop more local supplies and improve water use efficiency, there are not many options to develop new water sources. Presently, the primary available options are recycled water and seawater desalination.

CHAPTER 3 – WATER AND WASTEWATER TREATMENT AND DISTRIBUTION

This section will discuss, due to their similarities, both the energy intensity of potable and waste water treatment and distribution and the distribution of recycled water.

Figure 3-1: Water Use Cycle – Treatment and Distribution



Energy use for water distribution loads is primarily for pumping water and maintaining sufficient pipe pressure to assure that flows can be made at scheduled rates while maintaining sufficient pressure for fire service.

Water and wastewater treatment processes also use large quantities of energy. In water treatment, energy requirements depend primarily on the characteristics of the raw water, plant size, treatment process, and the distance and elevation of the treatment plant in relation to water sources and water distribution systems. In wastewater treatment, the characteristics of the influent and the level of treatment (primary, secondary or tertiary) are principal drivers of energy consumption.

Electric loads at water and wastewater treatment plants consist primarily of pump motors but also include air blowers, injection equipment, controls, lighting, and, in

some cases, ultraviolet light disinfection and ozonation. Wastewater treatment plants also require activated sludge and sludge handling systems that consume large quantities of energy. The Energy Commission Demand Office estimates that a total of about 9,000 GWh of electricity is used annually by both water and wastewater facilities. This is based on both electric and water meter data and assumptions from engineering handbooks and other sources about the electricity use of certain equipment. Because the meter data is not reported in separate categories it cannot be disaggregated to separate water from wastewater treatment.

The Association of California Water Agencies (ACWA) estimates that the state's water and wastewater treatment facilities collectively draw about 3,000 MW at peak, with 1,800 MW occurring in Southern California Edison's (SCE) service territory, with the rest geographically distributed throughout the state more or less in proportion with population.

Both water and wastewater treatment processes require pumps and motors to transport water before, during, and after treatment. Pumping is not as significant a portion of the load for wastewater as for water because wastewater treatment processes are significantly more energy intensive, and both wastewater collection and disposal typically rely heavily upon gravity. Thereafter, the treatment processes and their relative energy intensities vary considerably.

Water treatment has historically been a comparatively modest user of energy, relying primarily upon settlement and passive filtration to remove particles from water, and chemical treatment (chlorination or chloramination) for disinfection. As new water quality regulations are implemented, energy-intensive technologies such as membranes, UV and ozonation will require large quantities of energy. Wastewater treatment requires much more energy, with each progressive level of treatment requiring still more. In secondary treatment, most of the energy is used for biological treatment; pumping of wastewater, liquid sludge, biosolids and process water; and processing, dewatering, and drying of solids and biosolids. Tertiary treatment requires additional energy for aeration, pumping, and solids processing. All of these processes present opportunities for energy reduction.

To reduce energy costs, many utilities have already replaced pumps and motors with newer, more efficient equipment. The addition of variable frequency drives and customized pumping algorithms provide the capability to further reduce energy requirements by more closely matching pumping capacity with loads. In addition, both water and wastewater utilities have recently demonstrated that significant reductions in energy consumption could be achieved by employing interim storage to shift processing to off-peak periods and balance processing loads among multiple plants to optimize plant efficiencies.

In the mid-1990s, EPRI and HDR Engineering, Inc. conducted an audit of the energy savings potential for water and wastewater facilities in California. At that time, they estimated that more than 880 million kWhs could be saved by implementing several measures: load shifting, variable frequency drives, high-efficiency motors and

pumps, equipment modifications, and process optimization with and without Supervisory Control and Data Acquisition (SCADA) systems. These estimates did not include incorporating interim storage to shift loads and optimize plant efficiencies. Industry experts estimate that untapped energy efficiency opportunities through the optimization of water and wastewater treatment processes could be as high as 30 percent of existing processes.

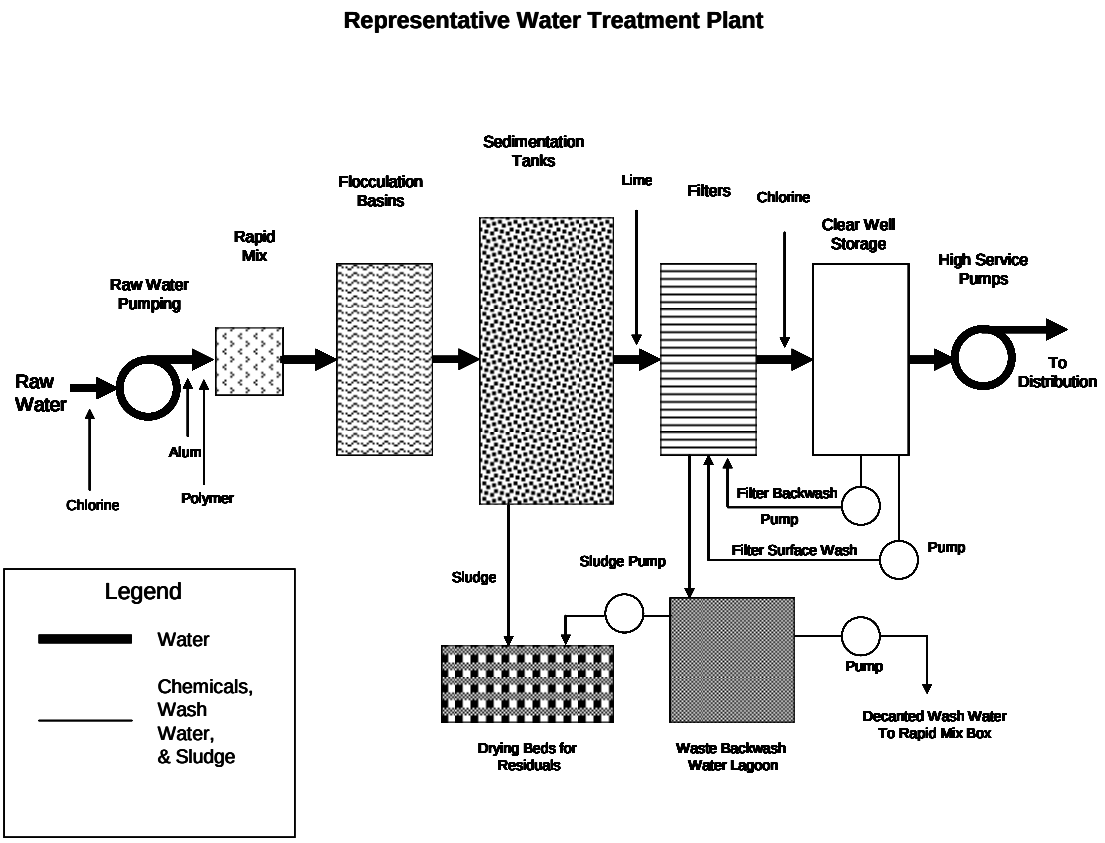
The sections below will describe energy uses for water treatment and distribution, and for wastewater treatment.

Water Treatment

Source water quality and the end use of the water dictate the level of treatment required. For potable uses, a typical sequence of operations for surface water treatment is described in the following steps (refer to Figure 3-2).

- Raw water is first screened, pre-oxidized using chlorine or ozone to kill organisms.
- Alum and/or polymeric materials are added to the water.
- Flocculation and sedimentation remove finer particles.
- A second disinfection step kills remaining organisms.
- The clear tank allows contact time for disinfection.
- Treated water is distributed to consumers by high-pressure pumps (disinfectant residue is carried into the distribution system to prevent organism growth). Sludges and other impurities removed from water are concentrated and disposed of.

Figure 3-2: Sequence of Operations in Surface Water Treatment



Source: Electric Power Research Institute

As shown in Table 3-1, although no two treatment facilities are identical, the following survey of more than 30,000 public supply systems in the United States[22] indicates little variation in water treatment energy intensity for plant capacities of at least 1 million gallons per day[23].

[22] Inventory of public water supply systems maintained by the U.S. Environmental Protection Agency in the Safe Drinking Water Information System.
[23] *Water & Sustainability* (Volume 4): *U.S. Electricity Consumption for Water Supply & Treatment*, EPRI March 2002, Figure 2-1, page 2-2,

Table 3-1 Energy Use by Surface Water Treatment Plants

Plant Size (Million Gallons per Day)	Energy Intensity (kWh/MG)
1	1,483
5	1,418
10	1,406
20	1,409
50	1,408
100	1,407
Average	**1,422**

Source: Electric Power Research Institute

Water treatment energy requirements are driven principally by the characteristics of incoming raw water and by the distance and elevation of the treatment plant in relation to water sources and the distribution system. Actual energy demand is highly variable by water utility. Lowest is pristine Hetch Hetchy water, which is exempted from filtration by the U.S. Environmental Protection Agency (US EPA)[24]. However, most surface and groundwater sources require treatment to meet regulatory standards and the taste and odor preferences of the public. Some treatment plants also have unique requirements, such as the removal of industrial chemicals from well water that require more energy. Net energy demand is expected to change as more energy-intensive disinfection processes are used to address water quality concerns and meet increasingly stringent potable water rules under the federal Safe Drinking Water Act (see discussion in Chapter 6).

Despite extensive data searches, staff found only a few studies that attempted to determine the exact electricity use for water treatment facilities. One of the most comprehensive and innovative studies came from an effort in Sonoma County to address greenhouse gas emissions. This study included energy use by municipal facilities, including the county's wholesale water agency, the Sonoma County Water Agency, and all of its municipal system water customers.

The Sonoma County Water Agency provides domestic water to 540,000 domestic water users in Sonoma, Marin, and Mendocino counties. Its only source of water is the highly variable flow of the Russian River and storage in two reservoirs on tributaries of the Russian, Lake Sonoma, near Healdsburg, and Lake Mendocino, near Ukiah. The EPA has listed the Russian River as impaired because of dissolved solids and nutrients. To both avoid these impairment issues and comply with federal

[24] The high quality Hetch Hetchy's water supply, produced by Sierra snowmelt in a protected watershed, has been granted a filtration exemption from the U.S. Environmental Protection Agency (U.S. EPA) and the California Department of Health Services (DHS).

Endangered Species Act limitations on stream withdrawals, many of the county water agency's municipal customers mix the river water with about equal amounts of groundwater, which is generally less costly.

The Sonoma County Water Agency required nearly 2,600 kWh/million gallons to pump and treat water from the river over the period of April 2000 to September 2002. Pumping costs were essentially linear throughout the year (that is, the electricity use per million gallon rate was essentially constant) except for spikes in January and February, when large amounts of surplus water were transferred to storage in reservoirs, especially in Marin County (Rosenblum 2003). Data are insufficient to determine the amount of energy used for pumping the water (which corresponds to the "Collection, Extraction and Conveyance" portion of the water use cycle described in Chapter 2) as opposed to energy used solely for water treatment.

In addition to Hetch Hetchy, EBMUD is an example of an agency with energy intensity of water treatment on the lower end of the spectrum. EBMUD gets 95 percent of its water from the Mokelumne River, delivered by gravity through the Mokelumne Aqueduct. The Mokelumne water is relatively high quality at its source, requiring little treatment; and the EBMUD's treatment facilities are located high in the East Bay Hills, using elevation to help pressurize its distribution system. Because of these factors, EBMUD's electricity use is a low 150 kWh/million gallons for conveyance, and 275 kWh/million gallons for treatment (EBMUD 2000 and Navigant Consulting 2004).

Desalination

Desalination involves removal of salts and dissolved solids from seawater or brackish water. Most desalination processes are based on either thermal distillation or membrane filtration technologies, both of which are very energy intensive.

The primary benefit of desalination is its ability to increase potable water supply by reclaiming water of poor quality. The most significant challenge of desalination is that it is a very energy-intensive source of water, and its highest use will likely coincide with extended drought periods when hydropower production is lowest.

Unlike every other type of water facility, where staffing edges out energy use as the main expense, desalination's primary operating cost is for energy, with seawater desalination being considerably more energy intensive (9,780-16,500 kWh/million gallons) than brackish groundwater desalination (3,900–9,750 kWh/million gallons).[25] The difference between seawater and brackish desalination ranges is due primarily to the difference in the initial water quality, and within each range the variance is due primarily to the plant design and technology employed. Most desalination plants operate continuously, so this electricity is used during all seasons and at all times of

[25] California Department of Water Resources Desalination Task Force Final Report 2003.

the day. Current plants are operating 90 percent of the time, with downtimes only for maintenance (DWR, 2005).

According to the *2005 Water Plan Update*, a 50 MGD seawater plant (approximately 50,000 acre-feet per year, or 16.25 billion gallons, assuming operations 90 percent of the time) would require about 33 MW of power.[26] This translates to about 5,200 kWh per acre-foot, or 16,000 kWh per million gallons, which is the upper-end of California's energy intensity of water supplies. Multiple efforts are underway to increase the energy efficiency of desalination through improved membranes, dual pass processes, and additional energy recovery systems.

Present estimates indicate that existing desalination facilities use 370-890 GWh per year. As stated in Chapter 2, if all of the planned new capacity is built, total production of desalination will increase from about 70,000 acre-feet per year to nearly 300,000 acre-feet. Assuming an average of 3,900 kWh/acre-foot (about 12,000 kWh per million gallons),[27] an incremental 230,000 acre-feet would require about 897 GWh. In the IEUA example, desalination of local brackish groundwater supplies can produce a net energy benefit when displacing higher energy intensity desalted seawater or SWP imports.

Desalination of seawater has the highest energy intensity of all water treatment options.

Water Distribution

Once treated to potable standards, the water must be distributed to customers, generally through a network of storage tanks, pipes, and pumps. During distribution, water must be kept moving and under pressure to minimize corrosion and biological contamination. Storage tanks and water mainlines must be flushed periodically to prevent oxidation and control biofilms (AWAARF 2000). Even the farthest reaches of the network must be kept under adequate pressure and constantly flushed since low pressure and low flow allow microbes to flourish (ACWA workshop April 14, 2005).

On average, staff estimates that city water agencies use about 1,150 kWh/million gallons of electricity just to deliver water from the treatment plant to their customers. The energy required for distribution pumping is mainly driven by the distribution system configuration, its relative size, elevations, and system age.

The water supply diagram and the results of the EPRI survey in Table 3.1, above, reflect little variation in the amount of energy required to treat and distribute a unit of water for systems requiring at least 1 million gallons per day. For this large survey

[26] *California Water Plan Update 2005* Volume 2, Resource Management Strategies, Chapter 6 – Desalination.
[27] The average of the Chino desalter and seawater desalination in IEUA's water supply options.

size of approximately 30,000 public water supply systems, distribution pumping of treated water remained fairly constant at between 80 to 85 percent of total energy requirements when treatment and distribution energy loads are combined. For purposes of this paper, staff adopted this ratio and assumed prototypical water distribution energy intensity to be about 1,200 kWh/MG.

Cities with hilly terrains can use hilltop tanks both as storage and to provide pressure into the distribution system; San Francisco is perhaps the best example of this, serving virtually all of its customers from hilltop tanks. But the water must first be pumped up to the tank, often several hundred feet in elevation. In addition, though water agencies loathe wasting water and energy, they often must flush water from the tanks to prevent microbial contamination and then fill them up once again through the pumping station. In fact, this flushing accounts for the bulk of electricity used in EBMUD's distribution system.

Wastewater Treatment

Other than water devoted to landscape irrigation, or lost through evaporation (such as in cooling towers and other processes), almost all the water entering homes and businesses in California eventually leaves as wastewater. Wastewater treatment is similar to freshwater treatment. But most wastewater treatment systems have the additional step of using biological reactors that use bacteria to break down waste. Wastewater pumps are inherently more inefficient because they must pump both liquids and solids, and must have greater clearances between the pump impeller and the casing, allowing much of the pumped water to return to the intake plenum. Energy use in a wastewater system is primarily from use of very large electric pumps and blowers and use of natural gas to heat the anaerobic digesters.

Digester biogas (approximately 60 percent methane and 40 percent CO_2) is produced by anaerobic bacteria. The gas can be collected and used to generate electricity, usually powered by an internal combustion engine and used to run the facility itself. Waste heat recovered from the engine can be used to heat the digesters and displace natural gas use.

The number of water and wastewater treatment techniques and the combinations of techniques are expected to increase over time as more complex contaminants are discovered and regulated.

Wastewater consumes electricity in three stages: transport to the facility, treatment, and disposal/recycle. The first stage, transporting from the customer to the wastewater treatment facility, requires about 150 kWh/million gallons of electricity on average to pump the water, depending on topography, system size, and age. When they have a choice, agencies prefer to place water treatment facilities above their customers and the wastewater treatment facilities below, to harness the pull of

gravity where possible, and to place water intakes above wastewater outfalls on rivers.

There are levels of treatment, and each progressively requires higher levels of energy use. These steps may consist of physical processes, biological processes, or chemical processes.

Physical Processes
The initial steps involved in the sewage wastewater treatment are physical processes, which separate larger solids from liquid using screening or grit removal. Steps that remove larger solids are termed preliminary treatment. The solids separated from the preliminary processes are usually disposed of in a landfill. After removal of larger solids, primary treatment follows to separate the smaller solids. Some chemicals may be added to assist with solids removal.

Biological Processes
The physical processes are followed by biological aerobic treatment in which extended aeration (oxygen) and environmental conditions are provided for microbes to break down organic material into carbon dioxide and water. Equipment used for the aerobic treatment includes tricking filter, aeration basin, and others. This biological aerobic treatment is commonly called secondary treatment.

After the aerobic treatment, the wastewater is separated with a sedimentation tank to separate the sludge and the clear effluent. The sludge is then sent to an anaerobic digester where the organic material is broken down into biogas, which is primarily methane and carbon dioxide.

Chemical Processes
The clear effluent, after the secondary treatment is further treated with physical filtration, chemical, or ultraviolet disinfections. This further treatment is commonly called tertiary treatment. The tertiary effluent can be used for beneficial reuse or discharged to surface water.

The progressive levels of treatment are commonly referred to as “primary”, “secondary” and “tertiary”, with primary being the lowest level, and tertiary the highest. Effluent from both secondary and tertiary treated water can be reused. The levels of treatment required for types of reuse (i.e., recycled water) are described in Table 2-2 in Chapter 2.

The major driver of unit energy consumption is the degree of treatment required. As noted above, there has been a trend toward more thorough treatment, with upgrades or replacements of older systems that could not provide this higher level of treatment. This trend is seen in comparing the estimated unit electricity consumption in 1988 with consumption in 2000: the baseline unit energy consumption was

estimated to increase at an average compound rate of about .08 percent per year. This upward trend in unit electricity consumption is expected to continue as more thorough treatment is required.

Unlike water treatment and distribution systems, unit volume energy requirements for wastewater treatment plants vary greatly depending upon plant size. Energy intensity for a 1 MGD wastewater treatment plant can be approximately three times that of a 100 MGD wastewater treatment plant[28]. As expected, unit electricity consumption rises as the degree of treatment and complexity of the process increases. For example, advanced wastewater treatment with nitrification is three times as energy intensive (due to additional pumping requirements) than that of a relatively simple trickling filter plant.[29] Further complicating the assessment of prototypical unit volume energy intensity are unique operational environments, discharge limitations, influent characteristics, permitted effluent limitations, and variations in plant permitting cycles.

Table 3-2 Energy Intensity of Wastewater Treatment Facilities

Source of Data	kWh/MG
Inland Empire Utilities Agency	2,971
City of Santa Rosa	2,920
East Bay Municipal Utilities District	2,001
Metropolitan Water District	2,655
Methodology for Analysis of Energy Intensity in California's Water Systems	1,911
Energy Down The Drain, The Hidden Costs of California's Water Supply	2,302
Energy Benchmarking Secondary Wastewater Treatment	2,625

Source: Multiple, see Appendix C

Table 3-2 shows wastewater treatment plant energy intensities reflecting a range of energy intensity for facilities operating in California and cited in studies. Based on this range, 2,500 kWh/ MG has been adopted as the prototypical wastewater treatment energy intensity (for more detailed discussion and references see Appendix C).

One of the most interesting opportunities for reducing energy use for wastewater treatment is to improve storm water management. During rainy weather, a considerable amount of runoff ends up in wastewater systems, greatly increasing treatment costs. Even communities that do their best to keep stormwater out of their sewer systems see nearly double the flow during a winter storm than during the dry summer months. This “infiltration/inflow” of stormwater into the sewer system has on

[28] *Water & Sustainability* (Volume 4) *U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century*, EPRI 2002, Pages 3-4 & 5 and Table 3-1.
[29] *Water & Sustainability* (Volume 4) *U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century*, EPRI 2002, Pages 3-4 & 5 and Table 3-1.

occasion forced many communities to discharge raw or minimally treated wastewater directly into local waters.

For example, Sonoma County's largest wastewater facility, the Laguna Wastewater Treatment Plant, operated by the City of Santa Rosa, experienced a peak inflow of nearly a billion gallons per month in January and February of 2000 and 2002, while average inflow in the summer months was just over half that amount (Rosenblum 2003, Figure 7). Its wastewater treatment electricity use is proportionate to these flows, and therefore nearly twice as high in winter than in summer.

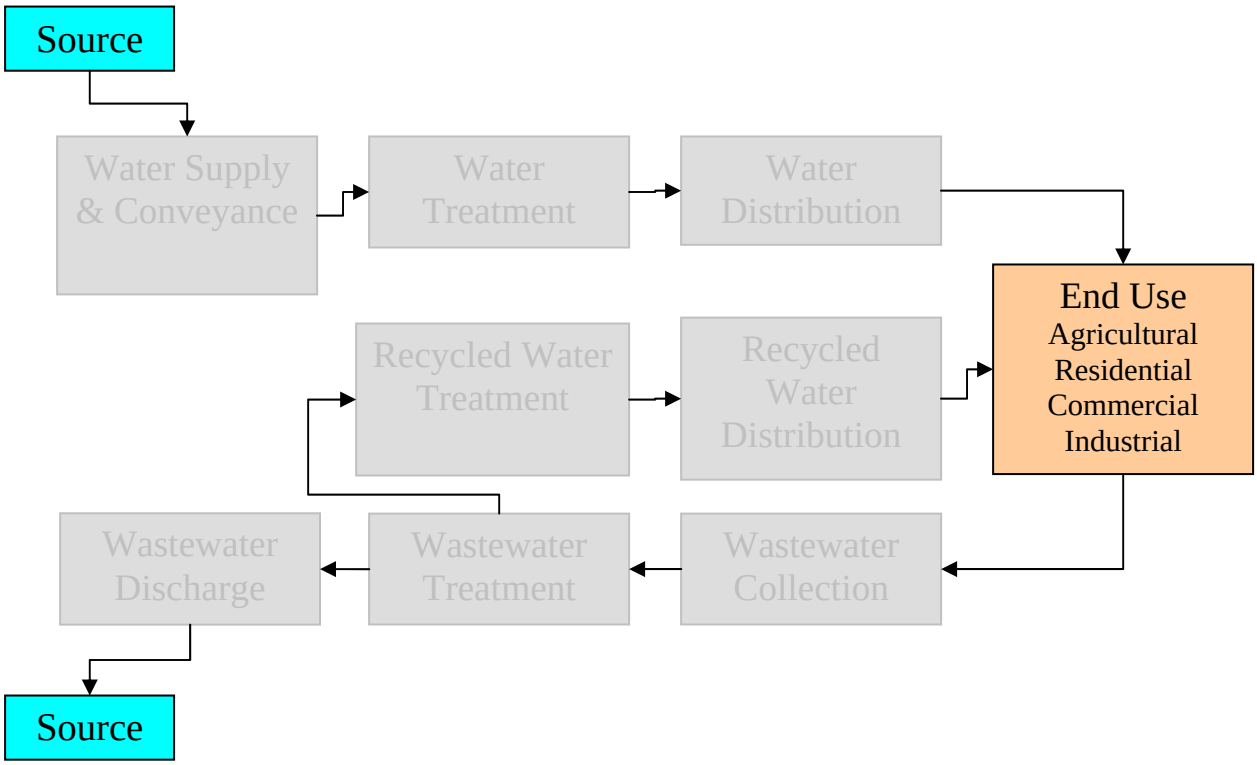
Conclusions

In this chapter, staff has generally described water energy intensity for water treatment, wastewater treatment, and water distribution. Staff has also identified areas that will require additional information and analysis to better understand these systems and how modifications or improvements could benefit the energy sector. Future regulatory changes made in response to health and water quality concerns will affect the overall energy demand of these systems.

CHAPTER 4 – WATER RELATED END-USE EFFICIENCY

This chapter addresses opportunities to increase water and energy end-use efficiency.

Figure 4-1: Water Use Cycle – End Use



The Energy Impact of Water Use Efficiency

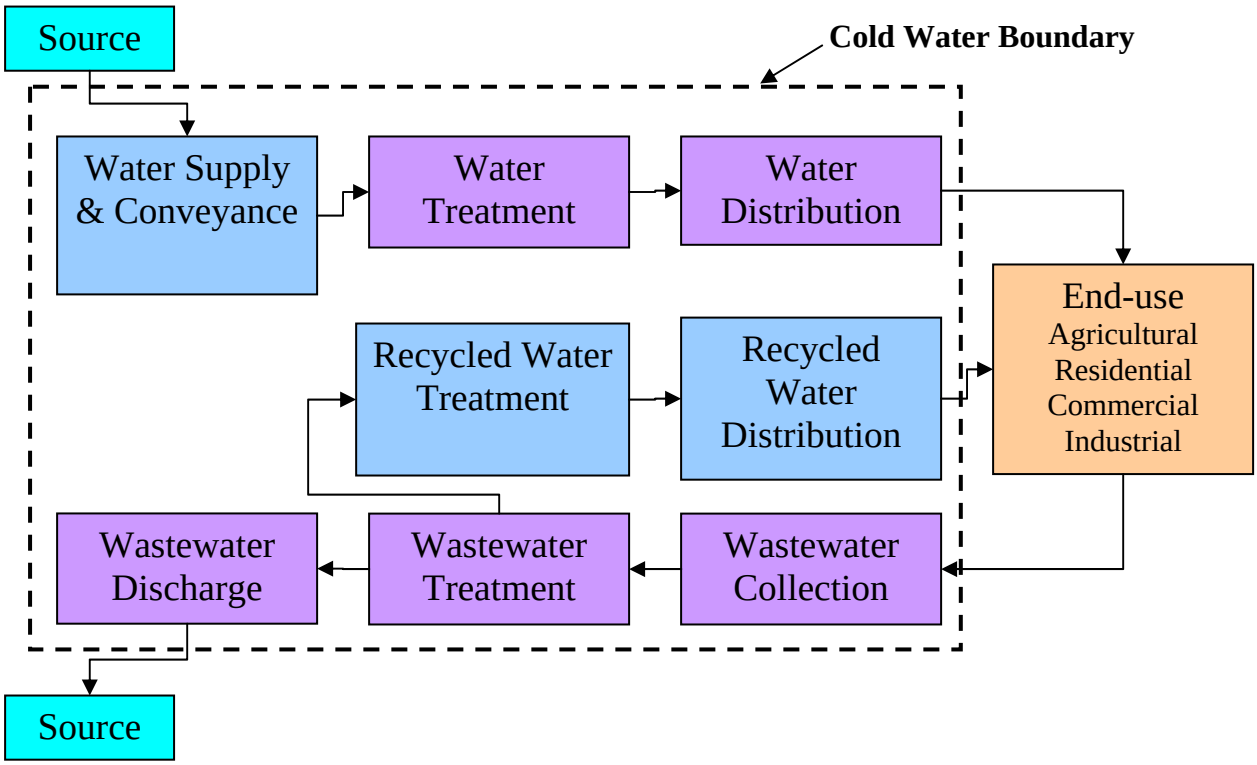
Water end-use applications in California use more energy than any other part of the state's water use cycle. Energy efficiency water programs have traditionally focused on either saving energy in water and wastewater treatment facilities or saving energy in end-use applications including water heating, clothes washing and drying or process heating. Water use efficiency programs have similarly focused on saving water in end-use applications. In both cases, end-use efficiency measures are beneficial, to both utilities and end users, when the value of the saved energy or water exceeds the cost of the measure.

For the most part, these efficiency improvements have been pursued separately by water and energy utilities, although there are some examples of close coordination, including the effort to introduce high-energy-efficiency and low-water-factor clothes washers to the consumer market. What appears to be missing is the recognition that saving water also saves energy throughout the conveyance, treatment, distribution and wastewater treatment processes of the water use cycle.

The energy intensity of water use varies depending on its end use and location in the state. For example “statewide average,” agricultural end uses are less energy-intensive than either “statewide average” urban end uses or agricultural end uses in Southern California that rely upon SWP or Colorado River Aqueduct water deliveries. All are more energy-intensive than those in Northern California. On average, urban water uses in Southern California are more than three times as energy-intensive as those in Northern California.

While these relationships are useful for policy development and planning, it is important to recognize that the actual energy intensity of the water use cycle is very location- and application-dependent; this information is important as specific projects are considered. Figure 4-2 shows the overall cold water boundary. To apply the concept of energy intensity, the cold water boundary must be identified for specific locations and applications. Further details are in Appendix C.

Figure 4-2 Cold Water Boundary in the Water Use Cycle



Conserving a unit of cold water avoids using the energy that would have been needed to supply, treat, deliver, consume, collect, treat, and dispose of it as wastewater. The actual amount of energy saved depends upon the type and source of water supply, the distance the water has to travel, the nature and extent of its treatment, and the type of end use.

In California, saving cold water, both indoors and outdoors, saves energy. The energy saved is primarily electricity. Saving outdoor water saves the energy it takes to extract, convey, treat, and distribute water to customers. Saving indoor water saves the additional energy, again mostly electricity, used to collect, treat and dispose of the waste water. Saving indoor hot water saves the additional energy needed to heat this water. In California, this additional energy is mostly in the form of natural gas.

From an energy perspective, saving cold outdoor water is good. Saving cold indoor water is better. Saving hot indoor water is better still.

Saving end-use energy can also save water and the energy associated with the applicable portion of the water use cycle. For example, when air conditioning is reduced in large buildings that use cooling towers to remove the heat, every unit of energy that does not need to be removed means that less water is needed in the process. Also, saving electricity in any fashion saves water at power plants that use cooling water.

Agricultural Water Use Efficiency

About 79 percent of the state's water is used by the agricultural industry to grow more than 200 crops that generate more than $29 billion dollars a year for the state's economy (CDFA, 2003). Because water conveyance and pumping are very costly, efficient irrigation technologies and farming practices hold promise for reducing both the amount of water needed and the energy intensity of crop production.

While a unit of agricultural water is not as energy intensive as a unit of urban water, the agricultural industry strives to meet water conservation objectives, save money, and preserve water resources. Many times the adoption of natural resource conservation practices creates new energy expenditures. The industry can reduce these costs by participating in energy efficiency and demand response programs through the public goods charge funds administered by their investor-owned utilities (IOU).

Energy Efficiency and Conservation Measures

Since the mid-1990s, the agricultural industry has adopted multiple water conservation practices, among which are installation of drip- and micro-irrigation

technologies. The use of on-farm pressurized irrigation methods has increased from about 1.4 million acres in the early 1980s to more than 4.2 million acres today.[30] These changes can result in better crops, reduced water use, and the reduced use of fertilizers and chemicals, all of which result in greater productivity and energy efficiency.[31]

To be more productive, farms must also improve the efficiency of their water pumping systems. Since the 2000-2001 energy crisis, thousands of farmers and irrigation districts have used state- and ratepayer-funded pump test and repair program incentives. Many of the pumps were repaired to boost their pumping plant efficiencies.[32] When pump tests are performed and cost-effective pump repairs are completed, pump efficiencies can increase by 5 to 15 percentage points. This improved efficiency provides increased pumping capacity. Where previously a farmer might have used seven days to water his fields, it might now instead take five or six days to do the same work. Most farmers will adjust their irrigation set times to reflect the new water output and reduce the total number of hours of operation, saving both water and energy.

These measures can more than offset the new energy requirements that most often accompany drip system installations. Although there will be a higher demand for connected load from the installation of booster pumps, the total hours of operation will depend on the source of water and the irrigation system that is being converted to drip. Most often farms are required to pump from groundwater sources to satisfy the on-demand, clean, and flexible water delivery needs of the drip systems, possibly increasing their energy costs. Studies have shown that the conversion from surface irrigation to drip/micro- and sprinkler-irrigation technologies has lead to increased on-farm groundwater pumping on the east side of the San Joaquin Valley.[33]

Adoption of Time of Use (TOU) Agricultural Electric Rates

Large numbers of both Pacific Gas and Electric (PG&E) and SCE agricultural customers have signed on to TOU electric rate schedules. In the PG&E service area 81 percent of agricultural revenues and 89 percent of agricultural kWh sales are on TOU rates, representing 40,000 accounts of the total 80,000 agricultural accounts[34]. In the SCE service area, 71 percent of agricultural kWh sales are on TOU rates, generated by 18 percent of the utility's customer accounts[35].

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[30] CalPoly ITRC, Memorandum, 2005
[31] CalPoly San Luis Obispo University, ITRC Report No. R 96-001, Row Crop Drip Irrigation on Peppers Study - High Rise Farms, 2006
[32] Nexant, M&V report from the California Energy Commission Agricultural Peak Load Reduction Program, 2003
[33] CalPoly ITRC, California Agricultural Water Electrical Energy Requirements, 2003
[34] Personal communication with Keith Coyne, PGE, 8 4 2005
[35] Personal communication with Cyrus Sorooshian, SCE, 8 11 2005

Although there are many accounts on TOU rates, farmers still use energy during peak-period hours. If crop water needs require irrigating during peak periods, the farmer will exercise the option to use on-peak power and pay the penalties, leading to higher average energy costs. The farmer's goal is to provide water to crops when it's needed, in the proper amount, using high distribution uniformity for optimal crop growth. It is not always possible to meet all of these requirements and take maximum advantage of TOU rates.

Staff recognizes that, to pump water during off-peak hours, farms will require larger pumping plants with properly designed irrigation systems, improved control systems, and flexible working hours. To take full advantage of these changes farmers will have to maintain high efficiencies in their pumping and irrigation systems in addition to adopting scientific irrigation scheduling management practices.

Agricultural electricity end users would benefit from energy policies that allow end users to choose the demand response practice that best meets the requirements of their business. The industry will also be more inclined to invest in peak load reduction measures with both flexibility and strong stable price signals.

Other Factors Affecting Agricultural Water Energy Use in California

There are several trends to watch that affect the future use of energy to provide water to agriculture, including:

- Sustained adoption of drip and micro irrigation technologies. Although there are more than 4 million acres under drip irrigation, from a total of less than 9 million acres of irrigated land reported for the state, it is reasonable to assume that, over time, another 3 million acres could be converted to drip irrigation. The agriculture industry will make the conversion partly to meet water conservation goals but mostly by recognizing the production benefits from the technology. CalPoly ITRC forecasted an increase of 2.9 million kWh from the doubling of drip irrigation acreage.[36]

- Continued reliance on ground water, with reductions in surface water. There is a high probability that farmers will continue to pump from wells to supply groundwater to drip systems until irrigation districts provide surface supplies with flexible schedules.

- An increase in agricultural water conjunctive use programs with transfers to urban regions. There are many water transfer agreements already in place, with more to come as the urban sector finds that the agricultural industry can provide storage services as well as new water transfers from achieved

[36] CalPoly ITRC, California Agricultural Water Electrical Energy Requirements, 2003.

conservation measures. There are significant energy expenditures to accomplish the process of banking the water, pumping it for extraction and delivering it to the water account owner[37].

- Conversion from diesel-powered pumping systems to electric motors. On August 1, 2005, a new rate schedule (AG-ICE) became available for current agricultural diesel-driven irrigation pumps in both PG&E's and SCE's service territories. The rate encourages the switch from engines to electric motor-driven systems for agricultural customers with diesel engines of greater than 50 horsepower for irrigation pumping before September 1, 2004. In the PG&E territory it is possible that 200 to 300 MW of new coincident peak load could be added to its system during the course of the two-year open enrollment period.[38]

The Energy Commission's *2005 California Energy Demand Forecast* shows that agricultural electricity consumption is expected to increase by 1.4 percent a year through 2016.[39] The actual amount will fluctuate depending upon the total number of irrigated acres, the crop patterns, the source of water and, obviously, the price of electricity.

From a state energy policy perspective, the agricultural industry's effort to achieve electricity use efficiency and demand response savings would satisfy the first target in the state's loading order. The agricultural industry also has the opportunity to adopt the second item in the loading order with installation of renewable energy systems.

The agriculture industry does have great potential to develop renewable energy sources. However, investment recovery will require the aggregation of electricity account meters so that the generated power can be applied to all existing accounts. Today, these accounts can only apply the power produced to the single connection attached to the power system. Therefore only a limited amount of power can be sold at the retail price, with the remainder sold at wholesale prices. This situation is similar to that faced by water and wastewater utilities. These issues affect many customers in the state and are being considered by the CPUC as it attempts to balance a wide variety of factors related to distributed generation in California.

The agricultural industry's economic sustainability greatly depends upon nature's water cycle. During dry years, the amount of energy used to deliver water increases. In drought years, groundwater sources are used extensively to supplement lower surface water deliveries. Several consecutive dry years can also lower the groundwater subsurface level of the water table, requiring more energy to overcome the lift needed to pump the water up to the surface. Typical groundwater lifts vary by

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[37] CalPoly ITRC, California Agricultural Water Electrical Energy Requirements, 2003) [http://itrc.org/reports/energyreq/energyreq.pdf].
[38] Personal communication with Keith Coyne, PG&E August 4, 2005.
[39] *California Energy Demand 2006-2016, June 2005*

region throughout the state, which influence both motor size and power usage. The state has been fortunate in that there has not been a continuous series of dry years since the 1988-1992 drought. Since then, new groundwater recharge basins have been developed to serve as infrastructure for water transfer transactions. These measures are important both for water management flexibility and energy efficiency.

Additional small-scale water storage systems located in irrigation districts and on farms could help increase the flexibility of water deliveries. Surface and tank storage facilities can store water during off-peak periods and reduce the need for on-peak electricity consumption.

Urban Water Use Efficiency

Approximately 21 percent of the state's water is for urban uses. Urban water use efficiency includes improvements in the residential, commercial and industrial sectors. It includes opportunities to increase the efficiency of water-related end uses that use either electricity or natural gas.

In November 2003, the Pacific Institute published a study[40] that estimated the minimum cost effective urban water conservation at around 2 million acre-feet (651 billion gallons) per year, about 22 percent of all urban water use -- without technological change. The California Urban Water Conservation Council (CUWCC) recently posted the results from 32 percent of the agencies that signed on to their memorandum of understanding to institute best management practices (BMPs) in their water agencies. Taking only those BMPs for which water savings could be quantified, the reporting agencies saved more than 27 billion gallons of water in 2004, resulting in significant electricity energy savings, as shown in Table 4-1. The water savings from the BMPs, reported in 2004, are roughly 4 percent of the potential described by the Pacific Institute.

[40] *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* The Pacific Institute, November 2003.

Table 4-1: Energy Value of Saved Water Due to Implementation of 2004 BMP Measures

Statewide	Annual Savings Water (MG)	Annual Savings Electricity (kWh)	Useful Life (Years)	Life-Cycle Electricity Savings (kWh)	NPV Electric Avoided Cost ($)
BMP 1 Water Survey Programs MF/SF	1,897	17,114,500	5	85,572,500	6,220,866
BMP 2 Residential Plumbing Retrofit	311	2,814,000	5	14,070,000	1,022,865
BMP 4 Metering & Commodity Rates	1,587	14,317,200	11	157,489,200	9,472,790
BMP 5 Large Landscape Conservation Programs	5,320	34,595,450	10	345,954,500	21,149,701
BMP 6 High-Efficiency Washing Machine Rebate	317	2,860,100	15	42,901,500	2,346,888
BMP 9 Conservation Programs CII	4,814	43,433,300	12	521,199,600	30,567,522
BMP 9a CII ULFT	258	2,328,300	25	58,207,500	2,522,363
BMP 14 Residential ULFT	12,987	117,184,600	25	2,929,615,000	126,950,010
Statewide Total	27,492	234,647,450		4,155,009,800	200,253,005

Source: California Urban Water Conservation Council (CUWCC) Reporting Database, April 2005 with 86 of 269 Reporting Units (32%) reporting BMP expenditures in 2004. Reporting Units include: water utility districts, water agencies, irrigation districts, city and county water departments and water service companies implementing BMPs.

Saving this water also saved more than 234 million kWh of electricity. Taken over the lifetime of each measure, the net present value of the energy for this saved water is more than $200 million. The saved energy was computed using the urban use energy intensity of 4,000 kWh/MG in Northern California and 12,700 kWh/MG in Southern California. These values assume that all water delivered to these uses is also treated as wastewater and applies to all of the BMPs (except the landscape conservation programs, which used a lower number to account only for the water delivery portion of the water use cycle). The computations were done separately for Northern and Southern California and aggregated to arrive at the statewide totals shown in the table. Details of this analysis can be found in Appendix C.

The energy saved from the saved water was passed on to the California water and wastewater treatment utilities that participated in implementing the BMPs. It also showed up as reduced electricity sales and some peak demand reduction. However, energy savings from savings in the water use cycle were not recognized by either the CPUC or by the energy utilities as fundable energy conservation measures.

Members of the Water-Energy Relationship Working Group presented testimony on this topic, suggesting it would be valuable to assess how large the energy value of the conservation potential identified by the Pacific Institute might be in comparison with energy efficiency programs currently approved by the CPUC. Table 4-2 presents the comparison of programs funded in 2004-2005 with those planned for 2006-2008. The water use efficiency (WUE) program is based on the Pacific Institute's expressed water saving potential.

Table 4-2: Comparison of Energy Efficiency Programs Resource Value to Water Use Efficiency

	Energy Efficiency Programs		
	2004-2005	2006-2008	WUE
GWh (Annualized)	2,745	6,812	6,500
MW	690	1,417	850
Funding ($ million)	$762	$1,500	$826
$/Annual kWh	$0.28	$0.22	$0.13
WUE Relative Cost	46%	58%	

Source: California Public Utilities Commission, with WUE estimates from Appendix C

The numbers for the energy programs are from CPUC documents.[41] The numbers for the WUE program are discussed in detail in Appendix C. The energy savings were assigned to Northern and Southern California based upon their respective populations. The cost of water efficiency measures assumes an average of $384 per acre-foot, based on a range of $58-$710.

There is clearly significant untapped energy savings potential in programs focused on water use efficiency. If all of the identified urban water savings could be achieved, the energy savings would achieve 95 percent of the savings expected from the 2006-2008 energy efficiency programs, at 58 percent of the cost. Peak savings could account for 60 percent of the utilities' expected demand reductions.

TOU Water Tariffs and Meters

The idea of TOU water tariffs and meters was suggested several times during the proceedings as a means to give customers a more accurate assessment of the value of the water they use. Historically, water agencies have treated their product as a commodity; water flows and people use it. Before the 2000-2001 energy crisis, even though water agencies were on standard TOU and demand rates, the incremental costs between on and off peak were not large enough to affect their decision making. They did not attach time value to water until SWP and the state water contractors became sensitized to hourly energy costs in the highly volatile bulk power market. At the retail level, it is important to recognize that many water customers in the state do not even have water meters, although legislation is changing that. Currently, TOU water meters do not exist. Water agencies are also grappling with how to develop tariffs and rate schedules that both properly reflect the value of water at different times during the day and account for delays between

[41] 2004-2005, CPUC Rulemaking R.01-08-028, Decision D.03-12-060, 2005-2006, CPUC Rulemaking R.-01-08-0228, Decision D.04-09-060.

energy consumption and water use. The Energy Commission is funding a project to look at the feasibility of these meters and associated tariffs.

Because the vast majority of the financial benefits of water use efficiency go to customers instead of water, wastewater, or energy utilities, informing customers of the financial upside of more efficient appliances and practices could be very effective. The new "Flex Your Power at the Tap" campaign is one example. In the longer term, water and energy bills could also serve as informational pathways leading customers to efficiency investments and choices that are best for both them and the greater society.

Water Storage for Peak Electric Load Shifting

Water and wastewater treatment require approximately 3,000 MW of peak load. There is a minimum level of electrical consumption needed to operate their systems during peak periods. Beyond that, virtually all of the on peak energy use is discretionary - if there is sufficient storage. For example, the El Dorado Irrigation District reduced its on-peak electric usage by more than 60 percent by allowing their tanks to drop to a lower minimum level and installing an additional 5-million-gallon storage tank. An estimated 250 MW of peak demand could be saved if water agencies statewide viewed their storage as an energy asset as well as a water asset. Another 1,000 MW of peak demand could be saved from increased treated water storage in urban areas. In total this represents more than one-third of the water use cycle load.

Investing in Water and Energy Efficiency

California has water-related energy programs to increase the energy efficiency of existing water and wastewater utility operations; increase the energy efficiency of the appliances that move water; and increase generation from renewable resources. These programs include building and appliance standards, technical support and loan programs, and incentive programs funded through the state’s energy utilities. The state also conducts research to modify existing treatment processes; develop more efficient water and wastewater treatment and water supply technologies; increase the efficiency of heating, cooling, and moving water for end users; and improve the effectiveness of renewable energy sources.

However, since the state’s largest energy utilities have no authority to invest in programs that save cold water to capture the upstream energy benefits, these benefits are not realized. If the CPUC authorizes investment in cold water savings, the state will have a new source of energy savings.

Because of the interconnectedness of water and energy resources in California, the fact that cost-effectiveness is determined solely from a single utility and single

resource perspective is a glaring problem. Water utilities value only the cost of treating and delivering water. Wastewater utilities value only the cost of collection, treatment and disposal. Electric utilities value only saved electricity. Natural gas utilities value only saved natural gas. This causes underinvestment in programs that would increase the energy efficiency of the water use cycle and increase agricultural and urban water use efficiency.

By valuing a unit of water on its total value – the water resource itself, plus its energy intensity and externalities throughout the entire water cycle -- many water and energy programs and measures that could not meet the earlier cost-effectiveness threshold are now possible. California could reap large energy benefits by encouraging greater collaboration between energy, water, and wastewater utilities.

Conclusions

In this chapter, staff has generally described the water energy intensity for agricultural and urban end uses. Staff recommends additional research to provide needed information to better understand these systems and how modifications or improvements could benefit the energy sector. Future regulatory change will also affect the overall energy demand of these systems. To ensure high-quality water supplies for the state, energy and water utilities should collaborate to efficiently operate water and wastewater treatment facilities. Water and wastewater utilities can take advantage of current energy efficiency programs for near-term retrofits and design modifications to increase efficiency now, with existing technology. Additional research is needed on technologies and system designs.

CHAPTER 5 – RENEWABLE ENERGY GENERATION POTENTIAL

The most widely recognized aspect of the water-energy relationship is power production in large scale hydroelectric dams. However, water and wastewater utilities have other opportunities to develop energy supplies. These include biogas cogeneration at wastewater treatment plants and development of local renewable resources on water and wastewater utilities' extensive watersheds and rights-of-way. For purposes of this paper, we will address the potential for new renewable generation by water and wastewater utilities for two distinctly different types of opportunities:

- Distributed generation
- Utility scale generation

These energy generation opportunities require different types of permits, approvals, metering, and interconnections, and have different production characteristics, economics, and operating and financial risks. Detailed aspects of distributed generation and large-scale hydroelectric generation are addressed separately in the *Energy Report*. [42]

Table 5-1 illustrates the range of renewable power production opportunities for water and wastewater utilities.

Table 5-1: Renewable Power Production Opportunities

Energy Resource	Distributed Generation	Utility Scale Generation
Hydropower	Energy Recovery through In-Conduit Hydropower	▪ Relicensing ▪ Pumped Storage ▪ Repowering
Biogas	Biogas Co-Generation	Biosolids Waste-to-Energy plants that utilize methane from sewage digesters, dairy manure, agricultural and food processing wastes, and other organic materials
Solar	Photovoltaics for irrigation pumps & motors	Central concentrating solar power plants (solar thermal and photovoltaics)
Wind	Modest site specific applications	Wind farms on watershed lands
Advanced Generation, including Fuel Cells and MicroTurbines	Potential applications for small pumping loads	n/a

[42] For a complete listing of all documents and reports associated with the IEPR proceeding, including distributed generation, please see [http://www.energy.ca.gov/2005_energypolicy/documents/index.html].

The potential, issues, and challenges of these opportunities are discussed below.

Distributed Generation

The term distributed generation is used to describe both customer-side and utility-scale generation. For purposes of this staff report, distributed generation refers to generation facilities sited on the customer side of the meter that are used primarily to serve a customer's own energy requirements, specifically a water or wastewater utility. This discussion is limited to opportunities for water and wastewater utilities to self-generate power, and the barriers and hurdles that prevent them from generating more. These facilities include in-conduit hydropower, biogas combustion, and other small-scale distributed generation facilities.

In-Conduit Hydropower

Wherever there is flowing water, there is both energy and the potential to capture and utilize that energy. In-conduit hydropower captures the energy from flowing water in a pipeline with a turbine or generating device installed directly in the conduit. Most of the state's large water conveyance projects already take advantage of the energy in water flowing through their pipelines, canals, and aqueducts. Additional opportunities remain to develop new or retrofitted generation in the state's water systems, if costs and risk can be minimized. These are environmentally attractive because they are built in existing water and wastewater systems.

In most cases, in-conduit hydropower potential ranges from very small – 1 or 2 kW to a high of about 1 MW. Often, the hydropower site is not near loads, requiring construction of expensive transmission or distribution lines to interconnect to the electric system. Even in cases where it may be cost-effective to construct such lines, existing rules do not allow the produced power to be credited against the water or wastewater utility's total energy bills. Instead, wherever such self-produced power cannot be directly connected to an existing load, it must be sold into the wholesale bulk power market. The costs and complexities of participating in the wholesale bulk power and transmission markets are daunting, even for large generators. They are prohibitive for very small generators.

A recent Energy Commission Public Interest Energy Research (PIER) study estimated the statewide developable potential of hydropower capacity in manmade conduits (including pipelines, irrigation ditches, canals and aqueducts) at about 255 MW - 231 MW at coincident peak - with annual production of approximately 1,100 GWh. The potential was about evenly split between municipal and irrigation district systems.[43]

[43] *California Small Hydropower and Ocean Wave Energy Resources*, Mike Kane, Energy Commission PIER, April 2005.

The PIER study focused on identifying the statewide potential for RPS-eligible small hydropower (less than 30 MW). Under SB1078, RPS-eligible hydropower must be constructed on or after September 12, 2002, and must not require a new diversion or a new appropriation of a water right.[44] Consequently, staff determined that the most likely class of hydropower to be developed under the present RPS is small hydropower within conduits. The PIER study only considered sites with potential of at least 100 kW since projects of lesser size tend to be uneconomic.

Changes in technology may reduce the economic threshold of in-conduit hydropower to less than 100 kW. New packaged systems are being developed that could be dropped into pipelines and other types of conduits – like canals and aqueducts - without expensive civil works or permitting costs. However, the challenge of siting in-conduit hydropower close to local loads remains.

Another way to look at in-conduit hydropower is to view it as an increase in the energy efficiency of the water delivery system. Without water agency investment in the water delivery system in the first place, this resource would not be available. Currently in-conduit hydropower is treated like any conventional energy generation resource owned and operated by a non-utility generator. This classification seems inappropriate since there is no prime mover and no new natural resource is used to generate the electricity.

Existing energy efficiency programs can be tailored for special circumstances, using customized incentives and standard performance contracting. Water agencies have taken advantage of these incentives for energy efficiency improvements, including increasing pipe diameter to reduce friction losses and the requisite pumping requirements; installing a parallel pipe system; and changing pump impellers and lining pipes to reduce friction losses. In-conduit hydropower could be looked at in a similar fashion and be included as an element of these tailored programs. Again, the issues of interconnection and the sale or application of the power to multiple accounts will still need to be addressed.

Biogas

Another option for developing generation in the water sector is to increase beneficial use of digester gas produced by the sewage wastewater, dairy manure, and food processing wastes/wastewater. Biogas, primarily composed of methane, can be used for a combined heat and power production.

California has 311 sewage wastewater treatment facilities, 2300 dairy operations, and 3000 food processing establishments. Currently, about 50 percent of sewage sludge, 2 percent of dairy manure, and less then 1 percent of food processing wastes/wastewater generated in the state are utilized to produce biogas. Converting

[44] *Renewables Portfolio Standard Eligibility Guidebook*, Energy Commission Publication Number 500-04-002F1, adopted August 11, 2004.

these wastes into energy can help operating facilities offset the purchase of electricity and provide environmental benefits by reducing air and groundwater pollutants discharged.

Unused biogas is typically flared to the atmosphere. Not only is this a waste of a renewable resource – flared biogas creates odors and air emissions.

Biogas producing facilities can be near significant loads, for example the wastewater treatment plant itself. However, this load may be on multiple meters and current rules discourage full use of the available biogas for maximum generation for onsite or offsite loads. Currently, there are provisions under regulated tariffs that enable dairy operations to produce electricity from biogas resources at one location and use it to offset electricity use at multiple locations, under multiple accounts, for one customer. This same approach would significantly increase opportunities for biogas-fired (and other renewable) generation in water and wastewater agencies.

The Inland Empire Utilities Agency (IEUA) is a leader among regional wastewater treatment agencies for innovative and proactive energy management. IEUA's facilities process 65 million gallons of wastewater into high-quality recycled water. IEUA's wastewater treatment system has three anaerobic digesters. Dairy manure is collected from seven nearby dairies and processed through two of IEUA's digesters. At one facility, biosolids from the sewage treatment process are combined with dairy manure. At another facility, dairy manure alone is used to produce the methane that is piped to the Chino Basin desalter, where it is used to produce electricity for desalination of groundwater.

IEUA believes there is significant potential for increasing biogas production by combining different types of biosolids. For example, by blending dairy manure with food waste, IEUA expects this year to double its amount of biogas production (from 0.5 MW to the total load of the Chino desalter of 1 MW).

IEUA's biogas power production is expected to continue to grow as it adds another 15 MGD wastewater treatment plant next year, and it plans to develop another 10 MW in renewable biogas generating capacity with a centralized biodigester that will take dairy waste, green and food residuals (generally used to make compost) and biosolids to produce biogas for power generation and compost. IEUA is also considering using its excess biogas to heat water and sell a new product, hot process water, to industrial customers.

While IEUA has been much more successful than other wastewater utilities in the innovative development of biogas power production, it has not been simple.

Other Distributed Generation Options

Other distributed generation options include solar thermal, photovoltaics, small wind power, and advanced generation technologies including fuel cells and advanced

microturbines. These distributed generation opportunities are discussed at length in the *Energy Report* proceeding.

Utility Scale Generation

Many water and wastewater utilities have the opportunity to develop utility-scale power production facilities that produce more power than utilities need for their own processes. With technical and funding support and removal of major barriers, water and wastewater utilities could become net exporters of power. Whether conventional hydropower facilities developed in conjunction with large water conveyance systems - like the Oroville Hydroelectric Facility, owned and operated by DWR on behalf of the State Water Project, or wind farms constructed on watershed lands – substantial untapped renewable resource potential resides with water and wastewater utilities that have little incentive, and, in fact, many barriers and disincentives, to develop these resources.

Large-Scale Hydropower

In addition to the in-conduit hydropower opportunities described above, utility scale generation consists of conventional hydropower (less than 30 MW) produced by water releases from natural or manmade impoundments like reservoirs and dams.

Opportunities for new hydropower dam and storage projects are extremely limited in California for a variety of reasons. Most economically viable sites have already been developed; but even where suitable sites exist, development is limited by lack of availability of unallocated water rights, environmental protection measures (such as Wild and Scenic Rivers, Endangered Species, and Wilderness Area designations), and strong opposition from environmental advocates.

Staff has investigated ways to balance the electric system benefits offered by hydropower with their significant adverse environmental impacts. Both the Energy Commission's *2003 IEPR*[45] and staff's *California Hydropower System: Energy and*

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[45] *2003 Energy Report*. California Energy Commission, *2003 Integrated Energy Policy Report*, December 2003, Docket No. 02-IEP-1, Publication No. 100-03-019, page 43.

> "Hydroelectricity has historically played an important role in meeting California's electricity needs. Its low production costs and unique ability to meet critical peak demand have long benefited the state's ratepayers. Some hydroelectric projects unfortunately have serious environmental consequences, such as significant, ongoing impacts to many California rivers and streams, native salmon and trout populations, and the water quality needed to support sustainable riverine ecosystems.
>
> The restoration of imperiled salmon and trout fisheries is one of California's environmental policy objectives. ... [D]ecommissioning of high environmental impacts hydroelectric facilities that supply little power is a possible method of restoring important aquatic habitat."

Environment[46] provide key findings with respect to hydropower's value and impacts. Staff provides recommendations to minimize the adverse environmental impacts of these facilities.

At this time, only two utilities are expected to develop hydroelectric resources. [47] The Sacramento Municipal Utility District (SMUD) proposes the Iowa Hill Project to add 400 MW of pumped-storage capacity to its Upper South Fork American River Project. This may be especially helpful for integrating wind energy produced in the Delta, since the Delta breeze on a hot summer day usually begins a few hours after the daily load peak, which is driven by air conditioning. For San Diego Gas and Electric (SDG&E), about 40 MW of new hydro are planned, beginning in 2008, from San Diego County Water Authority projects.

Long lead times are needed to plan new hydro projects, prepare appropriate environmental documents, obtain a license from the Federal Energy Regulatory Commission (FERC), and build the project. However, opportunities for incremental development, such as adding or improving generation facilities attached to existing dams, water conveyance facilities, and powerhouses, remain an option for increasing California's hydropower production.[48] These opportunities include pumped storage and retrofit.

Pumped Storage

Pumped storage typically involves pumping water from a water source into a reservoir or tank, to be held for later scheduled hydropower production. Water is pumped uphill during off-peak hours and provides peaking capacity during on-peak hours. Pumped storage has high energy value since it is virtually the only viable means to store energy. There are several significant pumped storage projects currently under development:

- The proposed 500 MW Lake Elsinore Advanced Pumped Storage Project (LEAPS)[49].

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[46] California Energy Commission, *California Hydropower System; Energy and Environment*, Appendix D to the *2003 Environmental Performance Report*, prepared in support of the *2003 Integrated Energy Policy Report*, October 2003, Publication No. 100-03-018. Prepared in support of the *Electricity and Natural Gas Report* under the Integrated Energy Policy Report proceeding (02-IEP-01), October 2003, Publication 100-03-018.

[47] *California and Western Electricity Supply Outlook Report* Draft, California Energy Commission, July 15, 2005, pages 74-76, posted on the website of the California Energy Commission.

[48] Excerpt from the *California and Western Electricity Supply Outlook Report* Draft pages 74-76, in progress for posting to the website of the California Energy Commission, July 15, 2005. For information about California's overall hydropower outlook, please refer to the Energy Commission's 2005 report, *Potential Changes in Hydropower Production from Global Climate Change in California and the Western United States*, prepared in support of the *2005 Integrated Energy Policy Report* proceeding (Docket # 04-IEPR-01G).

[49] EVMWD Web site (www.evmwd.com).

- SMUD's proposed 400 MW Iowa Hill Pumped Storage Development.

- The US Bureau of Reclamation is also exploring several pumped-storage options in the Upper San Joaquin River Basin.[50]

As with any dam or reservoir, development of new pumped-storage facilities faces major challenges. Some of the issues associated with conventional hydroelectric power generation and typical on-stream pumped hydroelectric storage facilities include:

- Water resources impacts - hydroelectric facilities may change stream flows, reservoir surface area, the amount of groundwater recharge, and water temperature, turbidity, and oxygen content.

- Biological impacts, including the possible displacement of terrestrial habitat with a new lake environment, alteration of fish migration patterns, and other impacts on aquatic life due to changes in water quality and quantity.

- Possible damage to, or inundation of, archaeological, cultural, or historic sites (primarily if a reservoir is created).

- Changes in visual quality.

- Possible loss of scenic or wilderness resources.

- Increase in potential for landslides and erosion.

- Recreational resource impacts/benefits.

Another possibility for developing new pumped-storage projects is to connect two or more existing reservoirs or lakes with new pipelines or penstocks for water pumping and power generation. A U.S. Department of Energy (DOE) study identified dozens of such potential reservoir pairs in California, requiring construction of an average of about 10 miles of pipeline to connect each pair. (Lamont 2004). Though this type of development would increase operating flexibility and peaking capacity without need to construct new reservoirs, it would still involve construction of large pipelines through difficult terrain on protected lands, which could require significant expense for environmental mitigations and permitting.

Because of the costs associated with new pumped-storage facilities using existing or new reservoirs, development of modular pumped storage (MPS) may have greater potential in the near future. MPS systems are not dependent upon

[50] USBOR website 2005a.

natural waterways and watersheds and can be sited in areas that avoid many of the issues described above. In fact, they are generally purposely sited away from sensitive areas to avoid the regulatory and operational complexity often associated with conventional pumped hydroelectric storage facilities. MPS systems can also be added to existing water systems wherever the necessary elevation difference exists. They could also be developed in places like abandoned mines, taking advantage of elevation differences and storage created by mine shafts and open pits. If their capacity was less than 30 MW, these pumped-storage facilities could also qualify for supplemental energy payments under the RPS.[51]

Retrofit[52]

Retrofitting existing hydroelectric facilities, specifically replacing turbine runners and generators with new, more efficient equipment, may increase the capacity of these facilities. To the extent that retrofit does not result in changed flows, no permits may be needed. Hetch Hetchy Water and Power increased the capacity of its system 48 MW by replacing turbine runners and generators with newer, more efficient equipment – at a capital cost of $8 million, less than 17 percent of the cost of installing a new unit of comparable capacity. Since the purpose of these retrofits was to increase the efficiency of hydropower production using the same amount of flows, no permits or approvals were required.

Existing hydropower facilities can be upgraded to increase both capacity and output without changing flows. Below are the primary means for attaining such efficiency gains:

- Tunnels. Most power tunnels in California were built using drill and shot methods for rock excavation. The resulting rough rock linings have high friction losses and capacity issues. Existing unlined tunnels could be lined to decrease friction losses and produce more power with the same amount of water. Existing lined tunnels can be made smoother by relining or coating abraded surfaces. Some tunnels can be enlarged or made smoother by selectively trimming tunnel walls. The longer the distance of the tunnel and the greater the friction, the greater the opportunity for incremental gains in power production. Some tunnel lining projects have increased hydropower production up to as much as 7 percent.

- Penstocks and Pipelines. Similarly, penstocks and pipelines could be relined or replaced to reduce friction losses during times of high flows. The decision to reline or replace is an economic one that depends in large part upon the remaining useful life of the hydropower facility itself. The potential benefit also

[51] Aspen 2004
[52] Matthew Gass, Engineering Manager, Hetch Hetchy Water and Power, San Francisco Public Utilities Commission.

depends upon the length of the penstock or pipeline, and the amount of friction losses. Here, again, benefits of up to 7 percent have been documented.

- Turbines. The easiest and frequently most economical improvement could be to replace a turbine's runner. Computerized design, manufacture, and improved testing and modeling methods have increased the efficiency of turbine runners. Minimum efficiency gains for replacements of turbine runners installed in the 1970s and 1980s have been reported at 1 percent. When older designs are replaced by customized efficiency designs, increased output as high as 30 percent has been reported.

Other types of hydropower efficiency gains are attainable through improved planning, controls, and management. Most large hydropower plants in California are multi-unit facilities. In many cases, there are opportunities to optimize operations by balancing the loads of individual units. Specialized computer selection software has helped attain performance improvements of 1-3 percent. In addition, improved controls and monitoring systems allow more efficient operations and reduce downtime from unplanned outages. All of these things have potential to increase net power production. Applied to the state's hydropower inventory, these minor tweaks could cost-effectively increase the state's total hydropower production by at least 3 percent within just a few years.[53] However, FERC rules regarding system modifications and upgrades will need to be reviewed to confirm the trigger points that could reopen a license to scrutiny.

There is constant tension among competing interests for water supply, water quality, hydropower production, and flood control. A better understanding of opportunities for optimizing the state's hydropower supplies and the key stakeholders needed to attain those incremental benefits would provide a useful framework for identifying feasible options and resolving points of conflict.

Other Renewable Resources

Both water and wastewater utilities have extensive watershed lands and rights-of-way with potential for wind and solar development.

- In spring 2005, the Semitropic Water Storage District completed installation of a 1 MW solar facility that provides peaking power for local pump loads.[54]

- At the Solar Power 2004 Conference and Exposition, San Francisco announced that it will soon build a 225 kW solar facility covering 20,000 square feet at its Southeast Water Pollution Control Plant.

[53] Matthew E. Gass, P.E., Engineering Manager Hetch-Hetchy Water and Power.
[54] Boschman 2005..

- IEUA will install solar panels on its new LEED Platinum headquarters, which was designed to reduce energy use by 90 percent and water use by 70 percent compared with its previous building. IEUA expects its headquarters to be completely energy independent by next year.[55]

- Hetch Hetchy conducted a wind resource assessment of its Calaveras watershed that indicated a potential of more than 30 MW.

The developable renewable energy potential owned by water and wastewater utilities is not yet known. It would be beneficial to identify, assess and prioritize these resources, and provide technical and financial assistance to help develop renewable energy for the benefit of all California ratepayers.

Barriers to Energy Production

Even when transmission is available to move the power out of a water agency's conduit hydropower, biogas, or solar facility, the water professionals interviewed for this paper expressed frustration with their limited ability to deliver self-generated power to their various facilities. Water and wastewater facilities are often dispersed over large distances. These facilities typically take electric service at multiple points and are metered separately at each point.

During public workshops and working group meetings, water and wastewater utilities cited the following primary barriers to self-generation:

- Complex, costly and long lead time interconnections.
- Prohibitive stand-by costs.
- Disincentives to fully utilize available renewable or distributed resources.

Issues of interconnections are being addressed by both the CPUC and the Energy Commission with respect to Rule 21.

Present regulations do not allow aggregation of a customer's electric metered loads within a single facility, much less with metered loads at their other facilities. Therefore, the only means for a water or wastewater utility to deliver self-generated power to itself anywhere on its system is to own and operate its own transmission and distribution systems -- essentially, to operate its own electric utility contiguous with its water service territory boundaries. Of course, this would be cost prohibitive.

At the April 8, 2005, *Energy Report* Committee workshop, IEUA identified the following barriers to its efforts to become energy self-sufficient and possible solutions to these barriers (Table 5-2).

[55] Davis 2005.

Table 5-2: Barriers to Energy Self Sufficiency

Barrier	Solution
Presently, IEUA is metered at multiple points, making it difficult to understand, plan and manage its total energy requirements.	The ability to aggregate all of IEUA's electric loads into a single consolidated load would enhance IEUA's ability to self supply its loads. In addition, it would enhance IEUA's ability to develop creative approaches, whether through modified system design and/or operations, to further reducing peak period consumption.
CPUC "single premise rules" discourage building generation greater than connected load.	IEUA would increase the size of its generation facilities if it had ability to wheel self generated power to itself.
Energy utility programs often fail to capture opportunities to encourage energy efficient design principles in water agencies' facilities.	IEUA and other water agencies have substantial continuous capital programs and, thus, opportunities to incorporate non-conventional energy efficient design principles into large facilities. For example, most of the cost of a new or replaced pipeline is in the trenching. The incremental cost of oversizing a pipeline is fairly modest and should be encouraged wherever cost-effective in reducing energy consumption. Some Energy Performance Contracting programs can be accessed for these types of projects; but applying for and collecting incentives are often difficult.
IEUA and other water agencies have unique opportunities for renewable energy development (e.g., biogas; pipeline conduit hydro; extensive rights of way and watershed lands); but the development costs and risks are often daunting for an entity for which energy is not its primary business.	IEUA is hosting various pilot programs that test and refine renewable energy technologies. Energy utilities could partner with water agencies to optimize development of their renewable energy potential, first to offset their own loads, and then potentially to also become net exporters of renewables and help energy utilities meet RPS and achieve other environmental benefits, including greenhouse gas reductions. Incentive programs are key to testing new technologies at scale. Net metering program (SB 728) will be essential to capturing value of renewable energy.

Source: IEUA testimony

Conclusions

Given the state's energy and capacity shortages, it would be beneficial to help water and wastewater utilities develop all potential renewable and distributed resources. This can be facilitated by allowing these utilities to aggregate their metered load and remove net metering caps. Excess power could then be sold to the energy utilities. Ultimately, the tension between energy utilities and their customers needs to be resolved through policy. The fundamental issue is whether customer-sited distributed generation provides an energy system benefit that reduces total societal costs.

CHAPTER 6 – POTENTIAL EFFECTS OF FUTURE CHANGES

Several factors are causing changes to California's water supply portfolio; legislative, regulatory, market, and technological changes will affect both water-related energy consumption and energy production.

The following discussion addresses a variety of known and anticipated energy impacts, the primary drivers of these impacts, and the extent to which the magnitude and timing of these impacts can be predicted. The primary drivers to be discussed are:

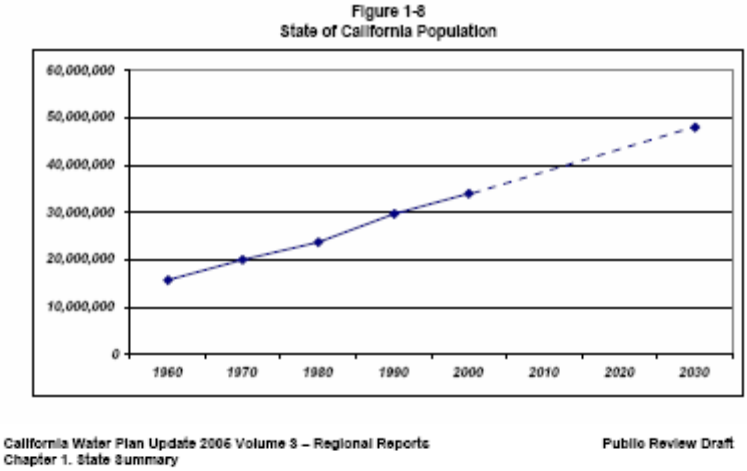
- Increased water demand
- Changes in water end use
- Changes in regulation and legislation
- Changes in water and energy markets
- Hydrology
- Technology
- Policy

Where reasonable bases exist for estimating these impacts, they will be described. If their impacts cannot be reasonably projected, staff identifies needed additional information.

Increased Water Demand

DWR, in the *2005 Water Plan Update,* based its estimates for water demand growth on data from the Department of Finance (DOF) that estimates California's population will increase more than 40 percent by 2030 - from about 34 million in 2000 to 48 million in 2030 (Figure 6-1). Absent mitigation, water-related energy consumption attributable to urban water use is expected to match this growth. The plan projects that, without mitigation, urban water use will increase substantially - as much as 6 million acre-feet, or 67 percent, by 2030.

Figure 6-1: Projected Population Growth in California



The actual impact of water demand growth on energy is difficult to predict for the following reasons:

1. The water supply portfolio planned to meet water demand growth is significantly different from the state's existing portfolio. Consequently, a simple extrapolation of the current average energy intensity of water supplies makes no sense.

2. The state water plan indicates that the largest new supply available to provide for the expected growth in water demand over the next 25 years is water use efficiency. To the extent that the state may not attain its targeted level of efficiency, any shortfalls in water supplies will need to be made up from other sources, most likely recycled water and desalination. Both of these options require new infrastructure that will need to be developed years before it is actually needed. If these are not in place in time, forced conservation, such as the shortage allocations during the 1987-1992 drought, may need to be implemented.

3. Industry experts predict there will be an increase in water market transactions. Some broad generalizations about water market transactions can be made. For example, to the extent that these transfers result in a net increase in physical deliveries of Northern California water supplies to Southern California or agricultural water use is converted to urban water use, energy consumption for water conveyance will increase. However, the net energy impact of increased water transactions cannot be determined. There are many variations in the types of transactions that could occur and no certainty as to which will or will not occur.

4. The recent Colorado River Quantification Settlement Agreement (QSA) requires that California beneficiaries of Colorado River water reduce their use over the next 14 years to California's basic annual allocation of 4.4 million acre-feet. A number of specific actions are being taken by Southern California water utilities to implement the QSA and make up for reductions in Colorado River imports.

Strategies include increased water use efficiency, increased imports from the State Water Project, development of 126,000 acre-feet of desalinated ocean water, managing the San Bernardino Basin as a groundwater facility, increased use of recycled water, and paying farmers to fallow their land. It seems likely that these strategies will have significant impacts on energy use. However, the net impacts of all of the combined strategies and any offsets, such as reduced energy due to lower Colorado River imports, are not yet known.

In order to assess its range of potential impacts, staff estimated the energy implications of the water supply portfolio strategy illustrated by DWR for low and high growth scenarios. Table 6-1 shows that energy associated with the water plan strategy will increase water sector energy use by 12.3 percent in the low-growth scenario, to as much as 25.8 percent in the high-growth scenario, over the period 2000 to 2030. The energy impacts were derived by multiplying the energy intensity numbers for each type of incremental water source from Figure 2-2 in Chapter 2, by DWR's projections.

Table 6-1: Estimated Energy Impacts of Proposed Incremental Water Supplies[56]

	Low Growth Projection				High Growth Projection			
	Water		Energy		Water		Energy	
Resource	MAF	%	GWh	%	MAF	%	GWh	%
Conjunctive Management	0.5	21.3%	475	19.2%	2.1	36%	1,995	40%
Recycled	0.9	38.3%	352	14.2%	1.4	24.1%	547	11%
Surface Storage	0.05	2.1%			1.0	17.2%		
Inland - Desalter	0.2	8.5%	340	13.7%	0.3	5.8%	570	11%
Ocean - Desalter	0.1	4.3%	440	17.8%	0.2	2.8%	726	15%
Conveyance	0.3	12.8%	870	35.1%	0.4	6.9%	1,160	23%
Precipitation Enhancemer	0.3	12.8%			0.4	6.9%		
	2.35	100.0%	2,477	100.0%	5.8	100.0%	4,998	100.0%
Current - Base	43		19,345		43		19,345	
Total Projected	45.35	5.5% Growth	21,822	12.8% Growth	49	13.5% Growth	24,343	25.8% Growth
Water Use Efficiency								
Urban	1.1				2.3			
Agriculture	0.2				0.9			
Total	1.3				3.2			

Source: 2005 State Water Plan Update, DWR for water projections. Appendix C for energy calculations

DWR's plan calls for urban and agricultural water use efficiency to make the largest contribution to the state's water supplies. However, conserved water will be redistributed to new users as the population increases. Recycled water, planned to provide almost 40 percent of incremental water supplies in the low-growth projection, will contribute 14 percent to incremental energy use. At the other extreme, ocean desalting is planned to provide only 4 percent of the incremental water, but will require almost 18 percent of the energy. These estimates are indicative of the need to better understand the energy implications when developing the state's future water supply portfolio.

[56] Low-growth projections reflect a 2030 water demand scenario where current trends continue, resulting in reduced agricultural irrigated crop area and reduced agricultural production. Urban water demand increases are linked to population increases and corollary increases in employment sectors. Under this scenario, per-household as well as per-employee water demand decreases slightly. Environmental water demand increases, and naturally occurring conservation decreases slightly. Population growth is based on Department of Finance (DOF) 2004 projections for growth and density.

High-growth projections reflect a 2030 water demand scenario where agricultural irrigated crop areas hold constant with year 2000; urban related water demand grows significantly, linked to population growth exceeding DOF projections by 12 percent, and lower overall population density and greater population growth occurs in inland and in southern hydrologic regions. Per-household and per-employee demand is elevated, and naturally occurring conservation decreases slightly. Urban water prices continue current trends.

Changes in Water End Use

A number of factors are driving changes in water end use. Changes impact both the urban and agricultural sectors. There are many types of changes – some that may increase energy consumption and some that may decrease energy consumption. Net impacts are difficult to predict. The discussion below about changes in agricultural water use illustrates the complexity of evaluating the net energy impacts of changed water use patterns.

Changes in Agricultural Water Use

As discussed in Chapter 4, changes in crops and irrigation methods affect overall energy demand. In the future, staff expects that periodic changes in crops will occur. Staff cannot predict what those changes will be. Consequently, only general statements can be made about the energy impacts of different trends. The *California Water Plan* projects that the agricultural sector will reduce overall water demand, predominantly through conservation. Any saved agricultural water will likely be applied to higher energy intensity urban uses.

Other signs point to decreased energy use in the agriculture sector, including efforts to conserve water and energy, following the example of urban agencies that universally follow a set of BMPs in managing their systems. For example, some irrigation districts have signed on to a program sponsored by DWR that requires implementation of Efficient Water Management Practices (EWMPs) that address energy management (Efficient Water Management Practices by Agricultural Water Suppliers in California, Memorandum of Understanding, January 1, 1999). That effort was prompted by the Agricultural Water Suppliers Efficient Water Management Practices Act of 1990. However, unlike urban water systems where water conservation also brings energy conservation, agricultural water conservation can often lead to increased energy demand. Reuse of tailwater, for example, requires installation of additional pumps, and drip and microspray irrigation need more electricity than other irrigation methods. Some of these uses, however, such as reuse of tailwater, could have the benefit of avoiding long-distance conveyance energy use.

Utilities and agencies are also addressing agricultural energy use through several energy efficiency programs. A good example is the Agricultural Pumping Efficiency Program (APEP), run by the Center for Irrigation Technology, which is part of the California Agricultural Technology Institute at the College of Agricultural Sciences and Technology, California State University, Fresno. The program receives funding from the Public Goods Charge on utility bills and provides free pump efficiency evaluations for farmers and irrigation districts served by the state's three large investor-owned utilities. Since 2002, the program has resulted in at least 15 GWh of savings from approximately 350 pump retrofit/repair projects.[57]

[57] Canessa 2005

Taken together, no definite conclusion can be drawn concerning the future trend of energy use in the agricultural sector. It is necessary to look at all applicable portions of the water use cycle when assessing the net energy impacts. More work is needed.

Changes in Regulation and Legislation

There are a number of regulatory and legislative actions that will impact both energy consumption and energy production by the water sector.

Water Quality Regulations

Energy use for water treatment will increase as more stringent water quality rules are implemented under the federal Safe Drinking Water Act. These new rules require multi-stage disinfection including treating potable water more than once, which ensures removal of harmful organisms that may grow during storage and transport, and improved disinfection technologies that reduce the risk of carcinogens and other potentially harmful disinfection by-products. These improved disinfection technologies – principally, ultraviolet treatment and ozonation[58] – are much more energy intensive than prior chemical methods.

Energy use for wastewater treatment is also expected to increase because of new requirements under the Clean Water Act for treating effluent before discharging it into natural waterways. However, by increasing the quality of wastewater effluent, more recyclable water can be added to the water supply portfolio. Therefore, any increased energy use for wastewater treatment may be accompanied by a decrease from increased use of low energy intensity recycled water that can be used to displace higher energy intensity water supplies.

The actual impact of these new regulations is not yet known, and water agencies are still making decisions as to which treatment processes and technologies to adopt. In addition, the net impacts need to be better understood. However, a 2002 EPRI study estimated that these new water quality rules could increase energy consumption by wastewater treatment facilities by 20 percent between 2000-2005 and another 20 percent between 2006 and 2050.[59]

FERC Relicensing

FERC licenses 119 hydropower projects in California representing 11,930 MW, or 85 percent of the state's hydroelectric capacity. Thirty-seven percent of the state's entire hydropower system, totaling 5,000 MW, will be relicensed by 2015.

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[58] Ozonation requires about twice the amount of electricity used by chloramination to disinfect the same quantity of water. In addition, the requirement for multi-stage disinfection increases the number of processes and overall electricity use.

[59] *Water & Sustainability* (Volume 4): *U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century*, EPRI, March 2002.

Typically, the FERC relicensing process results in increased requirements for in-stream flows. This has the result of decreasing overall hydroelectric generation. The National Hydropower Association reported a decrease of about 8 percent on average for the nation as a whole. The California experience has been less – a loss of about 2 percent in in-state hydroelectric energy production to date. An odd twist is that hydroelectric capacity actually tends to increase during FERC relicensing, as old units are either repowered or replaced.

In its *2003 Integrated Energy Policy Report*, the Energy Commission reported findings from analyses of six projects being relicensed. The analyses included studies of changes in energy capacity and production from the perspective of statewide and regional electricity supply adequacy and the reliability and cost of replacement power that would result if the proposals were implemented. The study concluded that combined annual energy production losses from relicensing would represent approximately 1 percent of the state's total annual hydroelectric production. The study concludes that "Specific decommissioning proposals would need to be fully evaluated on a case-by-case basis to identify potential local area reliability effects."[60]

Both the Energy Commission's *2003 IEPR* and staff's *California Hydropower System*: *Energy and Environment* provide key findings, as of October 2003, with respect to the potential energy and environmental impacts of FERC hydroelectric relicensing.

[60] California Energy Commission, *2003 Environmental Performance Report*. Appendix D, *California Hydropower System: Energy and Environment*, Sacramento, CA. 100-03-018, March 2003, p. D-4.

2005 Energy Policy Act

The 2005 Energy Policy Act (EPAct) recently signed into law by President Bush contains significant provisions that could affect both water-related energy use and production.

Water-Energy Relationship

- Funding for research, development, demonstration, and commercial applications to address water-energy issues including energy-related issues in optimal management and efficient use of water, and water-related issues in optimal management and efficient use of energy [Section 979].

Hydropower Incentives

- Ten-year production incentive payments for hydroelectric power from generation additions to existing dams or conduits completed within the next 10 years, limited to $750,000/year per facility [Section 242].

- Incentive payments for up to 10 percent of capital improvement costs for hydroelectric facilities that increase efficiency by more than 3 percent, not to exceed $750,000 per facility [Section 243].

- Inclusion of qualifying hydropower production (due to efficiency gains or capacity expansions placed in service after the date of the Act and before 2008) for Section 45 tax credits [Section 1301].

Other Renewable Energy Technology Development & Incentives

- Funding of more than $2.2 billion for fiscal years 2007-2009 for research, development, demonstration, and commercial application on renewable energy issues, including efficiency, cost and diversity, addressing a variety of renewable energy technologies (solar, wind, geothermal, hydropower, and other technologies) [Section 931].

- Funding of more than $750 million for fiscal years 2007-2009 to support a program of research, development, demonstration, and commercial applications for distributed energy resources and systems reliability and efficiency [Section 921].

- Funding for a State Technologies Advancement Collaborative (STAC) to research, develop, demonstrate, and deploy technologies where there is a common federal and state renewable energy interest [Section 127].

- Extension of in-service date deadlines to October 1, 2016, for facilities to receive renewable production incentive payments for solar, wind, biomass,

geothermal, plus the addition of landfill gas, livestock methane, and ocean-related energy resources [Section 202].

- Extension of in-service date deadlines for two years, to December 31, 2007, for renewable energy production tax credits under Section 45 of the Internal Revenue Code of 1986 for qualifying facilities: wind, closed and open-loop biomass, geothermal, small irrigation power, landfill gas, and trash combustion [Section 1301].

- An increase in the Business Solar Investment Tax Credit, from 10 percent to 30 percent [Section 1337].

- Amendment of the Public Utilities Regulatory Policy Act (PURPA) of 1978 to add the requirement that each electric utility shall make available to any electric consumer a net-metering service relative to an eligible on-site generating facility [Section 1251].

Where significant tax incentives exist, there is the opportunity to develop public-private partnerships that bring private investment to help develop renewable energy resources. The impacts of the 2005 EPAct on renewable energy development of water and wastewater utilities' resources and assets cannot be determined.

Changes in Water and Energy Markets

Changes in both water and energy markets have potential to impact energy consumption and production by the water sector. For both, the primary driver of change is economics.

Water Markets

California's water markets are changing. The ability to sell water under some circumstances without losing water rights will likely increase transactions. The provisions of the Colorado River Quantification Settlement Agreement are driving Southern California water utilities to make changes in their water supply portfolios. Further, changes in the mix of crops being planted in California and economic pressures to convert agricultural land to urban use will affect water-related energy consumption.

As discussed previously, because the wide variety of potential transactions, it is difficult to project the net impacts of water market transactions on future energy use. Not all water transactions result in more transported water. Transactions often involve exchanges of water rights among multiple interconnected parties that merely allow the downstream purchaser to take more water from existing sources for a price that compensates each party involved in the transaction. The transaction can sometimes result in a net energy benefit, especially when reducing SWP or other energy intensive imports.

Energy Markets

The 2005 Energy Policy Act will certainly have an impact on the pace and types of renewable energy development. In addition, other impacts - natural gas and diesel price volatility, the impact of competition for renewables to meet RPS goals, and the cost of bundled versus unbundled delivered energy to various load centers - will all affect how agriculture and water and wastewater utilities use energy.

One example is the agricultural pumping switch from diesel to electric. Thousands of diesel-powered pumps are now operating in the Central Valley. With diesel prices soaring and air quality rules tightening, farmers are being encouraged to consider switching back to electric motors. ITRC estimates that converting all of those diesel engine pumps back to electric would increase energy consumption by 1,131 GWh (ITRC 2003). On August 1, 2005, both PG&E and SCE's "AGICE" (Agricultural Internal Combustion Engine) incentive programs went into effect. They are available to owners of pumps of 50 horsepower and above, provide a 20 percent discount over other agriculture rates, increase at 1.5 percent per year until eliminated, and offer an environmental adder that will reduce the costs to the customer of extending distribution lines to the pump. PG&E's program is capped at $27.5 million per year in total incentives, including discounts and environmental adders.[61] SCE's program is capped at $9.2 million. In the PG&E territory, it is possible that 200-300 MW of new coincident peak will be added to its system during the course of the two-year open enrollment period.[62].

Hydrology

There are two primary types of hydrological conditions that could affect both energy consumption and energy production by water and wastewater utilities: drought and climate change.

Drought

Changes in hydrology significantly affect the availability of water supplies and water use from year to year. The worst case scenario, from both a water supply and energy perspective, is a multi-year drought. During past droughts, surface water deliveries dropped in some places to less than half of average year deliveries, forcing water users to rely much more on groundwater pumping and emergency conservation measures.

During prolonged droughts, certain types of electricity use increase. For example, when surface water supplies are low, more groundwater is pumped. During

[61] Mayers, 2005
[62] Keith Coyne, PG&E, August 4, 2005

sequential dry years, water must be pumped from even greater depths as aquifer levels fall. Periods of drought also significantly increase pumping from existing and future conjunctive use field, as agencies tap emergency water supplies. An extended multi-year drought could also spark the rapid development of additional desalination facilities.

Estimating the water-related energy impact of a multi-year drought, however, is more complicated than simply adding up projected increases of energy consumption. During droughts, water shortage policies and plans place limits on water use by various market sectors and customer groups to allocate limited supplies. In addition, SWP and other large water systems will not have as much water to pump. The combination of these impacts would need to be netted out against incremental energy consumption for water supplies - like groundwater pumping and desalination - to understand the true energy impacts.

In evaluating water-related energy consumption from prior years, staff has been unable to find data that definitively support the premise that water-related energy consumption increases during dry years. In general, staff can say that an increase in water-related consumption and a decrease in energy supply are likely during a dry year. However, water industry experts are divided as to whether there is a net positive or net negative impact in energy consumption during a prolonged multi-year drought where serious reductions in water storage could trigger mandatory water use reductions.

Climate Change

A change in the patterns of rain and snow could have significant effects on both electricity production and consumption. Climate change scenarios show that global warming trends may result in more rain, but less snow. As a result, even when total precipitation is near normal levels, spring runoff will likely occur earlier in the year, resulting in early “spills”[63].

The Energy Commission has already conducted substantial research into the effects of climate change and is taking a lead role for the state in developing strategies to reduce greenhouse gas emissions. These efforts, as well as other statewide studies, were summarized in two recent Energy Commission reports prepared in support of the *2005 Integrated Energy Policy Report*. The first report, *Climate Change Impacts and Adaptation in California,* summarizes available scientific literature and provides a brief overview of the research agenda. The second report, *Global Climate Change*, provides background and context to guide the formulation of policy options for reducing greenhouse gas emissions in California.

[63] Overfilling of reservoirs in spring months, with spills bypassing turbines and reducing energy production and sometimes, also reducing summer peaking capacity.

A third report, *Potential Changes in Hydropower Production from Global Climate Change in California and the Western United States,* evaluated the potential effects of climate change on hydropower operations and production. This study included the following findings and recommendations:

- Climate change studies to date have depended upon broad trend analyses and are not yet useful in predicting impacts at the local watershed level.

- California is experiencing a warming trend. This could precipitate earlier snowmelts, reduce summer hydropower production and capacity, and increase summer air-conditioning loads.

- Although more work is needed to predict local impacts, warmer temperatures could cause earlier snowmelts, reducing stored water supplies.

Reduction of stored water has several potentially adverse impacts:

- Less availability of surface water supplies (which could lead to increased use of more energy intensive supplies).

- Less hydropower peaking capacity.

- Lower head (reducing hydropower energy production as well).

Clearly, climate change impacts will need to be studied over many years before the true net impacts on both energy consumption and energy production can be accurately measured.

Technology

Changes in technology could change energy consumption and energy production, though the net impact of such changes is undeterminable. Below are some examples of potential changes in technologies that could affect water-related energy consumption or energy production:

- In addition to continually seeking more efficient water and energy systems and processes (e.g., desalination and disinfection technologies), research continues into streamlining system processes and plant designs.

- In addition, research continues into improving the efficiency of pumps, motors, and equipment to reduce energy consumption and increase operating flexibility to shift loads off-peak.

- Specific research into modifying the reverse osmosis process used in desalination to reduce energy requirements is occurring in multiple forums.

- New technologies are improving the design of turbine runners, making it possible to increase both capacity and output of existing hydropower systems through retrofits. In addition, research continues into developing packaged systems that can be dropped into existing pipelines without need for costly civil works and low head turbine technologies.

- Automated controls technologies also optimize water releases to better balance hydropower production with water supplies and electric loads, and allow more efficient pumping in water and wastewater treatment plants.

The American Water Works Association Research Foundation (Awwa-RF) and PIER are already collaborating on a portfolio of research and development projects related to the interdependencies of water and power.

Policies

Several policies have been adopted for both the water and energy sectors. Policies to reduce water and energy consumption will certainly impact both the water and energy sectors, but the net energy benefits may differ. Energy demand could go up as a result of water decisions. Ultimately, it matters tremendously what policy options are implemented and how well these policies are coordinated for mutual water and energy benefits. Thoughtful policies can mitigate the potential adverse impacts of water decisions on energy resources and infrastructure.

Conclusions

The common theme of all of these potential changes is that there are both threats and opportunities. In order to better understand these and develop plans and measures that leverage opportunities and mitigate threats, more information is needed by water and energy policymakers and implementing entities. Ultimately, the *net* energy impacts of various water policies and strategies need to be well understood in order to tailor effective mitigation measures.

CHAPTER 7 – STAFF RECOMMENDATIONS

Findings

During these proceedings, state and federal agencies, water and energy utilities, industry associations, research organizations, and a wide variety of other stakeholders came together to consider the state's water-energy relationship and what it means to the state's energy resources and infrastructure. While acknowledging there is much yet to be learned about the nature and extent of the state's water-energy relationships, some things are clear.

- The relationship between the water sector and the energy sector is complex and highly interdependent.

  - ✓ In-state hydroelectric power generation in 2004 accounted for approximately 11 percent of the state's in-state energy resources. When hydropower imports from the Pacific Northwest and the Desert Southwest are included, hydropower accounted for as much as 15 percent of the state's energy in 2004.

  - ✓ The water sector is the largest consumer of energy in California, estimated to account for 19 percent of total electricity and 32 percent of total natural gas consumed in the state.

- Saving a unit of water reduces the amount of energy used to collect, treat, deliver it, consume it, treat it, and dispose of it as wastewater. If used elsewhere, this saved water may displace the need to develop new, more costly water sources.

  - ✓ With few exceptions, the avoided energy value embedded in a unit of water throughout the applicable portion of the water use cycle is not accounted for by either water or energy utilities.

  - ✓ Presently, the magnitude of this total energy savings cannot be fully calculated, though sufficient information exists to compute a proxy to support near-term programs.

  - ✓ The state's current energy programs (codes and standards, incentives, and rebates) focus on energy saved at a single location from increasing water and process heating efficiency – not on energy that can be saved from reductions in water use. Not including cold water savings misses significant energy savings opportunities upstream in the water use cycle.

  - ✓ There are significant differences in the energy intensity of the water use cycle between Northern and Southern California because of differences in the energy intensity of water supply portfolios that are heavily dependent on imported resources.

- ✓ Options for new water resources in the future are limited. The least energy intensive option for future supplies is water use efficiency. The most energy intensive option is ocean water desalination.

- ✓ Water that is not consumed generally becomes available to offset highest marginal cost supplies.

- Modifications to the operations or design of the water system infrastructure present opportunities to reduce water system peak electric demand.

  - ✓ Some existing surface storage facilities can be modified to maximize generation opportunities and increase operational (peaking, load following) flexibility.

  - ✓ Many existing and most new water and wastewater treatment plants can be designed to detain water for treatment during off-peak hours.

  - ✓ Increased conjunctive use programs may allow for greater ability to shift energy demand seasonally.

- Currently, most water and energy systems are internally optimized on a single utility basis. Systems are rarely optimized in coordination with other systems (water, wastewater, electric and natural gas) or with their customers, missing opportunities to reduce total energy consumption, shift loads off-peak, or maximize energy generation.

- Opportunities within a utility system to develop additional generation resources (in-conduit hydroelectric generation, biogas combustion, and other renewable development) exist. However, significant barriers frustrate development of these resources.

- Energy demand in the water sector will likely increase over time due to a number of factors, including population and urban load growth, increased water and wastewater treatment because of more stringent water quality regulations to protect water quality, and market, economic, regulatory, and legislative changes.

- Several actions can be taken now to significantly reduce energy demand throughout the water use cycle and slow its future growth. This is particularly true in areas, like Southern California, which have tight energy supplies and constrained transmission systems.

The state's water and energy utilities separately seek to optimize their respective water and energy resources within their own portfolios. There are strong similarities between their IRP goals, methods and techniques. However, in developing its water resource strategy, DWR did not synchronize its water resource planning goals and

objectives with those of the Energy Commission to assure, for example, that local energy supplies and infrastructure can support greater desalination production. Where seawater desalination plants may be planned at points downstream of electric transmission congestion zones, the energy solution may be to build new generation in combination with the desalination plant. Another solution may be joint water and energy investments in recycled water infrastructure processing that could displace the need to build desalination facilities in the first place. This is one example of the types of water and energy tradeoffs that should be examined.

The most significant finding of this paper is that the greatest potential for positively impacting the state's energy circumstance is beyond current water and energy best practices. The opportunity is fortuitous, and the need is great. To accomplish mutually beneficial results will require increased coordination between programs and agencies, as well as a more complete understanding of the needs of both systems and customers. At a minimum, the state's future water plans should be coordinated with the state's energy management plans to both identify and reconcile potential areas of conflict and take advantage of points of synergy. Optimizing the systems and operations of both water and energy utilities throughout the state on a holistic societal value basis will provide the greatest net benefits.

Staff Recommendations

Based on the findings in this analysis, staff recommends an action-oriented approach that is structured to attain near- and long-term results. This approach should include policy integration that seeks to optimize the mutual and synergistic benefits of the water and energy systems and resources. A key aspect of this approach is the development and implementation of a comprehensive, statewide water-energy program that integrates water and energy resource planning and management. The following essential elements have been identified for a successful program.

1. Save energy by saving water.
2. Reduce water system net power requirements.

Importantly, while this is a significant undertaking, near-term benefits could be attained while longer-term plans and studies begin at the same time.

Save energy by saving water

Even though water efficiency programs and conservation efforts exist in the state, there are many missed opportunities to save energy and manage load. These include energy savings throughout the water use cycle through water use efficiency; changes in systems and operations to reduce peak time-of-use and seasonal demands; and changes in water management to reduce use of the highest energy intensive supplies. This is particularly unfortunate in areas where energy resources

are tight or peak energy demand is a problem. In fact, since load growth is the primary stressor of both water and energy resources, those areas that are shortest in water supplies are also energy constrained, making it even more crucial that the state's water and energy resources be managed on an integrated basis.

Staff concludes that the state could achieve nearly all of its energy and demand reduction goals for the 2006-2008 program period by simply allowing energy utilities to realize the value of energy saved for each unit of water saved. In that manner, energy utilities can co-invest in water use reduction programs, supplementing water utilities' efforts to meet as much load growth as possible through water efficiency. Remarkably, staff's initial assessment indicates that this benefit could be attained at less than half the cost to electric ratepayers for traditional energy efficiency measures. Staff should work with the CPUC and the energy and water utilities to evaluate the achievable savings and implementation strategies.

Staff therefore recommends that the state pursue policy options that achieve greater energy efficiency and saving through a more aggressive and comprehensive statewide water efficiency program. This program should target both site-specific efficiencies and actions that will result in net system energy savings. These actions could be a key part of the utility energy efficiency portfolios that accomplish savings needed to meet the CPUC's goals. Key elements of such a program include:

- Allowing energy utilities to count energy savings related not only to those achieved on site, but, where appropriate, those that can be identified throughout applicable portions of the water use cycle.

- Working with the Task Force, CPUC, DWR, and other stakeholders, refine data related to energy use and generation associated with the various parts of the water use cycle for use in accounting for the net energy impacts of this system and in calculating the effects of various programs designed to attain synergistic benefits.

- Target end user water efficiency measures that result in net energy savings – both on premises and in the water use cycle. For example, in addition to programs that save hot water, include programs that seek to maximize cold water savings in homes and businesses and count the net energy benefits attributable to a unit of avoided water consumption embedded in the entire water use cycle.

- Establish a collaborative with DWR, the CPUC, and the Energy Commission to achieve the state's least energy resource intensive water future by 2030. Align programs and policies to complement one another and remove barriers to mutually beneficial results.

- Invest in research that develops more water and energy efficient appliances, processes, designs, demand side management methods and technologies, and treatment systems.

- Establish a water resource loading order that incorporates the societal value of an avoided unit of water consumption that mirrors the preferred energy resource loading order in the *2005 Energy Report* and the Joint Agency *Energy Action Plan*.

- Establish a public goods charge equivalent for public purpose water conservation and efficiency programs that attain targeted net energy benefits.

- Require the state's energy and water planners to collaborate on plans and strategies to reduce net water sector energy consumption while meeting projected water and energy load growth with environmentally preferred resources and strategies.

- Commit public goods charge funds for expanded water efficiency programs and innovative technology development to reduce the net energy demand of the water use cycle in current 2006-2008 IOU energy efficiency portfolios.

Reduce water system net power requirements

The state should adopt a comprehensive policy to facilitate water and wastewater utility energy self-sufficiency by reducing water system net power requirements. This policy should include reducing operational energy requirements, shifting loads off-peak, and increasing energy generation from water- and wastewater-related resources and renewable opportunities. Implementing this policy is consistent with the objectives of the *2005 Energy Report* and the *Energy Action Plan* loading order and helps achieve the state's RPS goals.

- Develop cost-effective, environmentally preferred in-conduit, biogas and other renewable options for water and wastewater systems. To accomplish this, the Energy Commission should facilitate greater participation of water utilities in its loan and rebate programs by targeting planned retrofits at existing facilities and providing design assistance for planned facilities.

- Remove barriers to energy self-sufficiency by allowing water and wastewater utilities to self-generate power and provide this power to themselves anywhere on their systems; expedite and reduce costs of interconnections; eliminate economic penalties such as prohibitive standby charges; and remove caps on size of facilities eligible for net metering.

- Identify and implement retrofits in the water system that attain energy benefits, including but not limited to treatment system upgrades, turbine and pump replacements, and delivery system modifications.

- Require water and wastewater utilities to assess the energy impacts attributable to new or changed infrastructure and operations and evaluate feasible alternatives to reduce overall energy demand associated with these decisions.

- Provide incentives for incremental and/or joint infrastructure improvements that reduce total and peak energy requirements for water and wastewater conveyance and treatment.

- Facilitate collaboration among water and energy utilities and other local and state entities for the joint development of resources and infrastructure to further leverage benefits of their combined assets.

- Provide incentives for water, wastewater and energy utilities to optimize their joint resources beyond traditional discrete single utility service boundaries - water, wastewater, electricity, and natural gas.

In developing this report, Energy Commission staff established the Water Energy Relationship Working Group, which helped identify issues, evaluate possible resolution of those issues, and provide input on future policy options. This group demonstrated the need for the committed involvement of key stakeholders and an ongoing dialogue about the water-energy relationship. This cooperation and communication are vital to achieving the mutually synergistic benefits of water and energy systems.

Recommended Joint Actions

The Energy Commission, the DWR, the CPUC, the Air Resources Board, the State Water Resources Control Board, and the California Department of Health Services, should:

- Establish a valuation methodology for the water use cycle that accounts for embedded energy and externalities. This methodology is needed to capture these diversities in a manner that would assist planners in prioritizing their investments.

    - ✓ Incorporate a societal valuation approach in both water and energy utilities' resource pricing methodologies, water and energy efficiency program portfolios, and investment criteria.

    - ✓ To facilitate early results, establish a proxy for the societal value while a detailed methodology is being developed.

- Seek opportunities for joint investment that could produce incremental energy benefits but are not deemed cost-effective on a single-utility resource cost test.

- Leverage work already in progress by others, including the U.S. Department of Energy National Laboratories' Water-Energy Nexus Program, Pacific Institute, California Urban Water Conservation Council, and the Irrigation Training and Research Center. Work closely with these (and other) entities to:

  - ✓ Inventory, characterize, and measure California's water and energy interdependencies.

  - ✓ Develop pilot programs to test tools and methodologies for evaluating tradeoffs among these interdependencies.

  - ✓ Develop analytical models and tools for policymakers, regulators, utilities and other key stakeholders to use in developing cost-effective joint water and energy programs.

  - ✓ Research opportunities and technologies that improve the energy performance of the water use cycle and increase the generation capabilities of the water system.

Conclusion

While all of the nuances are not yet understood, it is clear that significant energy benefits are attainable through water use-efficiency and through increased energy efficiency in the water use-cycle. It is also clear that not nearly enough has been done to make sure that California's water supply strategies are synchronized with its energy strategies. Nor has enough been done to forge partnerships between the water and energy sectors and leverage the natural synergies of their joint resources and assets for the benefit of all Californians.

The state has the timely opportunity to reap near-term energy savings benefits by helping California's agricultural industry and water and wastewater utilities become more energy efficient. The CPUC could direct IOUs to invest current PGC funds for 2006-2008 energy efficiency programs in existing water infrastructure to improve operations, switch operations off-peak, and partially fund retrofits of equipment such as pumps and treatment equipment. These funds could also be used in conjunction with water conservation dollars to leverage greater water end use efficiency to realize net energy savings in the water use cycle. In addition, near-term actions could include minor adjustments to existing policies, programs, and market rules, to facilitate renewable and distributed generation development at water and wastewater facilities as well as agricultural resources to convert them from high energy users to net renewable energy producers.

For the long-term, California's water and energy policymakers need to commit today to joint planning and management of these critical resources. Conflicting policies and objectives need to be identified and conflicts resolved. Water resource plans need to include an accounting of energy impacts and evaluate alternatives to decrease

overall energy demand of water systems. The state's energy resource portfolio needs to consider and facilitate the development of all cost-effective and environmentally preferred water system related options. Water and energy agencies and utilities need to work together to identify mutually beneficial research and develop opportunities that the state can pursue to improve both systems, followed with market transformation strategies to accelerate adoption of resource efficient behavior. To achieve mutually synergistic benefits in the water and energy sector, policymakers, agencies, and utilities will need to work together and make long-term commitments of funds and programs.

APPENDICES

APPENDIX A: EXISTING ORGANIZATIONS, PROGRAMS, AND RESEARCH

The California Water Plan

The Department of Water Resources (DWR) is responsible for updating the *California Water Plan (Plan)*, which provides a framework for water managers, legislators, and the public to consider options and make decisions regarding California's water future. The *Plan*, which is updated every five years, presents basic data and information on California's water resources, including water supply evaluations and assessments of agricultural, urban, and environmental water uses to quantify the gap between water supplies and uses. The *Plan* also identifies and evaluates existing and proposed statewide demand management and water supply augmentation programs and projects to address the state's water needs. Often referred to as Bulletin 160, the most recent version is scheduled to be published in late 2005.

DWR is also responsible for managing the State Water Project, including the California Aqueduct, and managing the contracts for electricity created following the 2000-2001 energy crisis. The department also provides dam safety and flood control services, assists local water districts in water management, conservation, recycling and desalination activities, and promotes recreational opportunities.

Energy Use in the Water Cycle

Energy is used in every phase of water use within the state, from extraction through conveyance, treatment, use, and disposal. The Energy Commission has funded several projects to define this interaction between water and energy.

> **Electricity and Water Flows with California**
> The purpose of this project, conducted by the University of California, Santa Barbara and the Pacific Institute, is to identify the flows of both water and energy within California. This includes water for electricity generation (hydropower) and all of the electricity used for water – from initial diversion or extraction through conveyance, treatment, use, and disposal. This project will increase understanding of the electricity demand for different water uses within the residential, commercial, and industrial sectors. It will also further understanding of the energy intensity of the water cycle. The results of this study will help focus future water conservation programs where they will make the greatest impact on energy (PIER Environmental[64]).

[64] The names in parentheses at the end of the paragraphs identify the group within the Energy Commission that is responsible for the activity described in the paragraph.

Groundwater and Surface Water Management and Electricity Demand
Conjunctive use of surface and groundwater supplies is increasingly relied upon as a water management tool. Concern about a significant increase in conjunctive use and its associated electricity demand, particularly under drought conditions, is a major concern. Conducted by Lawrence Berkeley National Laboratory (LBNL), the aim of this project is to see how surface and groundwater supplies will be managed under different climatic conditions, and what the consequences would be for electricity demand and prices. It is important to consider not only the likely impact of new conjunctive use programs on regional electricity demands, but also how reservoir management will affect water supply for agriculture and municipal uses and electricity generation and demand. (PIER Environmental).

The U.S. Department of Energy's Energy-Water Nexus Team

In partial response to an identified gap in federal jurisdiction at the nexus of energy and water, the Energy Policy Act of 2003[65] directed the U.S. DOE to:

- Assess future water needs for energy, future energy for water purification and treatment, use of impaired water by energy, and technology for water use efficiency.

- Develop a program plan that incorporates scientific and technology requirements, decision tools, demonstration projects, and information transfer.

Eleven national laboratories and EPRI came together to form the federal Energy-Water Nexus Team (Team), which is charged with developing technology products that will help increase the nation's energy security. The scope of the Team's investigations is very broad:

- Energy versus water tradeoffs in optimizing hydropower and the implications of those tradeoffs on energy supply risk.

- Energy usage by water-related systems and processes (including municipal water, wastewater, and industry).

- Water used to produce energy, such as hydropower and water for cooling.

[65] Section 961, Subtitle (f) *Water and Energy Sustainability Program*.

- Development of tools, including benchmarking, and opportunities to improve efficiency both through more efficient energy consumption and redesigning processes, systems, and operations.

- Financial and economic analyses of markets and participants, including impacts on equipment manufacturers and utilities.

- Environmental impacts, including the economic impacts of hydrology and climate factors, relationships, impacts, and interdependencies.

Presently, the Team is undertaking a road-mapping process for the US DOE, viewed primarily from the perspective of water used for energy and energy used for water - particularly with respect to the research and development of new technologies to improve water and/or energy use and efficiency.

The Ernest Orlando Lawrence Berkeley National Laboratory and the Lawrence Livermore National Laboratory are participating in the Energy Commission's Water Energy Relationship Working Group and can help merge efforts undertaken by the state and the federal government.

The ***2005 Energy Policy Act*** (EPAct) expanded the scope of US DOE's studies on the water-energy nexus.

Water and Wastewater Facilities

Energy consumption is a significant cost component of providing water and wastewater services to the public. The Energy Commission is dedicated to providing resources to help water professionals reduce these costs through implementation of energy efficiency measures at their facilities.

AB 970 – Peak Load Reduction at Water and Wastewater Facilities
At the peak of the 2000-2001 energy crisis, AB 970 provided $4.5 million in grant funding to reduce 52.1 MW of peak electrical load at water and wastewater facilities in four categories: curtailment, efficiency, generation, and load shifting. The grants ranged from $9,000 to $486,000, with an average amount of roughly $110,000 per project, at a rate of $300 per peak kW reduction. This program has been completed (Energy Efficiency Division).

SB 5X – Water Agency Generation Retrofit Program
The program started in May 2001 and was completed in December 2003. Projects were funded in two categories - distributed generation and energy efficiency - with a total on-peak load reduction capacity of 17.7 MW. Of this capacity, distributed generation retrofits provided up to 9.2 MW of on-peak load reduction, while energy efficiency projects provided up to 8.5 MW of load reduction. Twenty-eight qualified applicants received $4.35 million from this

program. The program paid distributed generation participants an average of $259/kW for projects with a combined construction cost of $7,205,488. Energy efficiency participants received an average of $230/kW for their projects, which cost $6,598,108 to install. Overall, the program averaged $245/kW of electrical load reduction (Energy Efficiency Division).

Flex-Your-Power's Water and Wastewater Guide: Reduce Energy Use in Water and Wastewater Facilities Through Conservation and Efficiency Measures

In response to the 2000-2001 energy crisis, the state's Flex-Your-Power program worked with hundreds of California water and wastewater agencies to develop measures to reduce energy consumption by 15 percent within their systems and facilities, for the purpose of both reducing power costs and alleviating the risk of rotating outages. A four-step process was developed to increase energy self-sufficiency through a combination of on-site power production, total energy consumption reductions through energy efficiency measures and retrofits, and peak shifting to partial- and off-peak periods wherever possible.

Energy Partnership Program

This program provides customized technical assistance to water and wastewater facilities to identify energy efficiency projects, project costs, and associated savings. Consultants are paid up to $20,000 for a detailed study of the facilities. Approximately $260,000 have been paid so far to consultants for feasibility studies, comprehensive energy audits, reviews of energy projects proposals, identifying cost-effective energy-saving measures, review of specifications for energy efficient equipment, and assistance in selecting contractors and design professionals for the water and wastewater facilities that have participated in this program (Energy Efficiency Division).

Energy Efficiency Financing Program

Energy Efficiency Financing Program: The Energy Commission provides low-interest rate loans to fund up to 100 percent of the cost of energy efficiency and self-generation projects. Loans are provided on a first-come, first-served basis. Eligible projects must have an average simple payback of less than 9.8 years. If projects have a greater simple payback, the Energy Commission can provide a loan equal to 9.8 times the annual energy cost savings. Eligible projects include pumps and motors, variable frequency drives, lighting, building insulation, HVAC modifications, automated energy management systems, automated energy management controls, energy generation, streetlights and light emitting diode (LED) signals. The Energy Commission has provided more than $11.2 million in loans for projects associated with both improving the energy efficiency of water and wastewater facilities and reducing the energy costs of these facilities. These projects have saved public facilities about $1.9 million annually in lower energy bills. This is

equivalent to saving 23 million kWh annually, with billing demand savings of about 2.3 MW (Energy Efficiency Division).

Development of a Water and Wastewater Industry Energy Efficiency Roadmap

The Energy Commission collaborated with the American Water Works Association Research Foundation (AwwaRF) {Note: Thought I'd flag this since lower-case letters are so rare in acronyms – is this correct?] to develop a roadmap to fund the highest priority research and development energy needs of California's water and wastewater utilities. To achieve this, the Commission and AwwaRF in February 2003 conducted a workshop that was attended by water experts from water and wastewater facilities, electric utilities, academia, researchers, and consultants. More than 44 projects in eight research areas were developed and ranked according to their savings potential (in either kilowatts or dollars), likelihood of success, and timeliness. The Energy Commission and AwwaRF committed to more than $2 million in funding for the five highest-ranked projects. These projects are:

> **Development of a Utility Energy Index to Assist in Benchmarking of Energy Management for Water and Wastewater Utilities**
> The objective of this project is to produce industrywide energy performance metrics to describe the performance of water and wastewater utilities that will subsequently be incorporated within a comparison framework (benchmarking tool) to facilitate internal and external comparisons within and between utilities. The approach will be similar to the US EPA's **Energy Star®** program, which makes energy performance comparisons in commercial buildings (PIER Industry, Agriculture and Water).
>
> **Zero Liquid Discharge and Volume Minimization for Inland Desalination**
> This project is discussed in the section on desalination (PIER Industry, Agriculture and Water).
>
> **Assessing Risks and Benefits of Drinking Water Utility Energy Management Practices**
> The project will develop a decision framework based on risk management principles for water utilities implementing energy management strategies. The risks and benefits of a broad array of both supply-side and demand-side energy management options will be assessed. The decision framework will provide a management tool for water utilities to mitigate possible downsides to water quality and reliability when implementing energy management practices or technologies (PIER Industry, Agriculture and Water).

Water Consumption Forecasting to Improve Energy Efficiency of Pumping Operations

The purpose of this project is to provide the best options for short-term water consumption forecasting for water utilities. Short-term consumption forecasting (SCTF) is required for water utilities to proactively optimize both their pumping and treatment operations and water supply and treatment costs while maintaining a reliable and high-quality product for their customers. The project will provide information on various techniques, performance data, benchmarks, selection criteria, and functional requirements to help utilities evaluate and select the best forecasting techniques. The project will examine different forecasting methods currently used at public utilities. These forecasting methods will be tested at utilities that are not currently forecasting their water consumption, and the results will be documented. The SCTF performance data will be analyzed for all seasons of the year to provide peak, off-peak, and average-day consumption data (PIER Industry, Agriculture and Water).

Evaluation of the Dynamic Energy Consumption of Advanced Water and Wastewater Treatment Technologies

The objectives of this project are to quantify the actual and theoretical energy consumption of selected water and wastewater advanced treatment unit operations, evaluate the factors that affect energy consumption, and identify energy optimization opportunities while still maintaining treatment performance (PIER Industry, Agriculture and Water).

Future Projects in Collaboration with AwwaRF

Five more projects from the roadmap are being considered for future funding by the Energy Commission and AwwaRF.

1. Review of international desalination research. The product would be a searchable CD ROM database similar to Desal Net, owned by AWWA (not AwwaRF). Desal Net is a searchable CD ROM database for the U.S.
2. Energy consumption of ultraviolet and chlorine/hypochlorite disinfection.
3. UV disinfection: Develop next generation of energy efficient UV disinfection systems for water and wastewater treatment.
4. Development of a guidance manual to design and operate desalination facilities for maximum energy efficiency.
5. Identification and evaluation of innovative water treatment processes.

Agricultural Water

Energy consumption is a significant cost component of providing water to the agricultural industry. State and IOU ratepayer funds, administered by the Energy Commission, CalPoly San Luis Obispo, and Fresno State University have delivered energy efficiency and water conservation programs aimed at conservation and peak load reduction in agriculture. Programs include:

SB 5X –Agricultural Peak Load Reduction Program

- The program started on June 1, 2001, and was completed on December 31, 2004. The program components related to electricity used for water purposes, include:
- 1. The development and implementation of a pump test and repair program to improve pumping plant efficiencies.
- 2. Funding projects with irrigation districts and large farming companies to participate in demand response and TOU schedules. Over 60 MW of on-peak load reduction was achieved. Thousands of pump tests were performed and many of the tested pumps were repaired to achieve even higher efficiencies (Nexant, M&V report for California Energy Commission Agricultural Peak Load Reduction Program, 2003). More than $7 million were dedicated to water-related energy projects.

CPUC- Public Goods Charge (PGC)-Third-Party Administrator for Pump Test and Repair Program

The program, administered by the Fresno State University Center for Irrigation Technology, delivers pump test services to customers in the PG&E and SDG&E service territories. The pump tests are conducted by private sector providers that have enhanced the quality and standards of properly conducted pump test results for several years. The program also provides pump repair incentive payments. The educational component is a valuable tool for communicating efficiency principles and water conservation practices to farmers. A $5 million annual appropriation from the CPUC has funded this effort to date.

Development of an Agricultural Water Energy Efficiency Roadmap

The Energy Commission's PIER Agricultural Program Technology Roadmap was accomplished in collaboration with CalPoly San Luis Obispo, Fresno State University, the University of California Cooperative Extension Program, industry associations, farmers, and irrigation district managers. The roadmap document calls for research and development efforts that improve irrigation efficiency, create flexible water delivery systems, and achieve peak load reduction. Possible research, development, and demonstration projects include reducing the total pressure required to operate drip irrigation technologies (including the filter system as well as the pipe and micro-sprayer

technologies), advancing the use of longer-lasting materials for pump components, and working with the State Water Project, the Central Valley Project, and the irrigation districts to increase the flexibility of water deliveries to farms. Additional information is available at: [http://energy.ca.gov/2005publications/CEC-400-2005-002/CEC-400-2005-002.PDF].

PIER Agriculture Energy End Use Efficiency

The purpose of this contract is to improve the energy efficiency in the transportation, delivery, and utilization of agricultural water provided by irrigation districts. Proposed outcomes include:

1. Documenting the implementation of new technologies.
2. Developing a simple procedure for tuning controller constants for automatic upstream control of canal check structures.
3. Developing new devices resistant to plugging or tangling moss for volumetric metering of delivered water - trash shedding propeller meters.
4. Testing and evaluating new electronic technologies for the volumetric metering of delivered water such as magnetic meters, ultrasonic meters (Doppler), vortex shedding meters, and ultrasonic flow-measurement meters.
5. Developing strategies for energy-efficient transition from low-pressure non-reinforced concrete pipe.
6. Verifying power quality measurement and conditioning methods.
7. Assessing use of variable frequency drives on agricultural pumps.

National Programs

Development of a National Water-Wastewater Industry Energy Roadmap
In order to bring together the energy efficiency and water/wastewater communities to define avenues for increasing energy efficiency in the water and wastewater sectors, the American Council for an Energy Efficient Economy (ACEEE) organized a national road mapping workshop to further explore and plan next steps for greater energy efficiency in the water/wastewater sectors. A workshop was held in Washington, D.C., in July 2004, and a final report is being refined for publication. The Energy Commission was a member of the advisory committee. The advisory committee defined the scope of this effort, developed a mission statement for the project, and established a set of goals. It also assisted ACEEE staff in identifying key issues relating to energy use in the water and wastewater industries. These issues formed the basis for design of a survey instrument that was used to collect impressions of key issues from a wider group of

stakeholders identified by the advisory committee. Based on this research and the goals of the workshop, ACEEE staff and the advisory committee developed an agenda that addressed key topics (Energy Efficiency Division).

National Municipal Water and Wastewater Facility Initiative
In 2002, the Consortium for Energy Efficiency (CEE) formed the Water and Wastewater Exploratory Committee to:

- Serve as a platform for members to exchange program information and resources.
- Better understand the water and wastewater industry - its structure, energy use, decision-making, and regulatory environment.
- Begin outreach efforts to the water and wastewater industry and other industry stakeholders.
- Explore the merits of a national program initiative to improve the effectiveness of local programs serving this sector. This initiative is intended to maintain a sustained focus on facility energy-efficiency at the national and local levels by increasing demand for energy-efficiency products and services within the municipal water and wastewater sector, and by transforming the delivery of products and services to the municipal water and wastewater sector by encouraging industry stakeholders to incorporate energy-efficiency as a standard business practice. The Energy Commission is a founding member of this initiative (Energy Efficiency Division).

US EPA's ENERGY STAR Water and Wastewater Facilities Initiative
ENERGY STAR is a voluntary program that helps organizations, businesses, and individuals protect the environment through superior energy performance. The ENERGY STAR Water and Wastewater Facilities Initiative helps improve energy performance by creating momentum for the continued improvement of energy efficiency by identifying and tackling barriers to energy efficiency in the water and wastewater industry, providing tools and resources to enhance energy performance, uncovering new energy-saving opportunities, and encouraging information-sharing on efficiency in the water and wastewater industry. The Energy Commission is one of the founding members of this initiative. The first Web conference on the Energy Star Water and Wastewater Facilities Initiative was on May 12, 2005 (Energy Efficiency Division).

Water Supply

Desalination

Desalination is one of the sources of new water identified by the Department of Water Resources in the ***2005 Water Plan Update***. It is also the most energy intensive of these new sources. There are several efforts underway to assist in the

development of low-cost, energy-efficient desalination technologies for various source waters using membrane and thermal processes.

Improving Energy Usage, Water Supply Reliability and Water Quality Using Advanced Water Treatment Processes

The Energy Commission and the Metropolitan Water District of Southern California are jointly funding the full-scale demonstration and refinement of newly developed electro-technologies for producing potable and non-potable water. These technologies remove salts and disinfect various source waters, including Colorado River water, brackish groundwater, municipal wastewater, and agricultural drainage water. There are 18 individual projects and eight research partners involved in this research program (PIER Industry, Agriculture and Water).

Zero Liquid Discharge (ZLD) Desalination of Inland Waters

At coastal facilities, concentrate is typically discharged to the ocean. This option is not available at inland facilities, and the need to protect surface water and groundwater sources may preclude disposal into the environment. The alternative is ZLD, in which the concentrate is further treated to produce desalinated water and essentially dry salts. In collaboration with AwwaRF, this research project will develop technologies that reduce the cost and energy consumption for inland desalination (PIER Industry, Agriculture and Water).

West Basin Municipal Water District – Demonstration of a Low Energy Sea Water Reverse Osmosis (SWRO) Desalination

Energy is the single largest cost component of operating seawater desalination systems. The purpose of this project is to demonstrate that SWRO desalination can be performed at 1.6 kWh/m^3 of permeate produced. The project will also establish the relationships between reverse osmosis recovery rate, membrane salt rejection, permeate quality, boron levels, feed pressure, and energy consumption. These relationships will help the SWRO desalination industry establish optimum recovery, flux, and salt rejection rates using today's best-available technologies. This research is being conducted by the West Basin Municipal Water District, in collaboration with the DWR, several local water agencies, and the industry, in collaboration with the Naval Facilities Engineering Service Center's Seawater Desalination Test Facility at Port Hueneme, California (PIER Industry, Agriculture and Water).

California Desalination Task Force

In September 2002, AB 2717 (Hertzberg) was signed into law, directing the DWR to convene a Desalination Task Force (Task Force) to "make recommendations related to potential opportunities for the use of seawater and brackish water desalination." The work of the Task Force and its subsequent findings and recommendations provided a useful background to DWR in developing Proposition 50 guidelines for funding desalination

projects and for estimating the future potential and prospects of desalination in the ***2005 California Water Plan Update***. The Energy Commission served as one of the four co-chairs of the Task Force along with California Coastal Commission, State Water Resources Control Board, and State Department of Health Services (Energy Efficiency Division).

Salton Sea Desalination Demonstration Project Using Geothermal Heat
Energy Commission staff is serving on the advisory panel for U.S. Bureau of Reclamation's geothermal-driven vertical tube evaporation (VTE) desalination test project at the Salton Sea, to be conducted by Sephton Water Technology (SWT). The purpose of this project is to demonstrate the feasibility of controlling the salinity, nutrient, selenium, and other contaminant content of seawater by using geothermal waste steam to drive a VTE desalting system. The project satisfies one of the principal goals of the California Desalination Task Force, which is to identify potential opportunities for brackish water desalination, as well as the Energy Commission's need to improve the energy efficiency of water and wastewater treatment facilities in California. The project also addresses the problem of concentrate disposal. In this case, the plan calls for the concentrate to be pumped "down hole" to help recharge the geothermal aquifer, resulting in zero liquid discharge from the desalting plant (Energy Efficiency Division).

National Programs

Implementation of the U.S. Bureau of Reclamation's Desalination Roadmap
In 2001, Congress directed the Bureau of Reclamation to work with Sandia National Laboratories (SNL) to develop a desalination technology research plan for the United States. With the help of a multidisciplinary committee of representatives from academia and the public, private, and non-profit sectors***, The Desalination and Water Purification Technology Roadmap: A Report of the Executive Committee (Roadmap)*** was published in January 2003. The ***Roadmap*** presents a summary of water supply challenges facing our nation through 2020 and suggests areas of research that could lead to technological solutions for these challenges. The ***Roadmap*** may be used as a planning tool to facilitate science and technology investment decisions or as a management tool to help coordinate research efforts. To develop a mechanism to implement the recommendations of the Desalination Roadmap, the Joint Water Reuse and Desalination Task Force (JWR&DTF) was formed and is conducting workshops to establish a desalination research funding process. The Energy Commission was a member of the JWR&DTF planning committee that organized these workshops, and will participate in these workshops in the near future (Energy Efficiency Division).

Working Group on Concentrate Management Guidelines for Desalination and Water Reuse
Both the U.S. Bureau of Reclamation's ***Desalination and Water Purification Technology Roadmap,*** published in 2003*,* and the California Desalination Task Force identified concentrate management as a major area where research is needed to create next-generation desalination technologies. To help address the identified technical and environmental concerns associated with desalination and water reuse concentrate, Sandia National Laboratories initiated an effort, in cooperation with the Bureau of Reclamation, the American Water Works Association, the American Society of Civil Engineers, and the Water Reuse Foundation, to jointly develop guidelines for concentrate management. Energy Commission staff actively participate in the Concentrate Management Working Group, which is working on these guidelines (Energy Efficiency Division).

National Salinity Management Conference
This high-profile annual national conference is jointly sponsored by Multi-State Salinity Coalition, the US Desalination Coalition, the Northern California Salinity Coalition, the Water Reuse Association, the Southern California Salinity Coalition, and others in conjunction with the Nevada Water Reuse Association. It includes invaluable presentations, industry tours, and roundtable discussions on technical, policy, and program issues concerning energy issues in desalination. Energy Commission staff are regular members of the planning committee for this conference (Energy Efficiency Division).

Water Treatment

Developing and Validating an Energy Efficient Arsenic Removal Process
The current EPA standard for arsenic, a naturally occurring contaminant in groundwater, is 50 parts per billion (ppb). Effective January 2006, federal standard for arsenic in drinking water will be lowered to 10 ppb. The new arsenic standard will leave many public drinking water supply systems out of compliance, including several hundred systems in California. California has set a long-term public health goal for arsenic in drinking water at 4 parts per trillion (ppt) -- 2,500 times lower than the new federal standard of 10 ppb.

To attain this standard, the water systems in California will have to first meet the EPA standards in a cost-effective manner. Currently, the average cost of lowering arsenic from 50 ppb to 10 ppb from drinking water is in the range of $58 to $237 per household per year. Lawrence Berkeley National Laboratory is conducting research on an innovative medium, which, if successful, will lower the arsenic removal cost to $1 per household per year and have little or no incremental energy costs over current practices (PIER Industry, Agriculture and Water).

Wastewater Treatment

Development and Demonstration of a Digital System for Control and Mentoring of Oxygen Transfer Efficiency (OTE) Measurements
The majority of wastewater treatment plants nationwide uses an activated sludge secondary treatment process. Blowing air into the activated sludge aeration tanks accounts for 50 to 80 percent of a wastewater treatment plant's entire energy consumption. Over time, the diffusers through which this air blows become fouled by bacterial slime growth and scale buildup from hard water. One of the challenges of the wastewater industry is to monitor in real time the performance of wastewater treatment and how well aeration systems function.

Aeration system performance can be correlated with power consumption and calculated from material balances, but these results are not obtained in real time and can take weeks or months to obtain. A much better method is to measure OTE directly, using data collected from an instrument that measures oxygen in the gas released from the surface of the aeration basin. Currently, commercially available OTE instruments are large, heavy, and fragile, and require a crew of several people to operate. The purpose of this project is to design and demonstrate a new digital, fully-automated off-gas testing technology for purposes of evaluating and optimizing oxygen transfer efficiency, which would reduce energy demand (PIER Industry, Agriculture and Water).

Water-Related End Uses

Several projects underway are looking at ways to reduce the energy consumption of water-related end uses. Other efforts are focusing on increasing water use efficiency.

Waste Not, Want Not: The Potential for Urban Water Conservation in California
In 2003, the Pacific Institute published a report that quantified the unrealized potential for cost-effective water conservation in California. The report estimated that nearly 30 percent of potable water consumed in California – as much as 2 million acre-feet per year – could be cost-effectively conserved. In the context of the Pacific Institute's report, cost-effective is defined as "… the point where the marginal cost of the efficiency improvements is less than or equal to the marginal cost of developing new supplies."

Energy Down the Drain -The Hidden Costs of California's Water Supply
In the western United States there is a close connection between water and power resources. Water utilities use large amounts of energy to treat and deliver water, and even after utilities deliver water, consumers use even more

energy to heat, cool, and use it. This August 2004 report from the National Resources Defense Council (NRDC) and the Pacific Institute shows how water planners in California have largely failed to consider the energy implications of their decisions, and suggests a model for policymakers to calculate the amount of energy consumed during water use. Integrating energy use into water planning can save money, reduce waste, protect the environment, and strengthen the economy.

Water for Growth: California's New Frontier
According to the Public Policy Institute of California, which issued this report in July 2005, California's population grew by over 10 million between 1980 and 2000. It is expected to increase by another 14 million by 2030, reaching a total of 48 million by that date. One of the most serious concerns of policymakers is whether the state will be able to supply enough water to support a population of this size. If per capita urban water use remains at its 2000 levels of 232 gallons per person per day, California will face an expansion of water demand of 40 percent, or 3.6 million acre-feet, by 2030. Policymakers and water planners have begun to consider several ways to bring supply and demand into balance over the years ahead. Options include expansion of nontraditional sources of supply (for example, underground storage, recycling, and desalination), reallocation through water marketing and conservation incentives and regulations.

California Water 2030: An Efficient Future
On September 13, 2005, the Pacific Institute released its newest report on the potential for saving water in California by 20 percent over the next 25 years while satisfying a growing population, maintaining a healthy agricultural sector, and supporting a vibrant economy. The report discusses how smart technology, strong management, and appropriate rates and incentives can allow the state to meet its needs well into the future, using less water.

The Irrigation Training and Research Center (ITRC)
The Irrigation Training and Research Center (ITRC) was established in 1989 at California Polytechnic State University, San Luis Obispo, as a center of excellence built upon a history of contributions to agriculture. The ITRC has a number of ongoing programs to develop and promulgate irrigation best practices in California. While ITRC's research focuses on irrigation for agriculture, the tools, technologies, and techniques are often applicable to landscape irrigation as well (PIER Industry, Agriculture and Water).

California Urban Water Conservation Council (CUWCC)
The CUWCC is a non-profit organization created to increase efficient water use statewide through partnerships among urban water agencies, public interest organizations, and private entities. The Council's goal is to integrate urban water conservation BMPs into the planning and management of California's water resources. Presently, more than 300 urban water agencies

and environmental groups are signatories to a historic memorandum of understanding pledging to develop and implement 14 comprehensive water conservation BMPs. To the extent that the state adopts a policy allowing energy utilities to invest in water savings for their energy and environmental benefits, CUWCC's goals and activities are certainly in direct alignment.

Residential Hot Water Distribution System Research Project
The purpose of this project was to conduct a scoping study to establish the first-order estimate for the water and energy wasted in hot water distribution systems in California and the United States. This study found that the losses in residential hot water distribution systems total more than $1 billion per year in California and $10 billion per year in the United States, including the cost of energy, water, and wastewater treatment. A roadmap to identify future activities was part of the original project but has not been completed (PIER Buildings).

Testing of Hot Water Distribution Systems
The purpose of this project was to systematically test the performance of hot water distribution systems. Field work assessing the types of distribution systems in current construction practice was combined with laboratory testing. Test procedures were developed and used on ½- and ¾-inch copper piping and ¾-inch PEX-Aluminum-PEX piping. Tests were conducted in air on both uninsulated and insulated pipe. The results of this project will be combined with additional testing to support the 2008 Title 24 Residential Building Energy Efficiency Standards proceeding (PIER Buildings).

Water Heating R&D for the 2008 Residential Building Energy Efficiency Standards
This research will provide hot water distribution system data, analysis, and recommendations to the 2008 Title 24 Residential Building Energy Efficiency Standards proceedings. Specific efforts will inform the building standards proceeding in the areas of multi-family water heating, hot water pipe losses, single family water heating construction practices, and hot water distribution system modeling. This project will also study California housing's current hot water performance issues and cost-effective retrofit opportunities, and identify future research priorities for hot water distribution systems (PIER Buildings).

Super Efficient Gas Water Heating Appliance Initiative
This research will develop the foundation for a multi-year initiative to determine the best approach for achieving a 30 percent efficiency improvement in gas water heaters. Technical and market analysis will be conducted, along with stakeholder involvement, to implement a product development competition that develops and tests prototypes for safe, reliable, and cost-effective replacements for natural gas water heaters (PIER Buildings).

Market and Technical Considerations for a Next Generation Instantaneous Water Heater

Gas-fired instantaneous water heaters are highly efficient and can play an important role in reducing energy consumption. The barriers to the current generation of instantaneous water heaters include higher initial cost, installation cost adders, water waste associated with start-up, the inability to adjust to low flow rates or relatively warm incoming cold water, and the inability to meet large household or simultaneous demands. The goal of this research is to determine if current state-of-the art instantaneous water heaters can meet both current and projected California domestic hot water needs and to identify technology(ies) that can be incorporated into instantaneous water heaters to overcome current market and technical barriers (PIER Buildings).

Energy Efficiency Potential of Gas-Fired Commercial Water Heating Equipment

The goal of this research is to establish representative gas loads for both the installed base and higher-efficiency hot water systems in commercial kitchens, based upon a review of current literature monitoring data for three commercial food service sites (a quick-service, full-service, and institutional facility). This field experience will form the basis for a design guide for hot water systems in commercial food service (PIER Buildings).

Water for Electricity Generation

Water is used to generate electricity, both directly in hydropower plants and indirectly as part of cooling systems in thermal electric facilities. The Energy Commission has funded several projects to evaluate ways to reduce the effects of electricity generation on California's freshwater supplies and on aquatic species and habitats.

The Ecological Effects of Pulsed Flows from Hydropower Plants

The Center for Aquatic Biology at the University of California, Davis, is conducting research addressing the ecological effects of ramping and other pulsed flows from hydropower plants. These discharges are results of load following, sediment and vegetation management, and recreational requirements. Seven different projects are evaluating a wide range of issues, from the effects of these flows on invertebrates residing in stream and river bed sediment to the effects on the potentially threatened foothill yellow-legged frog. The purpose of this research is to provide information that will prompt regulatory decision making that would not otherwise be accomplished within the regulatory process. The information from this research will be used by regulators to establish information needs for impact assessment, set impact thresholds, and establish suitable mitigation measures. Research partners include the State Department of Water Resources, California Department of Fish & Game, PG&E, EBMUD, and NOAA Fisheries (PIER Environmental).

Development of Bioassessment Criteria for Hydropower Operation
The California Department of Fish and Game is conducting research to develop environmental indicators, using benthic macroinvertebrates, to assess and monitor the effects of hydropower operation on rivers and streams. The purpose of this project is to establish a low-cost assessment and monitoring tool that will provide a direct indication of ecosystem health, as opposed to relying upon indirect factors such as water temperature or flow. Research partners include the California Department of Fish and Game, California State Water Resources Control Board and California State University, Chico (PIER Environmental).

Integrated Forecast and Reservoir Management Project
Runoff and stream flow forecasting has historically relied upon limited hydrologic records. With the development and refinement of global circulation models and an improved understanding of climate conditions and their ramifications for California, future runoff probabilities can be more accurately predicted. Using these forecasts on an hourly to seasonal basis can result in better planning and optimization of California's water resources. The Energy Commission is funding a demonstration of this approach for four Northern California reservoirs: Shasta, Trinity, Oroville, and Folsom. This effort uses global circulation model scenarios, downscaled to hydrologic models, that encompass the catchments of each of these reservoirs, as well as the entire Sacramento River. This information is used to create probabilistic forecasts on an hourly to month-long basis. Since these major reservoirs are all multi-purpose, the project includes the development of decision support models that will allow reservoir operators to make better decisions about the balance between flood control, water supply, hydropower generation, and instream flow requirements. Based upon a retrospective analysis of Folsom Reservoir using this methodology, the researchers showed that there could be a15 percent increase in hydropower generation. Research partners include the National Oceanic and Atmospheric Administration, CalFed, the Department of Water Resources, Sacramento Area Flood Control District, the U.S. Bureau of Reclamation and the Army Corps of Engineers (PIER Environmental).

Development of Seasonal Forecast of Hydropower Generation
Scripps Institute is developing seasonal forecasts of hydropower production in the Pacific Northwest and California. Since the amount of hydropower production in these two regions has a significant effect on the cost and availability of electricity within California, providing forecasts on a seasonal basis will improve energy planning, especially natural gas demand. Another aspect of this project is to develop seasonal temperature predictions for California based upon global circulation model simulations. This information will allow planners to predict whether an upcoming summer will be exceptionally severe and plan accordingly. Research Partners include the Western Electricity Coordinating Council (WECC), Pacific Northwest National Laboratory and the University of Washington (PIER Environmental).

Advanced Cooling Strategies and Technologies
This program is being managed by EPRI and addresses approaches for reducing freshwater consumption in the thermal generating sector. Specifically, the program addresses both the barriers to wider adoption of water conserving cooling technologies and alternative cooling technologies. These approaches, such as the use of air-cooled condensers, can substantially reduce the amount of water used within a power plant. There are, however, economic and performance issues to overcome before industry will adopt these approaches. Research partners include NETL, Reliant, AES and Crockett Cogeneration (PIER Environmental).

Ecological Effects of Cooling Water Intake Structures
Within California, a significant portion of in-state thermal electric generation is from coastal power plants that use once-through cooling, which uses millions of gallons of water per day. The intake of these vast amounts of cooling water, which is not evaporated, means that millions of the eggs, larvae, and other early life stages of fish, clams, and other aquatic species are destroyed by the heat transferred to the cooling water. The ecological effects of this once-through cooling are not known. In addition, there is a need to develop new assessment techniques and establish the suitability of innovative technology to reduce this impact. The Moss Landing Marine Laboratory, a part of California State University, San Jose, is managing the research program on this topic. Research partners include the California Costal Commission, the California Department of Fish and Game, NOAA Fisheries and the University of California, Santa Cruz (PIER Environmental).

RPS-Eligible Small Hydropower Resource Assessment
The purpose of this project is to assess the magnitude of in-conduit resources potentially available for greater small hydropower development in California. Specifically, the study focuses on irrigation and municipal water systems where no new appropriation or diversion is required, which retains RPS eligibility under the conditions of SB1078. This study does not cover new or incremental power at existing dams or other potential in-conduit resources such as industrial process water and municipal wastewater (PIER Renewables).

Use of a Down-Hole Pump as a Turbine-Generator
The purpose of this project is to demonstrate and assess the performance of a reverse operated down-hole pump commonly used in the oil and gas industry as a turbine-generator for power production. The unit will be demonstrated in a Northern California Power Agency injection well at the Geysers, where the feedstock will be treated wastewater used to replenish and extend the life of the region’s underground steam fields. If successful, this would provide a means of partially offsetting the cost of pumping wastewater to the injection site (PIER Renewables and GRDA).

APPENDIX B: 2001 CALIFORNIA ENERGY CONSUMPTION BY END USE

2001 California Energy Consumption by End Use

Sector	Description	Electricity (GWh)	Percent Related to Water	Natural Gas (million therms)	Percent Related to Water	Adjusted Electricity (GWh)	Adjusted Natural Gas (million therms)
AG & WP	Domestic Water Pumping	11,953	1.00	19	1.00	11,953	19
AG & WP	Crops	3,284	1.00	103	0.05	3,284	5
AG & WP	Irrigation Water Pumping	2,269	1.00	5	1.00	2,269	5
AG & WP	Livestock	1,216	0.50	15	0.50	608	8
RESIDENTIAL	Clothes Drying	5,769	1.00	145	1.00	5,769	145
RESIDENTIAL	Water Heating	2,352	1.00	1,079	1.00	2,352	1,079
RESIDENTIAL	Indirect Hot Water Heating for Clothes Washing	1,053	1.00	486	1.00	1,053	486
RESIDENTIAL	Washing Machine	726	1.00	0		726	0
RESIDENTIAL	Indirect Hot Water Heating for Dish Washing	686	1.00	316	1.00	686	316
COMMERCIAL	Water Heating	549	1.00	174	1.00	549	174
RESIDENTIAL	Evaporative Cooling	519	1.00	0		519	0
RESIDENTIAL	Solar Water Heating	18	1.00	7	1.00	18	7
COMMERCIAL	Cooling	12,916	0.50	66	0.50	6,458	33
MINING & CON	Oil and Gas Extraction	3,958	0.50	2,775	0.50	1,979	1,388
RESIDENTIAL	Dish Washing	2,008	0.50	0		1,004	0
INDUSTRY	Publishing and Broadcasting Industries	955	0.50	9		478	0
INDUSTRY	Printing and Related Support Activities	773	0.50	19		386	0
INDUSTRY	Nonmetallic Mineral Product Manufacturing	710	0.50	116		355	0
TCU	National Security and International Affairs	2,649	0.20	60	0.30	530	18
RESIDENTIAL	Residential Miscellaneous	24,419	0.05	168	0.05	1,221	8
COMMERCIAL	Commercial Miscellaneous	19,156	0.05	722	0.05	958	36
INDUSTRY	Petroleum Refining and Related Industries	7,194	0.05	1,464	0.05	360	73
COMMERCIAL	Refrigeration	6,771	0.05	5	0.05	339	0
INDUSTRY	Food Manufacturing, Beverage and Tobacco	4,939	0.05	390	0.50	247	195
INDUSTRY	Chemicals	3,674	0.05	226	0.05	184	11
RESIDENTIAL	Cooking	3,595	0.05	286	0.05	180	14
INDUSTRY	Electronic Components	3,261	0.05	39		163	0
INDUSTRY	Computer and Electronic Product Manufacturing	2,988	0.05	37	0.05	149	2
INDUSTRY	Plastics and Rubber Products Manufacturing	2,886	0.05	40		144	0
TCU	Telephone	2,289	0.05	3		114	0
INDUSTRY	Fabricated Metals	2,045	0.05	122	0.05	102	6
INDUSTRY	Transportation Equipment	1,960	0.05	84		98	0
INDUSTRY	Machinery Manufacturing	1,777	0.05	24		89	0
INDUSTRY	Miscellaneous Assembly Industry	1,300	0.05	14		65	0
INDUSTRY	Sugar and Canned, Dried, and Frozen Food	1,283	0.05	299	0.50	64	149
MINING & CON	Construction	1,213	0.05	22	0.05	61	1
INDUSTRY	Primary Metals	1,192	0.05	133	0.05	60	7
INDUSTRY	Pulp, Paper, and Paperboard Mills	1,149	0.05	110	0.50	57	55
TCU	Electric and Gas Services, Steam Supply	1,006	0.05	25	0.05	50	1
INDUSTRY	Lumber	951	0.05	56		48	0
INDUSTRY	Paper Products; Excludes SIC 261,262,263,266	895	0.05	51		45	0
INDUSTRY	Furniture and Fixtures	793	0.05	9		40	0

Sector	Description	Electricity (GWh)	Percent Related to Water	Natural Gas (million therms)	Percent Related to Water	Adjusted Electricity (GWh)	Adjusted Natural Gas (million therms)
TCU	Airports, Flying Field and Airport Terminal Service	771	0.05	5	0.05	39	0
COMMERCIAL	Cooking	758	0.05	141	0.05	38	7
INDUSTRY	Electrical Equipment, Appliance, and Component Manufacturing	646	0.05	7		32	0
MINING & CON	Mining (except Oil and Gas)	615	0.05	58	0.05	31	3
INDUSTRY	Textile Products	397	0.05	8	0.05	20	0
INDUSTRY	Textiles	386	0.05	65	0.05	19	3
INDUSTRY	Textile Products	183	0.05	14	0.05	9	1
RESIDENTIAL	Pool Heating	60		100		0	0
RESIDENTIAL	Hot Tub Fuel	168		93		0	0
RESIDENTIAL	Water Bed	2,150		0		0	0
INDUSTRY	Glass manufacturing	877		128		0	0
INDUSTRY	Cement, Hydraulic	1,636		38		0	0
RESIDENTIAL	Pool Pump	3,024		0		0	0
RESIDENTIAL	Solar Pool Heating	0		64		0	0
RESIDENTIAL	Refrigeration	13,282		0		0	0
RESIDENTIAL	Solar Heater Pump	97		0		0	0
RESIDENTIAL	Hot Tub Pump	901		0		0	0
TCU	Water Transportation	48		0		0	0
TCU	Pipeline	935		16		0	0
COMMERCIAL	Heating	2,625		670		0	0
COMMERCIAL	Indoor Lighting	31,568		0		0	0
COMMERCIAL	Office Equipment	1,405		0		0	0
COMMERCIAL	Outdoor Lighting	5,332		0		0	0
COMMERCIAL	Ventilation	9,325		0		0	0
STLT	Street lighting and Traffic Control	1,713		0		0	0
RESIDENTIAL	Central Air Conditioning	4,199		45		0	0
RESIDENTIAL	Color Television	3,425		0		0	0
RESIDENTIAL	Freezer	2,461		0		0	0
RESIDENTIAL	Furnace Fan	1,273		0		0	0
RESIDENTIAL	Room Air Conditioner	486		0		0	0
RESIDENTIAL	Central Space Heating	3,245		2,339		0	0
TCU	Other Local Transportation, Parking Garages	212		5		0	0
TCU	Trucking and Warehousing	545		2		0	0
TCU	Post Office	528		3		0	0
TCU	Shipping Terminals	262		1		0	0
TCU	Air Transportation, Carrier	121		2		0	0
TCU	Transportation Service	201		2		0	0
TCU	Telegraph Communication	6		0		0	0
TCU	Radio and Television	461		1		0	0
TCU	Cable TV	514		1		0	0
TCU	Railroad Transportation	143		3		0	0
TCU	Rapid Transit	400		5		0	0
TCU	Sanitary Service	2,012	1.00	27	1.00	2,012	27
	Totals	**250,494**		**13,571**		**48,012**	**4,284**
	Percent					**19%**	**32%**

This table comes from the California Energy Commission's Demand Analysis Office. The data are for 2001 and are based on energy utility reporting for that year. They also include self generation above 1 MW. The percent of the energy related to water was discussed by the WER Working Group on July 29, 2005. If we agreed that most of the energy was water related, we assigned it a 1. If we knew there was a relationship but didn't understand enough to know how big, we assigned it 0.05. If there was some intermediate relationship, we assigned it 0.5, except for National Security and International Affairs which we felt was typical of the overall energy relationship to water. We assigned zero to those categories where there did appear to be a relationship.

APPENDIX C: ENERGY IMPACT ANALYSIS OF EXISTING WATER MANAGEMENT PRACTICES

Introduction

This appendix examines various water management practices focused on water conservation and efficiency and estimates the effects of water efficiency activities on energy savings. The analysis in this appendix is intended to:

- ✓ Quantify energy requirements in water use cycle processes.
- ✓ Determine current water efficiency measure energy impacts.
- ✓ Compare water and energy efficiency program characteristics.
- ✓ Recommend policy changes to incorporate water efficiency in the energy efficiency portfolio.
- ✓ Identify areas of research to better understand water-energy interdependencies.

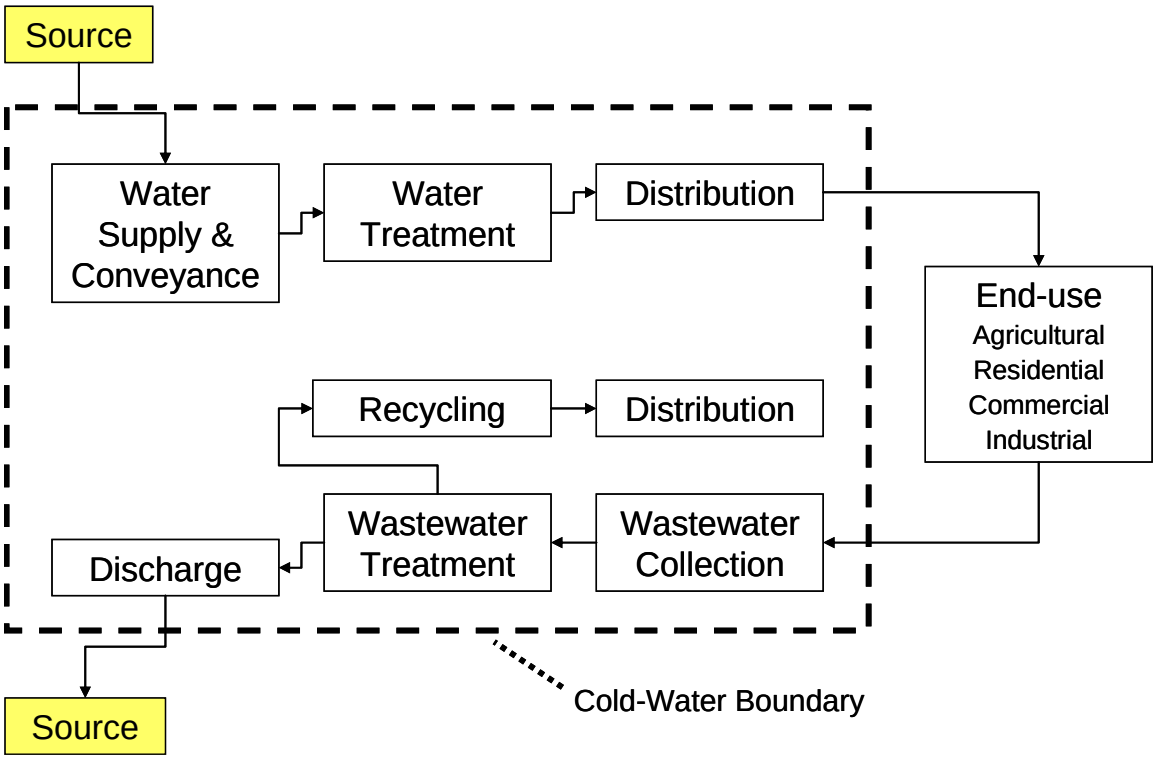
The Water Use Cycle

Electric and natural gas energy efficiency programs focus primarily on the application of energy consuming end-use technologies at utility customer facilities. In contrast to conservation, where usage is reduced through end-user behavioral changes, energy efficiency program planners target more permanent efficiency gains through known end-use technology or design applications. Likewise water use efficiency is achieved by implementing measures that result in reduced water consumption without customer behavioral changes.

In water systems, energy utilities target efficiency gains primarily by improving heating and pressurizing processes. For example, a low-flow showerhead saves energy because less hot water is used, thereby reducing the amount of energy needed to heat water. This is the case for water efficiency measures included in past energy efficiency programs such as faucet aerators, high-efficiency washing machines, and restaurant pre-rinse valves. Energy efficiency programs target efficiency gains in pressurizing applications by improving electric motor and/or pump efficiencies often at water and wastewater utility facilities. In each case the application is an end-use energy consuming technology located behind a customer meter.

When a unit of water is saved, so too is the energy required to convey, treat, deliver, perform wastewater treatment, and safely dispose of that unit of water. The energy intensity of the water use cycle must be examined on a systemic basis and varies widely by delivery location. Figure C-1 identifies the boundary of the water use cycle, showing the water processes that require energy, defined as cold water energy.

Figure C-1 Water Use Cycle



Significant customer-end use energy and water efficiencies have been, and are yet to be, achieved in the water sector[66]. These customer end-use efficiencies, while important, are excluded from this analysis to bring visibility to incremental cold-water energy savings.

When a water efficiency measure is implemented, the cold-water energy savings are achieved at multiple locations often transcending utility, city, and county jurisdictional boundaries. This analysis addresses the integration of water and energy demand-side management to increase cold water energy efficiency gains.

Water Use Cycle Energy Requirements

Electricity used to move or process water supplies (described above as cold water related energy) is quantified below in four primary stages or processes: conveyance, treatment, distribution, and wastewater treatment. The following table documents

[66] Even after accounting for expectations from existing efforts in this area, an additional 30-50 percent urban water (and associated energy) savings are possible with cost-effective existing technologies. (Waste Not, Want Not: The Potential for Urban Water Conservation in California, Pacific Institute, 2004.)

ranges of energy intensity for each process in terms of kilowatt-hours (kWh) per million gallons (MG):

Table C-1 Range of Energy Intensities for Water Use Cycle Processes (kWh/MG)

Water Cycle Segments	Low	High	Assumptions (Numbers in parentheses refer to sources listed below in this table)	
1. Water Supply & Conveyance	0	14,000	0: 14,000:	(1) Assume total gravity feed; (2) pg. 27 - SWP @ Pearblossom 4,444 kWh/AF or 13,638 kWh/MG (14,000 kWh/MG)
2. Water Treatment	100	16,000	100: 16,000:	(3) Water treatment without raw water pumping (max. gravity feed) and distribution pumping (accounted for under Distribution) = 99.7 kWh/MG Table 2-1, page 2-3 (7) Sea Water Desalination
3. Water Distribution	700	1,200	700: 1,200:	(6) (3) High Service Pumps To Distribution - 12,055 kWh/day for a Typical 10 MGD Surface Water Treatment Plant - figure 2-1, page 2-2 equivalent to 1,205.5 kWh/MG
4. Waste Water Collection	-	-		This category has been incorporated into the next category.
5. Waste Water Collection & Treatment	1,100	4,600	1,100: 4,630:	(4) Electric Use of Total Plant Operations Exec-1 and pg. 5, Table 3 - Range from 1,073 kWh/MG to 4,630 kWh/MG (3) Influent wastewater pumping is included in wastewater treatment process; figures 3-2 and 3-3, pages 3-3 and 3-4, respectively
6. Waste Water Discharge	0	400	0: 400:	(1) assumes gravity ocean outfall; 400 ground water recharge (3) pg. 3-7
7. Recycled Water Treatment	-	-		(4)(5) Tertiary/Advanced Waste Water Treatment Included under range of Waste Water Collection & Treatment
8. Recycled Water Distribution	400	1,200	Range:	(5) Municipal Recycled Water Use in California 2002: 46% Ag. Irrigation; 21 % landscape irrigation; 10% ground water recharge; Industrial 5%. This accounts for 82% of all recycled water. Energy needed for these applications fall within the ranges of the energy needed for typical water distribution and ground water recharge 400 - 1200 kWh/MG.

Sources:
(1) - Water Energy Working Group Assumption
(2) - Methodology for Analysis of the Energy Intensity of California's Water Systems; LBL January 2000
(3) - Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment, EPRI March 2002
(4) - Energy Benchmarking Secondary Wastewater Treatment and Ultraviolet Disinfection Processes at Various Municipal Wastewater Treatment Facilities, PG&E February 2002
(5) - DWR Water Facts No. 23
(6) - EBMUD 2003 Load Study by Navigant Consulting
(7) - California Water Plan Update 2005 Volume 2, Resource Management Strategies, Chapter 6 – Desalination. A 50 mgd seawater plant (approximately 50,000 acre-feet per year, or 16.25 billion gallons, assuming operations 90% of the time) would require about 33 MW of power. California Water Plan Update 2005 Volume 2, Resource Management Strategies, Chapter 6 – Desalination. This translates to about 5,200 kWh per acre-foot, or 16,000 kWh per million gallons

Regional Water-Energy Characteristics

The ranges of water use cycle energy requirements identified above vary significantly because of regional water system operating requirements. To project energy savings associated with unit volume reductions in water requires adoption of prototypical energy needs, incorporating the variability inherent in regional resource alternatives. Analysis in this appendix separates water energy regions broadly into the Northern and Southern California regions, but additional research to assess regional water-energy characteristics is needed (see Suggested Research Topics, below).

The Northern California Region: Contains the North Coast, San Francisco, Sacramento River, San Joaquin River, Tulare Lake and Central Coast[67] Hydrologic Regions as defined by the California Department of Water Resources. The Northern California region contains 42 percent of the state's population and 42 percent of urban residential and non-residential applied water[68]. The region is characterized overall by relatively higher annual precipitation than in Southern California and significant native ground and surface water resources.

The Southern California Region: Contains the South Coast Hydrologic Region; 53 percent of the state's population and 48 percent of urban residential and non-residential applied water[69]. The region is characterized by relatively low annual precipitation and limited native surface water resources and has historically relied heavily on groundwater and imported water to meet water demand.

Other Hydrologic Regions: Hydrologic regions not included in this analysis are the North Lahontan, South Lahontan and Colorado River Hydrologic Regions[70]. Future studies will need to refine analyses addressed herein and incorporate these regions.

For purposes of this analysis, the Northern and Southern California regions, as referred to in this appendix, include 95 percent of the state's population and 90 percent of urban residential and non-residential applied water.

Water Use Cycle Energy Intensity

Table C-2 reflects the variability between water use cycle energy requirements between Northern and Southern California.

[67] The Central Coast hydrologic region includes Santa Barbara and San Luis Obispo Counties that are served by the SWP Coastal Branch with transport energy intensity on-par with the SWP West Branch (water must be lifted over the coastal mountain range). For the purposes of this analysis, the Central Coast is included in the Northern California region because 80 percent of the population within the Central Coast Hydrologic region resides north and east of the mountain range in communities such as Salinas, Santa Maria, Santa Cruz, Lompoc, and Monterey.

[68] Department of Water Resources 2005 Water Plan Update, Volume 3, Chapter 1 Table 1-4. Year 2000 is referenced for all regional characteristics and is described (same reference Table 1-1, page 1-10) as the "Average Year" within the context of precipitation and Wet versus Dry Years.

[69] Ibid

[70] North Lahanton is the extreme northeast of the state; South Lahanton is the region east of the Sierra Nevada Mountains including Mono Lake, Owens Valley and Death Valley; Colorado River Hydrologic Region include eastern San Bernardino, Riverside and Imperial Counties.

Table C-2 Percent Electricity Use for Water System Components[71]

	Northern California	Southern California
Imported Water Supply	-	71%
Local Ground/Surface Water Supply	17%	6%
Local Distribution	26%	9%
Wastewater Treatment	56%	14%

As reflected in Table C-2, the majority of the water use cycle energy required for Southern California, due to imported water, is not present in Northern California. To define process energy savings from water unit volume reductions, representative applications have been adopted for each primary process type: conveyance, treatment, distribution, and wastewater treatment. Energy use scenarios adopted and supported here are based on prototypical values for each process type. For purposes of this analysis, north/south water conveyance energy requirements are addressed separately and water treatment, distribution, and wastewater treatment assumptions are constant.

Water Conveyance

Northern California: As described in Table C-1, the range of water energy intensity for supply and conveyance ranges from 0 to 14,000 kWh/MG. Zero is assumed for gravity-fed systems. Water supplies from native surface water and groundwater sources require much less energy per unit conveyed than in Southern California. Approximately 60 percent of Northern California's urban water requirements are met with surface water and 40 percent is met with groundwater[72]. Additionally, roughly 40 percent of the region's population is located in the San Francisco Hydrological Region, where much of the water is conveyed by gravity from higher elevation reservoirs.

In this analysis, a prototypical value for water conveyance for Northern California is taken from the raw water pumping requirements of surface water treatment, based

[71] Methodology for Analysis of Energy Intensity of California's Water Systems and An Assessment of Multiple Potentials Benefits through Integrated Water-Energy Efficiency Measures; Exploratory Research Project Supported by: Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency; Principle Investigator Robert Wilkinson, PhD. January 2000, pg-7.

[72] Surface water and groundwater supply percentages are calculated using Water Supply and Use information provided in the California Water Plan Update 2005, Volume 3 for the California Department of Water Resources' North Coast, San Francisco, Sacramento River, San Joaquin River, Tulare Lake, and Central Cost Hydrological Regions.

upon a survey of approximately 30,000 public water supply systems in the United States[73] (see Water Treatment, below) and is estimated at 150 kWh/MG[74].

Southern California: Groundwater meets 23 and 29 percent of Southern California's water demand in normal and dry years, respectively[75]. The Metropolitan Water District (MWD) of Southern California provides 85 percent of the region's water supply to 26 cities and water districts serving 18 million people[76]. MWD's *Integrated Resource Plan* cites goals to mitigate heavy dependence on imported water by balancing its supply portfolio between imports; storage and transfers; recycling; groundwater recovery; conservation; brackish and seawater desalination; and exchanges[77]. While the region's water agencies have compiled a wide array of water management tools and planning practices to bring local water resources on a more equal footing, the region remains dependent on imported water for at least 50 percent of its water supplies[78].

As water agencies develop and employ least-cost resources to meet regional water demands, imported water serves as the primary baseline or "marginal resource." The 2003 *Qualifying Settlement Agreement* enabled implementation of the "4.4 Plan," where California will reduce its use of Colorado River water from a high of 5.3 million acre-feet to its 4.4 million acre-feet annual apportionment, by year 2016[79]. For Southern California, State Water Project (SWP) water supplies from Northern California are treated as the marginal water resource. A brief description of SWP water delivery to Southern California follows:

> As the California Aqueduct moves water south along the west side of the San Joaquin Valley, four pumping plants raise it more than 1,000 feet before reaching the Tehachapi Mountains. Pumps situated at the foot of the mountains pump the water up 1,926 feet through tunnels, which take the water into the Antelope Valley. In the Antelope Valley, the aqueduct divides into two branches: the East Branch and the West Branch.

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[73] Water & Sustainability (Volume 4) U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century, EPRI 2002, Page 2-3

[74] Ibid, Figure 2-1, page 2-2, Raw Water Pumping 1,205 kWh per day for a treatment plant with 10 MGD capacity; equivalent to 120.5 per MG; assumption is raised to 150 kWh/MG as a minimum prototypical energy requirement.

[75] Ibid, Chapter 5, page 5-3

[76] Ibid, pages 5-2 and 3.

[77] MWD presentation to the Water Energy Working Group April 8, 2005.

[78] Ibid, page 5-5

[79] Department of Water Resources 2005 Water Plan Update, Volume 3, Chapter 5, page 5-8

> The East branch carries water through the Antelope Valley into Silverwood Lake in the San Bernardino Mountains. From Silverwood Lake, the water flows through the San Bernardino Tunnel, through the Devil Canyon Power Plant before continuing on to the southernmost SWP reservoir, Lake Perris. East Branch water energy intensity, net of any SWP system generation, is 3,236 kWh per acre-foot, or 9,931 kWh per MG. Water in the West Branch flows through the Warne Power Plant into Pyramid Lake in Los Angeles County. From there it flows through the Angeles Tunnel and Castaic Power Plant into Castaic Lake, terminus of the West Branch. West Branch water energy intensity, net of any SWP system generation, is 2,580 kWh per acre-foot, or 7,918 kWh per MG[80].

For purposes of this analysis, the energy intensity of Southern California's dominant and marginal water source, averaged between the SWP East and West Branch, is 8,924 kWh/MG (rounded off to 8,900 kWh/MG).

Water Treatment

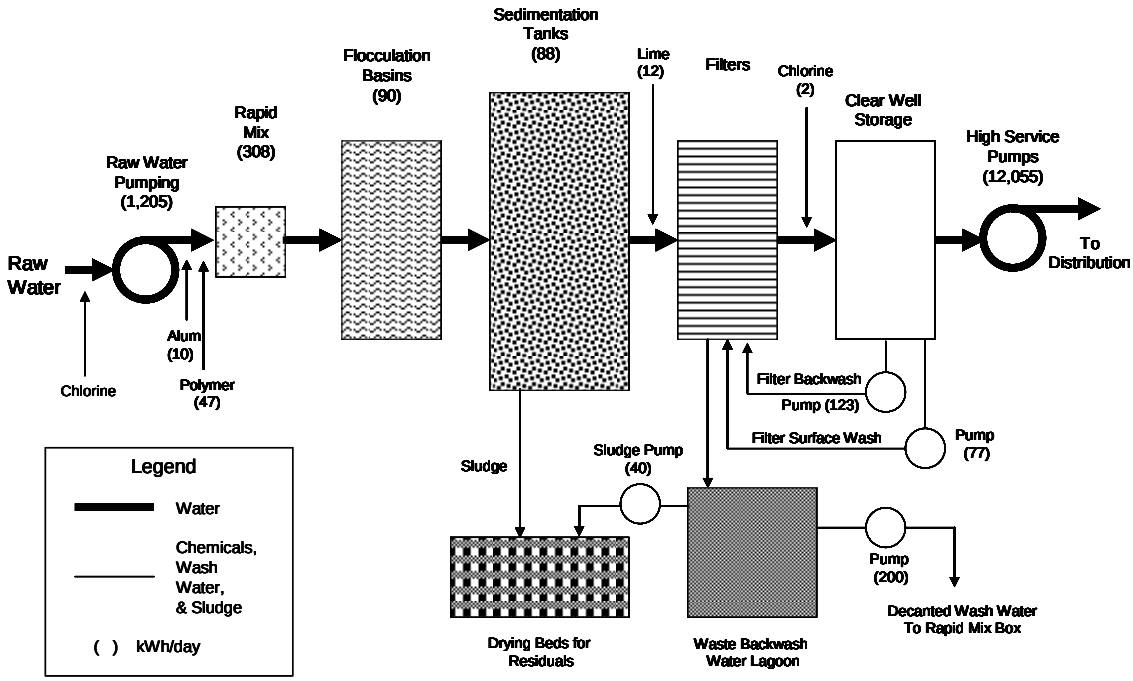
As explained above, for purposes of this analysis, water supply and conveyance energy requirements were addressed separately for Northern and Southern California. The remaining processes, water treatment, distribution, and wastewater treatment are considered similar enough between the two regions to assign the same prototypical water energy intensity. Due to the relative reliance on surface water supply in California, surface water treatment energy intensity has been adopted as prototypical.

In a typical sequence of operations for surface water treatment, the following steps are followed (see Figure C-2): Raw water is first screened and pre-oxidized, using chlorine or ozone to kill organisms; alum and/or polymeric materials are added to the water; flocculation and sedimentation remove finer particles; a second disinfection step kills remaining organisms with disinfectant residue carried into the distribution system to prevent organism growth; the clear well storage tank allows contact time for disinfection; and treated water is distributed to consumers by high-pressure pumps. Sludge and other impurities removed from the water are concentrated and disposed of.

[80] Methodology for Analysis of Energy Intensity of California's Water Systems and An Assessment of Multiple Potentials Benefits through Integrated Water-Energy Efficiency Measures; Exploratory Research Project Supported by: Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency; Principle Investigator Robert Wilkinson, PhD. January 2000, pages 24 through 27.

Figure C-2 Water Treatment Process Energy Requirements[81]

Representative Water Treatment Plant
Typical Daily Electricity Consumption for a 10 Million Gallon/Day Facility



Source: Electric Power Research Institute

[81] Water & Sustainability (Volume 4) U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century, EPRI 2002, Page 2-2, Figure 2-1.

Table C-3 Water Treatment Energy Intensity *(based on Figure C-2)*

		Surface Water Treatment Typical 10 mgd facility	kWh/MG
Public Supply	(Conveyance)	Raw Water Pumping	120.5
	(Treatment)	Alum	1.0
		Polymer	4.7
		Rapid Mix	30.8
		Flocculation Basins	9.0
		Sedimentation Tanks	8.8
		Lime	1.2
		Filters	0.0
		Chlorine	0.2
		Clear Well Storage	0.0
		Filter Backwash Pump	12.3
		Filter Surface Wash Pump	7.7
		Decanted Washwater to Rapid Mix	20.0
		Sludge Pump	4.0
		Treatment Subtotals	99.7
	(Distribution)	High Service Pumps	1,205.5
		Total	1,425.7

There is little variation in water energy intensity between plant sizes (shown in million gallons per day (MGD), as reflected in the following table:

Table C-4 Unit Electricity Consumption for Surface Water Treatment Plants[82]

Plant Size	kWh/MG
1 MGD	1,483
5 MGD	1,418
10 MGD	1,406
20 MGD	1,409
50 MGD	1,408
100 MGD	1,407

Referring back to Table C-3, in order to isolate the energy requirements for water treatment, the energy needed for raw water pumping and high service pumps to distribution have been removed. The remaining treatment processes total 997 kWh

[82] ibid, Page 2-3, Table 2-1. However, this study omitted the decanted wash water to rapid mix box pump rated at 20 kWh/MG from its totals. This amount was included in the numbers in the table.

per day for a typical 10 MGD capacity treatment plant or 99.7 kWh/MG. Actual energy requirements are driven by the site-specific characteristics of incoming raw water and water quality mandates. Industry standard practice, as well as process load metering, often doesn't differentiate raw water pumping, water treatment and distribution pumping loads adequately. Information provided in Table C-3 is drawn from large treatment plant populations and demonstrates this practice. Operational reporting of water treatment energy intensity is often driven more by the distance and elevation of the treatment plant in relation to water sources and the water distribution system than by the characteristics of raw water due to these vagaries. Typical water treatment processes are estimated at between 100 and 250 kWh/MG, and can be as high as 500 kWh/MG. In this analysis, 100 kWh/MG has been adopted as the prototypical and conservative water treatment energy intensity.

Water Distribution

Table C-4 shows there is little variation in the amount of energy required to treat and distribute a unit of water, regardless of plant size. As described above, Service Pumps to Distribution (for a typical 10 MGD water treatment plant) consume 12,055 kWh per day or 1,205.5 kWh per MG, or roughly 85 percent of total energy requirements (1,205 kWh/MG/1425 kWh/MG). For purposes of this analysis, a prototypical water distribution system energy intensity of 1,200 kWh/MG was adopted.

Wastewater Treatment

Unlike the water treatment and distribution systems, unit volume energy requirements for wastewater treatment plants vary greatly depending upon plant size. As would be expected, unit electricity consumption rises as the degree of treatment and complexity of the process increases. For example, advanced wastewater treatment with nitrification is three times as energy intensive (due to additional pumping requirements) as the relatively simple trickling filter plant[83]. Further complicating the assessment of prototypical wastewater treatment energy intensity are unique operational environments, discharge limitations, influent characteristics, and permitted effluent limitations as well as variations in plant permitting cycles. Table C-5 shows wastewater treatment plant energy intensities reflecting a range of energy intensity for facilities operating in California and cited in studies. Based on this range, 2,500 kWh per MG has been adopted as the prototypical wastewater treatment energy intensity.

[83] ibid, Pages 3-4 & 5 and Table 3-1.

Table C-5 Wastewater Treatment Energy Intensity

	kWh/MG
Inland Empire Utilities Agency [A]	2,971
City of Santa Rosa [B]	2,920
East Bay Municipal Utilities District [C]	2,001
Metropolitan Water District [D]	2655
Methodology for Analysis of Energy Intensity in California's Water Systems [E]	1,911
Energy Down The Drain, The Hidden Costs of California's Water Supply [F]	2,302
Energy Benchmarking Secondary Wastewater Treatment [G]	2,625

[A] Average of Five Wastewater Treatment Plants, CALeep Program Analysis May 2005
Program 1241-04, Conducted under the Auspices of the California Public Utilities Commission
[B] Laguna Wastewater Treatment
Sonoma County August 2002 Greenhouse Gas Emission Analysis, Page B-7
[C] EBMUD Load Studies Prepared by Navigant Consulting, December 2004
[D] The Metropolitan Water District of Southern California estimates that the wastewater facilities in its service territory consume between 1,470 to 3,840 kWh/MG
[E] Methodology for Analysis of Energy Intensity in California's Water Systems, January 2000, P. 43
Wastewater Treatment Plants with Nitrification
Ernest Orlando Lawrence Berkeley Laboratory
Principal Investigator: Robert Wilkinson, Ph.D.
Ref.: Burton, Franklin L. (Burton Engineering) , 1996 Water and Wastewater Industries
Electric Power Research Institute Report CR-106941, p. 2-45
[F] Wastewater Treatment with Nitrification (average 1-100 mgd plant capacities)
Energy Down The Drain, p. 26
[G] Energy Benchmarking Secondary Wastewater Treatment and Ultraviolet Disinfection Processes at Various (nine) Municipal Wastewater Treatment Facilities, PG&E February 2002
Electric Use of Total Plant Operations Exec-1 and pg. 5, Table 3 - 1,073 kWh/MG
Electric Use of Total Plant Operations Exec-1 and pg. 5, Table 3 - 4,630 kWh/MG

Summary of Water Energy Intensity for Northern and Southern California

The rest of this analysis is based on the following estimated energy intensities per million gallons of water (kWh/MG) delivered, treated, distributed, and disposed of in Northern and Southern California:[84]

[84] ibid (In this example NorCal system-wide Supply is estimated at 30 percent).

Table C-6 Prototypical Water Use Cycle Process Energy Intensity

	Northern California kWh/MG	Southern California kWh/MG
Water Supply and Conveyance	150	8,900
Water Treatment	100	100
Water Distribution	1,200	1,200
Wastewater Treatment	2,500	2,500
Total	3,950	12,700
Adopted	4,000	12,700

The Energy Efficiency of Water Use Efficiency

Energy savings associated with water savings provided in Table C-7 support the inclusion of water efficiency measures in energy efficiency program portfolios because of their relative low cost, long service life, and high resource value in terms of the avoided cost of energy. The following table reflects traditional water efficiency measures and their associated cold water energy savings resource values.

Table C-7 Water Efficiency Measure Cold Water Energy Savings

			Northern California			Southern California		
	Annual Savings Gallons/Year	Service Life	Annual kWh	Life-Cycle kWh	Resource Value	Annual kWh	Life-Cycle kWh	Resource Value
Residential								
Toilet Replacement 1.6 gpf (pre-1992)	2,250	25	9	225.0	$9	29	714	$32
Ultra Low-Flow Toilets	11,340	25	45	1,134.0	$44	144	3,600	$159
Energy Star Washing Machine	7,866	15	31	471.9	$27	100	1,498	$81
Commercial								
Ultra Low Flush Urinals	13,323	25	53	1,332	$52	169	4,230	$187
Waterless Urinals	25,568	25	102	2,557	$101	325	8,118	$359
Cooling Tower Condition Meter	729,906	10	2,920	29,196	$1,961	9,270	92,698	$5,609
Pre-Rinse Spray Head Installation	87,120	5	348	1,742	$136	1,106	5,532	$395
X-Ray Processor	1,042,723	5	4,171	20,854	$1,627	13,243	66,213	$4,733

Cost-effectiveness Assumptions

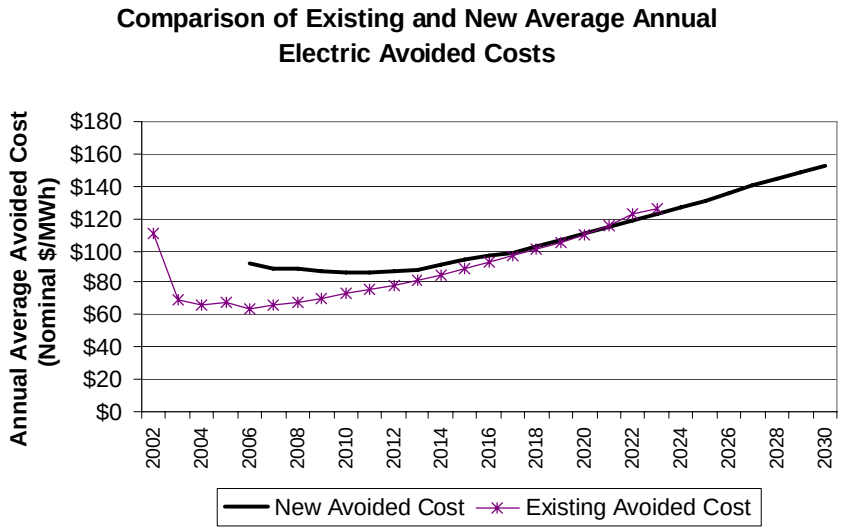
Resource values in this appendix were developed using the E3 Avoided Cost Methodology adopted by the California Public Utilities Commission (CPUC) in the April 7, 2005, Decision 05-04-024, Rulemaking (R.) 04-04-025. The CPUC adopted the E3 methodology for purposes of evaluating energy efficiency programs in R.01-08-028 and related energy efficiency proceedings.

The E3 model incorporates market price effects; the value of reliability through ancillary services; and the disaggregation of the avoided costs to time (hour, month, or time-of-use period) and to California climate zones. The E3 model forecasts the avoided costs of electric generation, transmission, and distribution that vary by hour, and the avoided costs of natural gas procurement, transportation, and delivery, which vary by month. Transmission and distribution (T&D) costs vary by utility service territory, planning division, and by the 16 Title-24 climate zones. Externality adders report environmental externalities: a T&D adder, which captures incremental demand-related capital expenditures, line losses and maintenance costs associated with increased energy use; a system reliability adder, which includes the cost of maintaining a reserve margin; and a price elasticity of demand adder, which recognizes that reduced demand results in a decrease in market-clearing price for electricity and therefore an increase in consumer surplus. The price elasticity of demand estimate varies by time-of-use period and month.

As currently utilized by the CPUC and energy utilities, the avoided cost projections in the E3 methodology extend to 2025. The calculations in this appendix include water use efficiency measures with 25-year service lives requiring that avoided cost projections be extended to 2030. The energy utilities submitted advice letter filings to the CPUC in April 2005 for purposes of updating their avoided cost projections. These filings projected utility avoided costs through 2030 for incorporation into the E3 methodology for valuing their energy efficiency resources. Figure C-3[85] compares the average utility avoided cost in place before and after the advice letter filings.

[85] Figure comes from E-3 published analysis of new and existing utility avoided costs.

Figure C-3



Source: E3

To calculate the resource value associated with the water use efficiency measures, the E3 methodology was modified to extend avoided cost projections to 2030. The adjustment from a 20-year to a 25-year measure results in less than a 7 percent change in the stated energy resource values. This means that the significant resource value potentials identified later in this appendix are not contingent upon modifying the avoided cost projections. E3 reviewed the adjustments and agreed the calculations were performed correctly.

Cold water energy savings are realized when one or more elements of the water use cycle - water conveyance, water treatment, water distribution systems and wastewater treatment facilities - process less water. They are also realized by avoiding incremental growth and requirements for plant expansions. In both cases the energy savings in the water use cycle result from the water use efficiency measures that were implemented. In this analysis water use cycle processes are assumed to operate 24 hours per day with an 85 percent load factor.

Energy Value of 2004 Best (Water) Management Practices

At a programmatic level, the California Urban Water Conservation Council (CUWCC) was created through the *Memorandum of Understanding (MOU) Regarding Urban Water Conservation in California* in 1991 to manage the process of implementing and updating the list of Best [water] Management Practices (BMP). To date 189 water agencies have pledged to implement the BMPs. CUWCC BMPs serve as a framework to quantify the energy resource value associated with water efficiency. The current lists of BMPs developed by the CUWCC follow.

Table C-8 CUWCC Best Management Practices[86]

BMP	Quantifiable Results
BMP 01: Water Survey Programs for Residential Customers	X
BMP 02: Residential Plumbing Retrofit	X
BMP 03: System Water Audits, Leak Detection and Repair	
BMP 04: Metering with Commodity Rates for all New Connections and Retrofit of Existing	X
BMP 05: Large Landscape Conservation Programs and Incentives	X
BMP 06: High-Efficiency Washing Machine Rebate Programs	X
BMP 07: Public Information Programs	
BMP 08: School Education Programs	
BMP 09: Conservation Programs for CII Accounts	X
BMP 09a: CII ULFT Water Savings	X
BMP 10: Wholesale Agency Assistance Programs	
BMP 11: Conservation Pricing	
BMP 12: Conservation Coordinator	
BMP 13: Water Waste Prohibition	
BMP 14: Residential ULFT Replacement Programs	X

Source: California Urban Water Conservation Council

[86] Quantifiable means annual reported BMP water use efficiency savings in acre feet per year, net of plumbing code compliance savings, reported pursuant to the 1991 Memorandum of Understanding Regarding Urban Water Conservation in California under protocol set forth by CUWCC. References: CUWCC (2005) *BMP Costs and Savings Study - A guide to Data and Methods for Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices* and (2003) *First Partial Revision*; M. Cubed (2003) *BMP Reporting Database Water Savings Calculations*; M. Cubed (1997) *California Urban water Agencies BMP Performance Evaluation, Final Report*; A&N Services (1996) *Guidelines to Conduct Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices*; U.S. EPA (1994) *Customer Incentives for Water Conservation, A Guide,* EPA/X820683-01-1, U.S. Environmental Protection Agency, Washington, DC. Measurement and evaluation is addressed by the CUWCC Measurement & Evaluation Committee.

To provide visibility to the potential impacts of integrated resource planning for water and energy efficiency programs, 2004 water sector BMP achievements were examined using the adopted energy efficiency avoided cost valuation methodology[87]. This analysis combines known planning criteria from each industry to assess the efficiency gain potential though programmatic integration.

Quantifiable water savings are available for eight of the BMPs, as shown in Table C-8. Each BMP includes several related water use efficiency measures. Assumptions for the water savings of each measure in gallons per day (GPD) and measure service life are reflected below in Table C-9.

[87] Resource values are produced using the E3 Avoided Cost Methodology adopted by the CPUC in the April 7, 2005 Decision 05-04-024, Rulemaking (R.) 04-04-025. The Commission adopted the E3 Methodology for the purposes of evaluating energy efficiency programs in R.01-08-028 and related energy efficiency proceedings. Avoided cost bases are maintained at the website http://www.ethree.com/CPUC/cpucAvoided26.xls

Southern California Resource Values: The E3 calculator utilized is version "SCE Tool 1q" and incorporates SCE's update to the E3 Methodology as described in SCE Advice 1187-E (U-338-E) of April 25, 2005 specifically "extending the avoided cost forecast to 25 years from the base year of 2006" and applying "a linear trend based on the last five years of data contained in the E3 Methodology" as described in the referenced Advice Letter, page 3, Section A.

Northern California Resource Values; The E3 calculator utilized is version "CEE_Calc_Tool_Commercial_1d" and incorporates PG&E's update to the E3 Methodology as described in PG&E Advice 2626-G/2654-E (U-39-M) of April 25, 2205 and reflect ATTACHMENT A, Table 4: Adjustments Made to Extend Forecast through 2030.

Table C-9 BMP Water Use Efficiency Measure Service Life and Savings

	Service Life	Savings gpd	Reference
BMP 01:	4.5	26.6	Residential Surveys: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
	5	21.0	Residential Surveys, Single Family: Metropolitan Water District of Southern California (MWD) program planning assumptions
	4	8.8	Residential Surveys, Multi-Family: MWD program planning assumptions
BMP 02:	5.1		Residential Plumbing Retrofits: BMP Costs & Savings Study (July 2000 ed.), page 2-13, mid-point range, equivalent useful life five years April 28 2003 M. Cubed Technical Memorandum to M&E Committee re; BMP Reporting Database Water Savings Calculations - Page 4 of 15
	5	5.5	Low Flow Showerheads: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	3.5	4.2	Toilet Displacement Devices: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	2	1.5	Faucet Aerators: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	8.5	0.64	Toilet Leak Detection: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	8.5	0.5	Other Household Leak Detection: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	4	12.2	Turf Audit: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	4	25.9	Turf Audit With Timer: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	25	24.2	Ultra Low-Flow Toilets (ULFT): BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
	17.5		Hot Water on Demand: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
BMP 04:	10.5	Reported	Metering With Commodity Rates: BMP Costs & Savings Study, Draft Revision March 2005, page 2-29 (though should probable be 20+, as if and when a meter fails, it would be replaced see Section 2.5
BMP 05:	10	Reported	Large Landscape: Budgets and Surveys: MWD Planning Practices; BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range) see Section 2.16
			Evapotranspiration (Eto)-based budgets: BMP Costs & Savings Study (July 2000 ed.), Table 1, page 53
			Large Landscape Surveys: Urban Water Conservation Potential (August 2001)
BMP 06:	14	21.6	H/E Washing Machines: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
	15	21.6	BMP Costs & Savings Study, First Partial Revision December 2003, page A-6
		13.8	BMP Costs & Savings Study, First Partial Revision December 2003, page A-8 range average
BMP 09:	12.4		CII Conservation Programs: Urban Water Conservation Potential (August 2001) (decay rate 10%)
		527.5	CII Surveys: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
	5	2,856.8	X-Ray Processor: MWD Program Planning assumptions
	3	136.6	Water Broom: MWD Program Planning assumptions
	5	300.0	Pre-Rinse Spray Head: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range 100-500 gpd); expected life span see page 2-80
	3	200.0	MWD program planning assumptions
	5	240.0	PG&E Non-Residential Work Papers Supporting Application For Approval of 2006-2008 Energy Efficiency Programs and Budgets filed June 20 2005, R.01-08-028, pages 40 - 43 (electric) and 57 - 59 (gas) of 279, Non-Res Deemed Savings pages 14 or 20
	5	892.7	Industrial Process Improvement: MWD program planning assumptions
	8	103.6	High-Efficiency Washers: MWD program planning assumptions
	5	22.3	Flush Valve Kit: MWD program planning assumptions
	10	1,999.7	Cooling Tower Conditioning Meter: MWD program planning assumptions
BMP 09a:	25	36.5	CII ULFT Replacement: M. Cubed (2003) Technical Memorandum to the CUWCC M&E Committee re; BMP Reporting Database Water Savings Calculations - Page 10 of 15; BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range); BMP Costs & Savings Study, First Partial Revision December 2003, page A-12, Example 2A
	25	30.4	CII Dual Flush CII ULFT: MWD program planning assumptions
	30	30.1	Ultra Low-Flow Urinals: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
	25	70.1	Waterless Urinals: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
BMP 14:	25	31.1	Res - ULFT: BMP Costs & Savings Study, First Partial Revision December 2003, page A-12, Example 2A; MWD program planning assumptions; BMP Costs & Savings Study (July 2000 ed.), page 2-29; April 2003 Technical Memorandum, page 15 of 15

Source: California Urban Water Conservation Council

The CUWCC reporting system for reductions in water used by member agencies reflects 2004 BMP achievements for BMPs with quantifiable results.[88] The energy savings for these measures, both annual and life cycle, are shown for each of these measures in Table C-10.

[88] Data was obtained from public access CUWCC website http://bmp.cuwcc.org/bmp/summaries/public/bmpsavings.lasso

Table C-10 Energy Resource Value in Water Use Efficiency (2006-2008 (E3) Avoided Cost)[89]

Northern California (PG&E/SMUD)	MG	Annual Savings kWh	Useful Life	Life-Cycle kWh Savings	NPV Electric Avoided Cost
BMP 1 Water Survey Programs MF/SF	802	3,208,000	5	16,040,000	1,251,113
BMP 2 Residential Plumbing Retrofit	132	528,000	5	2,640,000	205,919
BMP 4 Metering & Commodity Rates	671	2,684,000	11	29,524,000	1,929,737
BMP 5 Large Landscape Conservation Programs	2,249	3,261,050	10	32,610,500	2,190,009
BMP 6 High-Efficiency Washing Machine Rebate	134	536,000	15	8,040,000	474,057
BMP 9 Conservation Programs CII	2,035	8,140,000	12	97,680,000	6,217,380
BMP 9a CII ULFT	109	436,000	25	10,900,000	430,340
BMP 14 Residential ULFT	5,490	21,960,000	25	549,000,000	21,674,941
Total Northern California	11,621	40,753,050			$34,373,496
Southern California (SCE/LADWP/SDG&E)					
BMP 1 Water Survey Programs MF/SF	1,095	13,906,500	5	69,532,500	4,969,753
BMP 2 Residential Plumbing Retrofit	180	2,286,000	5	11,430,000	816,946
BMP 4 Metering & Commodity Rates	916	11,633,200	11	127,965,200	7,543,053
BMP 5 Large Landscape Conservation Programs	3,072	31,334,400	10	313,344,000	18,959,692
BMP 6 High-Efficiency Washing Machine Rebate Program	183	2,324,100	15	34,861,500	1,872,831
BMP 9 Conservation Programs CII	2,779	35,293,300	12	423,519,600	24,350,142
BMP 9a CII ULFT	149	1,892,300	25	47,307,500	2,092,023
BMP 14 Residential ULFT	7,498	95,224,600	25	2,380,615,000	105,275,069
Total Southern California	15,871	193,894,400			$165,879,509
Total Statewide Impacts	27,492	234,647,450			$200,253,005

Source: CUWCC Reporting Database, April 2005 with 86 of 269 Reporting Units (32%) reporting BMP expenditures in 2004 Reporting Units include: Water utility districts, water agencies, irrigation districts, city and county water departments and, water service companies implementing BMPs.

The numbers shown in Table C-10 reflect the variability in water conservation impacts on water related energy requirements, depending upon measure location.[90] The energy values have been obtained based on the multipliers for Northern and Southern California. The landscape numbers assume that the applied water is not treated as wastewater. In addition to the more than 27 million gallons saved from the 2004 BMPs, 234 million kWh were also saved that year, worth more than $200 million over their useful lives.

At this time it is reasonable to use the energy intensity values contained in this appendix as proxy values to support program planning. Future analyses of water energy intensity should be refined geographically by applying characteristics of hydrologic regions, planning areas or detailed analysis units as required, and finally

[89] See footnote 83.

[90] Water conservation activity is reported by CUWCC aggregated; to support disaggregating between SoCal and NorCal, electric service customer populations were used to establish approximately 60 percent - 40 percent shares for SoCal and NorCal, respectively.

applied to a structure that will align with energy efficiency planning climate zones[91] (See Suggested Research Topics).

The need to measure location-specific water-energy efficiency impact does not constitute a programmatic barrier for energy efficiency planners. This treatment is consistent with current energy efficiency program planning practices. For example, all current weather-dependent energy efficiency measure savings reflect location-specific savings across 16 climate zones - for example heating; ventilation and air-conditioning as well as building envelope measures; insulation; window glazing; and infiltration. Therefore, adopting savings for water-energy efficiency reflecting regional water energy intensity could be readily incorporated into current energy efficiency program planning protocols. The key point is that regional variability in water energy intensity should not defeat integrated planning. Energy efficiency planning already addresses many efficiency measures with varying degrees of savings in 16 geographic climate zones.

Statewide Water Use Efficiency (WUE) Potential

While the energy saving potential of 2004 BMP results are significant, they in no way indicate statewide potential. As related above, this appendix relied on the CUWCC's reporting database and used CUWCC's BMP reporting structure to provide visibility for associated energy benefits. CUWCC stresses that the reported savings are conservative and "the database does not include water efficiency for a whole series of BMPs for which CUWCC did not have a method to calculate water savings"[92].

The Pacific Institute, in its November 2003 report *Waste Not, Want Not: The Potential for Urban Water Conservation in California*, cites water savings potential, reflected in Table C-11. The 2004 BMP reported results in Table C-10 that represent approximately 4 percent of the minimum potential cost-effective savings identified here.

[91] The California Department of Water Resources subdivides the state into 10 hydrological regions, 56 planning areas plus a more detailed breakdown into 278 detailed analysis units. Existing spatial analysis (GIS) readily supports integration of water measures into energy-efficiency program planning climate zones to ensure regional values align with energy-efficiency program planning protocols.

[92] Comments of Mary Ann Dickinson, Executive Director of the California Urban Water Conservation Council at the California Energy Commission Energy-Water Relationship Comment Workshop, Docket No. 04-IEP-01-H, June 21, 2005; Proceeding Minutes page 22.

Table C-11 California Urban Water Use in 2000

Potential to Improve Water Use Efficiency and Conservation

California Urban Water Use by Sector	Current (2000) Water Use (AF/year)	Best Estimate of Conservation (AF/year)	Potential to Reduce Use (%)	Minimum Cost-Effective Conservation (AF/year)
Residential Indoor	2,300,000	893,000	39	893,000
Residential Outdoor	983,000 to 1,900,000 (b)	360,000 to 580,000 (c)	25 to 40	470,000
Commercial/ Institutional	1,850,000	714,000	39	Combined CII: 658,000
Industrial	665,000	260,000	39	(e)
Unaccounted-for Water	695,000	(d)	(d)	(d)
Total	**6,960,000** (+/- 10%)	2,337,000	34	2,020,000

Source: The Pacific Institute

The question is really how much energy savings can actually be achieved through this much water use efficiency. The following calculations were performed to make this determination:

1. The average of *Best Estimate of [Water] Conservation* and *Minimum Cost-Effective Conservation* (Table C-11 above) is 2,178,500 acre feet per year, rounded to 2,150,000.
2. As shown in Table C-6 (and applied in Table C-11), the average energy intensity for Northern and Southern California is 4,000 and 12,700 kWh/MG, respectively; the weighted average based on customer populations is 9,220 kWh per MG[93].
3. 2,150,000 AF or 700,580 MG of California's achievable water conservation, multiplied by the 9,220 kWh per MG (the state's weight average water use cycle energy intensity), yields equivalent energy savings of 6,450 GWh, rounded to 6,500 GWh.

[93] The weight average of water use cycle energy intensity is based on year 2000 customer populations for Northern California of 5.167 million customers (PG&E and SMUD) and for Southern California of 7.057 million customers (SCE, LADWP and SDG&E) representing 92 percent of California's electric customers. This yields a customer allocation of 42.3 percent for Northern and 57.7 percent for Southern California. Applying the rounded allocation of 40 percent and 60 percent to respective energy intensities of 4,000 and 12,700 kWh per MG yields a population based weighted average of 9,220 kWh per MG.

4. 6,500 GWh and an 85 percent load factor yield a demand reduction of 873 MW, rounded to 850 MW.

   In Summary:

   - ✓ Annual water use efficiency water savings:
     - 700,580 MG
   - ✓ Water use cycle energy requirements:
     - 9,220 kWh/MG
   - ✓ Water use efficiency energy savings:
     700,580 (MG) X 9,220 (kWh/MG) = 6,459,344,373 kWh or 6,459 GWh
     Assumed Water Use Cycle Energy Savings = 6,500 GWh
   - ✓ Water use efficiency demand reduction:
     Peak Load (kW) = kWh / (Load Factor * 8760)
     Peak Load (kW) = 6,500,000,000 / (.85 * 8760) =
     873,000 kW or 873 MW
     Assumed Peak Load Reduction = 850 MW

5. Information from multiple sources shows that the cost of most water use efficiency measures ranges from about $58 to $710 per acre-foot or $178 to $2,179 per MG, depending upon the program. These costs include the full cost to manage the programs, capital investments, and required staffing[94]. Assuming an average of this range, or $384 per acre-foot ($1,178 per MG), the approximate cost in terms of energy efficiency is $0.13 per annualized kWh (700,580 MG X $1,178/MG = $825.6 million / 6,500,000,000 kWh = $0.127/kWh, rounded to $0.13/kWh).

Table C-12 presents the results of these calculations and compares them to the California's energy efficiency programs for 2004-2005 and those planned for 2006-2008.

[94] Department of Water Resources 2005 Water Plan Update, Volume 2, page 22-2, Potential Benefits of Urban Water Use Efficiency, and; Potential Costs of Urban Water Use Efficiency

Table C-12 Comparison of Water Use Efficiency to Energy Efficiency Resource Value

	2004-2005 [1]	2006-2008 [2]	WUE [3]
GWh (Annualized)	2,745	6,812	6,500
MW	690	1,417	850
Funding ($ million)	$762	$1,500	$826
Cost per Annual kWh	$0.28	$0.22	$0.13
WUE Relative Cost	46%	58%	

[1] CPUC Rulemaking R.01-08-028, Decision D.03-12-060
[2] CPUC Rulemaking R.-01-08-0228, Decision D.04-09-060
[3] California Water Plan Update 2005, Bulletin 160-05 California Department of Water Resources, page 22-2

The table shows that the estimated energy savings from statewide water use efficiency is more than double the energy savings from the 2004-2005 energy efficiency programs and almost as large as those planned for 2006-2008. The estimated peak reduction from water use efficiency falls between the values for these years. From a program cost standpoint, water use efficiency is roughly one-half the cost of energy efficiency programs.

These estimates are reasonably robust. If the energy savings were only half as much or if the costs were twice as much, water use efficiency would be as cost-effective as current and planned energy efficiency programs.

One of the questions that came up during the California Energy Commission's (Energy Commission) *Integrated Energy Policy Report (Energy Report)* proceedings was concerned with the different ways that water and energy programs address the useful life of the same measures. To evaluate the potential impact of this difference, Table C-13 compares several measures that are common to both energy efficiency and water use efficiency programs. The Estimated Useful Life (EUL) and energy savings from water heating and from savings in the water use cycle (cold water savings) are presented for four common measures:

Table C-13 Energy Efficiency – Water Use Efficiency Common Measures

	Energy - EUL	Water – EUL	Heating Annual Savings (kWh)	Cold Water Savings (kWh)
Low-Flow Showerhead[1]	10	5	202	16
Faucet Aerator[2]	10	2	78	4
Clothes Washer[3]	15	15	644	100
Pre-Rinse Spray Valve[4]	5	5	12,310	1,106

[1] Measure #504 California Statewide Residential Sector Energy Efficiency Potential Study #SW063
[2] Measure #506 ibid
[3] Measure #601 ibid
[4] PG&E CPUC Application for Approval of 2006-2008 Energy Efficiency Programs and Budget (U 39 M), Advice Letter 05-06-004 ATTACHMENT 4, ERRATA FOR PROGRAM DESCRIPTIONS, Workpapers

As shown above, water use efficiency planners apply estimated useful lives to the same measures that are either equal to or lower than those applied by energy efficiency planners. For purposes of consistency with the energy savings calculations shown later in this appendix, the EULs used by the energy planners were adopted.

Another concern was that these four measures represent the full potential for additional water use efficiency gains. However, the small set of overlapping measures represents less than 2 percent of the *known* energy savings and resource value that can be created through cold water savings. These additional savings – 98 percent - will come from measures that have been generally overlooked by energy efficiency planners.

At one time water use efficiency was narrowly viewed as a temporary source of water supply in response to drought or emergency water shortage situations. However, this analysis shows that water use efficiency is a viable long-term water and energy resource supply option. In short, significant, attainable energy savings can be realized in the form of water use efficiency.

Comparing Water and Energy Efficiency Programs

Comparing water and energy efficiency programs reveals differences in treatment in the following areas: program oversight, resource valuation, technical potential, budgets (trends), planning, implementation and evaluation, measurement, and verification. This section examines how both programs address these areas.

Program Oversight and Compliance

There is significant variability between water and energy efficiency program targets, regulatory oversight, and compliance. Targets for water conservation are referenced

to a 10-year reporting period. Performance requirements for the BMPs with quantifiable results follow in Table C-14:

Table C-14 Best Management Practices

BMP	Requirements
BMP 01: Water Survey Programs for Single-Family and Multi-Family Residential Customers	Survey 15 percent of residential customers within 10 years
BMP 02: Residential Plumbing Retrofit	Retrofit 75 percent of residential housing constructed prior to 1992 with low-flow showerheads, toilet displacement devices, toilet flappers and faucet aerators
BMP 04: Metering with Commodity Rates for all New Connections and Retrofit of Existing	Install meters in 100 percent of existing un-metered accounts within 10 years; bill by volume of water use; assess feasibility of installing dedicated landscape meters
BMP 05: Large Landscape Conservation Programs and Incentives	Prepare water budgets for 90 percent of commercial and industrial accounts with dedicated meters; provide irrigation surveys to 15 percent of mixed-metered customers
BMP 06: High-Efficiency Washing Machine Rebate Programs	Provide cost-effective customer incentives, such as rebates, to encourage purchase of machines that use 40 percent less water per load
BMP 09: Conservation Programs for CII Accounts	Provide a water survey of 10 percent of these customers within 10 years and identify retrofitting options; OR reduce water use by an amount equal to 10 percent of the baseline use within 10 years
BMP 14: Residential ULFT Replacement Programs	Replace older toilets for residential customers at a rate equal to that of an ordinance requiring retrofit upon resale

Source: California Urban Water Conservation Council

A consistent and broadly acceptable method to evaluate (water use efficiency) cost-effectiveness and water savings is needed[95]. Documentation and evaluation of the achievements attributable to water use efficiency projects and programs, vital elements of successful water use efficiency efforts, need to be improved. The quantification of benefits for many projects lacks a necessary level of scientific

[95] Ibid

rigor[96]. Implementation of the BMPs by the water agencies is voluntary, and water efficiency program performance is self-reported, monitored by the CUWCC[97]. CUWCC is a non-profit agency with its governance administered by a committee comprising six representatives: three representatives from member water agencies and three representatives from public advocacy organizations[98]. Not all water agencies have signed onto the MOU agreement, and not all signatories are fully implementing the BMPs[99].

In contrast, the state's investor-owned utilities (IOU) energy efficiency programs are regulated by the CPUC[100]. The requirements include:

- ✓ Administrative structure for efficiency programs
- ✓ Program evaluation, measurement, and verification (EM&V)
- ✓ Separation between "those who do" and "those who evaluate" programs
- ✓ Protocols for measuring efficiency programs are defined in the *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs* [101]
- ✓ EM&V integration into the program planning process
- ✓ EM&V funding guidelines
- ✓ The type and frequency of EM&V studies conducted for each program and the major study parameters utilized for each study, including sample design, monitoring duration and schedule, and approaches undertaken to evaluate and minimize bias
- ✓ Cost-effectiveness tests used to evaluate program performance and proposed programs including:

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[96] Department of Water Resources 2005 Water Plan Update, Volume 2, page 22-4, WUE Challenges – Data Collection.

[97] CUWCC Governance Policies Section 10. Access to BMP Reporting Data: 10.1a.: "The Council will regard any data stored in the Council BMP Reporting Database that has been formally 'submitted as final" as public information', and; Section 10.1c.: "All publicly-released reports shall carry a disclaimer indicating that reports are based on self-reported data that has not been 100% validated by the Council."

[98] CUWCC Governance Policies Section 6.1, "The Council's Governance Committee shall be responsible for initiating the Executive Director's Annual Performance Review. The committee shall be responsible for oversight of Council governance, including review of bylaws, policies, membership development and training, communication (internal and external), strategic planning and meeting protocol." "The Governance Committee shall be composed of three Group 1 representatives (urban water supplier representatives) and three Group 2 representatives (public advocacy organizations) from the Steering Committee.

[99] Department of Water Resources 2005 Water Plan Update, Volume 2, page 22-3

[100] See CPUC Rulemaking 01-08-028, Decision 05-04-051 April 21, 2005

[101] As adopted by California Public Utilities Commission Decision 93-05-063 Revised March 1998 Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021,95-12-054, 96-12-079, D.98-03-063, and D.99-06-052.

- program costs and participation levels
- number and type of measures
- environmental adders informed by and coordinated with the Climate Change Action Registry
- continuity of the input assumptions and calculations for the tests of cost-effectiveness (California Standard Practice Manual[102])
- *ex post* (after-installation) measurement of lifecycle savings inform and update *ex ante* (pre-installation) assumptions for future programs
- values for the weighted cost of capital (instead of using different values for each implementer). The current authorized cost of capital for the IOUs ranges between 7.6 percent and 8.7 percent, depending upon the IOU.

Program Funding

Variations in program oversight and compliance might reflect, in part, energy efficiency program ratepayer funding and funding levels. California electric industry deregulation legislation and other regulation established minimum levels of energy efficiency funding from 1998 through 2001, and are currently used by both IOUs and local publicly owned electric utilities[103].

Additionally, in 2003 the CPUC ordered IOUs to file plans to include energy efficiency as part of their long-term procurement supply portfolios for the first year, five years, and twenty years[104].

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[102]http://www.cpuc.ca.gov/static/industry/electric/energy+efficiency/rulemaking/03eeproposalinfo.htm

[103] Electric Industry restructuring legislation Assembly Bill 1890 (Brulte, 1996) codified in Public Utilities Code (PU Code) under Division 1, Part 1, Chapter 2.3. Electrical Restructuring. Under Article 7 Research, Environmental, and Low-Income Funds, Section 381 directed the CPUC to require each IOU to identify a separate rate component to collect revenues used to fund cost-effective energy efficiency and conservation activities. Herein the IOUs were directed to fund not less than the following levels commencing January 1998 through 2001 ($ million dollars):

	1998	1999	2000	2001	Total
SDG&E	$32	$32	$32	$32	$128
SCE	$90	$90	$90	$50	$320
PG&E	$106	$106	$106	$106	$424
Total	$228	$228	$228	$188	$872

Article 8, Section 385 (a) directs each local publicly owned electric utility to establish a non-bypassable, usage based charge on local distribution service of not less than the lowest expenditure level of the three largest IOUs on a percent of revenue basis, calculated using the utility's total revenue requirement for the year ended December 31, 1994, and IOU total annual expenditures described above under section 381 (approximately 3 percent).

[104] CPUC Decision D.0312062 directs IOUs recover authorized procurement-related energy efficiency [costs] through its existing non-bypassable Public Purpose Programs Charge (PPPC), which applies to all IOU retail customers. Additionally, CPUC D.03-12-062 directs that incremental procurement

Table C-15 shows projected procurement costs for utility energy efficiency programs for the years 2004 through 2008 ($ millions):

Table C-15 IOU Supply Portfolio of Electric Energy Efficiency Procurement

Utility	2004	2005	2006	2007	2008	Total
PG&E	25	50	50	75	100	300
SCE	60	60	60	60	60	300
SDG&E	25	25	25	25	25	125
Total	**110**	**135**	**135**	**160**	**185**	**725**

Table C-16 shows the effect of combining the procurement budget with the budget for electric energy efficiency programs directed under the Public Goods Charge (PGC) funds for 2004 and 2005 ($ millions). This increases the total electric energy efficiency budget for 2004-2005 by $245 million, bringing the total to more than $760 million.

Table C-16 IOU Combined Electric Energy Efficiency Budgets 2004-2005

	PGC Budget	Procurement Budget	Total Budget
PG&E	258	75	333
SCE	183	120	303
SDG&E	77	50	127
Total	**518**	**245**	**763**

Current Energy Efficiency Program Funding

- $763 million was allocated to 2004-2005 electric energy efficiency programs, an increase of $245 million (43 percent) over statutory levels
- The 2006 – 2008 funding cycle was approved at just under $2 billion, of which approximately $1.5 billion is for electric energy efficiency, with the balance for natural gas.

Current Water Efficiency Program Funding

- In 2002 voters approved Proposition 50, which provides $180 million for water use efficiency programs in the years 2003 – 2007[105]. Proposition 50 annual

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energy efficiency costs be subject to recovery though a non-bypassable charge to all customers and orders IOUs to establish the Procurement Energy Efficiency and Balancing Account (PEEBA) to track costs and revenues.

[105] Proposition 50 Chapter 7 provides $180 million for water use efficiency programs per year as follows: Urban water use efficiency $60 million; Agricultural water use efficiency $60 million; Water

funding for water efficiency is estimated at $36 million (actual program funds provided water agencies is reported to be an average of approximately $30 million per year[106]).

- Funding for water efficiency programs also comes from several other sources, including the implementing water agency, the state's General Fund, federal funds, and general obligation bonds. While these sources add to the available funds, the total is significantly less than that committed to energy efficiency programs.
- Funding has fallen below commitments made in 2000 through the CALFED Record of Decisions, Stage 1 2000-2007. By 2003 investments lagged by $235 million[107].

Integrated Resource Planning

Currently, water efficiency programs receive no credit for, and planners do not quantify, the large energy savings associated with water saving measures that are implemented. Additionally, until energy efficiency regulation and policy are changed, energy utilities cannot include or target these significant energy-efficiency gains. Neither water nor energy efficiency program planners address or target these potential efficiency gains, and a significant gap exists in statewide water and energy resource planning.

Water, wastewater, and energy efficiency program planners acknowledge the importance of comprehensive resource management. Water efficiency programs are based on the same cost-benefit methodology as energy efficiency programs and reference the Standard Practice Manual.[108] This common methodology recognizes the importance of clearly understanding the following four cost-effectiveness perspectives:

1. Water, wastewater or energy program participants
2. The water, wastewater or energy utility
3. The water, wastewater or energy supply system
4. Society

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recycling $60,000. The Bond law was passed in November 2002, and the funding will be allocated through 2007 (five years). Proposition 13 also had funding for water use efficiency but in form of loan. DWR Water Use Efficiency Office is funded partially through the general fund; annual budget less than $1 million. In addition to Statewide funding, local agencies also budget for water use efficiency programs.

[106] See footnote 72, Proceeding Minutes page 23.

[107] Department of Water Resources 2005 Water Plan Update, Volume 2, page 22-2.

[108] "A Guide to Customer Incentives for Water Conservation" Prepared by Barakat and Chamberlain for CUWA, CUWCC, and US EPA, February 1994 (EPA # 230R94001).

However, water, wastewater, and energy efficiency cost-benefit valuation is performed from the utility and, in the best cases, the electric supply system ***or*** the water supply system ***or*** the wastewater collection system perspective (See 2 or 3 above). Ultimately the suboptimal affects of this discrete or isolated water, wastewater, and energy resource management is borne by the consumer who must pay the water, the wastewater, and the energy utility bills.

Under the broader societal perspective, transfer payments between the water utility and participating customers are canceled out; also eliminated are transfer payments among the water utility and other utilities. The costs that are avoided by the electric, gas, water, or wastewater utilities are viewed as societal benefits, and any additional costs that are incurred by these utilities as a result of a water efficiency program are societal costs. Drawing the boundary around the entire water use cycle and including all end users and affected utilities facilitates this societal valuation.

Analysis contained in this appendix has demonstrated that the state's water, wastewater and energy resources are inextricably entwined. Incomplete accounting understates the resource value of water use efficiency. Integrated resource planning of water, wastewater and energy must be performed from *society's* perspective and answer the question, "What mix of water and energy efficiency measures will create the greatest return on the combined ratepayer investment?"

An integrated water-energy societal total resource cost valuation would include the avoided marginal cost of water and wastewater treatment, related environmental externalities, and the associated marginal cost of energy (kWh), capacity (kW), transmission, distribution (including line losses), and environmental externalities. Environmental externalities related to avoiding water and energy use need to be itemized (to remove potential double-counting) and combined to reflect composite environmental impacts.

With a more complete avoided cost-based justification, improved cost-benefit ratios and corollary increased program funding, water-efficiency program market penetration could significantly increase. Integrated water and energy demand-side management would increase both water and energy efficiency program impacts.

Suggested Research Topics

1. Regional Cold Water Energy Intensity (near-term):

    a. Research and develop regional cold water energy intensities. Adopt proxy values and establish linkage to forecasting climate zones. The information being developed by the University of California, Santa Barbara and the Pacific Institute will help develop a proxy that can be relied upon to develop pilot water-energy programs while more detailed studies are being conducted. In particular, while studies of urban water

uses indicate that significant energy can be saved by reducing water consumption, the drivers for these opportunities are not well understood. A comprehensive inventory, characterization, and assessment of the primary types of water-related energy consumption by type of water source, system, function, and end use will eventually be needed to develop the detailed methodologies upon which cost-effective programs can be based. Water-related energy consumption can then be mapped from its source through various categories of end use to develop a comprehensive understanding of the points and relative magnitudes of energy consumption along the water supply chain, and the types of systems, processes, equipment, and measures that could reduce water and energy consumption at these points.

b. For existing cold ,water measures develop base case unit energy consumption (UEC), high-efficiency (HE) UEC, Base and HE Peak watt and demand savings, volume sensitive installed measure costs, and expected useful life values.
c. Identify opportunities for participating in demand response programs.
d. Identify and evaluate new cold water measures targeted to create resource value specifically suited to integrated water-energy resource planning not previously addressed under the discrete/isolated water/energy resource management regime.
e. For cold water measures found to be viable under item d., above, develop planning data identified for existing cold water measures.
f. Incorporate research elements (steps a. through d., above) into the Database for Energy Efficiency Resources (DEER) for use by energy efficiency program planners consistent with program planning protocols enunciated in CPUC Rulemaking 01-08-028, Decision 05-04-051.

2. Pilot Projects that Document and Quantify the State's Primary Water-Energy Interdependencies (longer-term):

    a. Select water utilities that collectively represent most of the primary types of water-energy interdependencies in California to include in the pilot. Several water utilities have already indicated interest in participating in such a pilot. These include the Metropolitan Water District (MWD), Inland Empire Utilities Agency (IEUA), the Los Angeles Department of Water and Power (LADWP), Palo Alto Utilities, and Sonoma County Water Agency.
    b. Conduct pilot projects to document the specific relationships.
    c. Inform and adjust proxy values developed above.

3. Seasonal Demand Shifting

    a. In Southern California, groundwater pumping uses approximately 30 percent of the energy required to import water from Northern

California. Groundwater aquifer source production and recharge requirements are fixed and finite. During periods of seasonal peak energy demand water agencies might rely on groundwater sources and recharge the aquifers using imported water months later in the off-peak season. In this manner ground water storage capacities could be used to encourage large-scale and long-term seasonal peak demand shifting.

b. Identify groundwater aquifers where groundwater pumping and recharge is being performed by water agencies.
c. Identify groundwater aquifers that are not currently being tapped for groundwater pumping.
d. Assess the operational feasibility and associated costs and benefits to encourage the seasonal demand shifting described above (item a.).

4. Conveyance-Related Peak Demand Reduction (State Water Project and other systems)

    a. Water agencies undertake projects to increase pumping and storage capacities based upon the given agency's operational cost-benefit perspective. Assess and report incremental cost-effective measures that can be implemented to increase pumping capacities and storage to reduce peak energy demands that are cost-effective, based upon a more comprehensive societal cost-benefit evaluation.
    b. Evaluate opportunities to reduce peak demand through the coordinated operation of federal and state water projects.

APPENDIX D: EXCERPT FROM CALIFORNIA WATER PLAN UPDATE 2005

VOLUME 1, STRATEGIC PLAN, CHAPTER 2, A FRAMEWORK FOR ACTION

Sustaining Our Water Resources

Fundamental Lessons

The Framework for Action embodies the following fundamental lessons, learned by California's water community through the experience of recent decades.

- The practice of water conservation and recycling in California has grown dramatically and must continue as a fundamental strategy for all regions and individual water users in California. The cumulative effect of each decision to use water more efficiently has an enormous impact on future water supplies and water quality.
- California must protect the quality of its water and use available supplies with great efficiency because water will always be a precious resource.
- Science and technology are providing new insights into threats to our watersheds, including our waterways and groundwater basins. California must use this knowledge to take protective actions and manage water in ways that protect and restore the environment.
- Sustainable development and water use foster a strong economy, protect public health and the environment, and enhance our quality of life. Sustainable development relies on the full consideration of social, economic, and environmental issues in policy- and decision-making. Sustainable water use assures that we develop and manage our water and related resources in a way that meets the needs of the present while protecting our environment and assuring the ability to meet the needs of the future.
- Solutions to California's water management issues are best planned and carried out on a regional basis. Hydrological, demographic, geopolitical, socioeconomic, and other differences among California's regions demand that the mix of water management strategies be suited to meet each region's needs for the long term.
- California needs additional groundwater and surface water storage capacity. Storage gives water managers tremendous flexibility to meet multiple needs and provide vital reserves in drier years.

Foundational Actions

To ensure that our water resource use is sustainable, water management at all levels – State, federal, regional, and local - must achieve these three foundational actions:

1. Use water efficiently.
2. Protect water quality.
3. Support environmental stewardship.

A number of resource management strategies that can be used to accomplish the foundational actions are listed in the following sections and described in more detail in Volume 2 Resource Management Strategies.

Use Water Efficiently

To minimize the impacts of water management on California's natural environment and ensure that our state continues to have the water supplies it needs, Californians must use water efficiently to get maximum utility from existing supplies. Californians are already leaders in water use efficiency measures such as conservation and recycling. Because competition for California's limited water resources is growing, we must continue these efforts and be innovative in our pursuit of efficiency. Water use efficiency will continue to be a primary way that we meet increased demand. In the future, we must broaden our definition of efficient water use to include other ways of getting the most utility out of our groundwater and surface water resources and water management systems:

- Increase levels of urban and agricultural water use efficiency.
- Increase recycled municipal water and expand its uses.
- Reoperate water facilities to improve their operation and efficiency.
- Facilitate environmentally, economically, and socially sound transfers.
- Reduce and eliminate groundwater overdraft.

As California's population grows from 36.5 million to a projected 48 million in 2030, there is bound to be an effect on California's environment. By wringing every bit of utility from every drop of water, Californians can stretch water supplies and help ensure continued economic and environmental health.

Protect Water Quality

California must also protect and improve water quality to safeguard public and environmental health and secure the state's water supplies for their intended uses. Water supply and water quality are inseparable in water management. While implementing projects to reduce water demand or to augment supply, water managers must employ methods and strategies that protect and improve water quality:

- Protect surface waters and aquifers from contamination.
- Explore new treatment technologies for drinking water and groundwater remediation.

- Match water quality to its intended uses.
- Improve management of urban and agricultural runoff.
- Improve watershed management.

Support Environmental Stewardship

To ensure sustainability, California must also manage water in ways that protect and restore the environment. Water is a vital natural resource for people and the environment, so water management activities must occur in the context of resource management and environmental protection. Water development in California has a rich history of conflict, at times pitting water supply projects against ecosystem protection. Water supplies and the environment must both be considered together. Water managers must support environmental stewardship as part of their management responsibilities. As managers develop and deliver reliable water supplies, environmental stewardship can be incorporated in many ways:

- Integrate ecosystem restoration with water planning and land use planning.
- Restore and maintain the structure and function of aquatic ecosystems.
- Minimize the alteration of ecosystems by water management actions.
- Improve watershed management.
- Protect public trust resources.
- Integrate flood management with water supply management.

Recommendations

California Water Plan Update 2005 provides recommendations for the next 25 years. These recommendations are directed at decision-makers throughout the state (referred to as California), the executive and legislative branches of State government, and DWR and other State agencies. (See Chapter 5 Implementation Plan for details.)

1. California needs to invest in reliable, high quality, sustainable, and affordable water conservation, efficient water management, and development of water supplies to protect public health, and to maintain and improve California's economy, environment, and standard of living.

2. State government must provide incentives and assist regional and local agencies and governments and private utilities to prepare integrated resource and drought contingency plans on a watershed basis; to diversify their regional resource management strategies; and to empower them to implement their plans.

3. State government must lead an effort with local agencies and governments to inventory, evaluate, and propose management strategies to remediate the causes and effects of contaminants on surface and groundwater quality.

4. California needs to rehabilitate and maintain its aging water infrastructure, especially drinking water and sewage treatment facilities, operated by State, federal, and local entities.

5. State government must continue to provide leadership for the CALFED Bay-Delta Program to ensure continued and balanced progress on greater water supply reliability, water quality, ecosystem restoration, and levee system integrity.

6. State government needs to take the lead in water planning and management activities that: (a) regions cannot accomplish on their own, (b) the State can do more efficiently, (c) involve interregional, interstate, or international issues, or (d) have broad public benefits.

7. California needs to define and articulate the respective roles, authorities, and responsibilities of State, federal, and local agencies and governments responsible for water.

8. California needs to develop broad and realistic funding strategies that define the role of public investments for water and other water-related resource needs over the next quarter century.

9. State government should invest in research and development to help local agencies and governments implement promising water technologies more cost effectively.

APPENDIX E: A WATER-ENERGY ROADMAP

Recommendations of the Water-Energy Relationship Working Group

Presently, water and energy utilities seek to separately optimize their respective resource portfolios. Since energy is typically their second largest cost,[109] water utilities already proactively seek opportunities to reduce energy consumption and increase energy production to reduce the net cost of their water supplies. However, the search for opportunities typically does not extend beyond their own systems and facilities. This is more a significant opportunity than a problem.

Stakeholder input for this staff paper indicates that the greatest potential for positively affecting the state's energy circumstance is beyond current best practices. Specifically, the primary opportunity is in the integrated value of water, energy, and externalities - like societal value - embedded in a unit of saved water. The incremental benefit of these integrated values can be realized by arranging the systems and operations of both the state's water and energy utilities around this holistic valuation approach.

For example, the state's single largest consumer of energy, the State Water Project (SWP), already strives to maximize off-peak and minimize on-peak pumping. However, if the goal were instead to minimize total and peak water-related energy consumption throughout the state, what options might be considered that would otherwise remain unconsidered? Below is a sample of the types of opportunities that could be possible if the planning perspective were broadened to include the optimization of water and energy resources statewide.

- Shift water pumping to off- and partial-peak time periods. Both DWR and the State Water Contractors (SWC) – 29 water agencies that purchase water from the SWP -- note that the SWP is designed to deliver water 24 hours a day, 365 days a year. Purchasers of SWP water need to take delivery when it comes down the aqueduct. Additional storage at strategic points along the aqueduct, whether owned by SWP or any of its customers, could increase operating flexibility and allow additional shifting of both SWP and SWC pumping loads to partial-and off-peak periods.[110]

- Shift water pumping to non-summer periods. Some water agencies in Southern California already rely heavily on groundwater pumping during the

[109] Salaries are usually first.
[110] Any increase in storage increases operational flexibility. This can be accomplished by oversizing aqueducts and canals, off-stream storage, and pipelines. SWP agricultural customers' systems are presently optimized for 24-hour deliveries. With proper incentives, it may be possible to modify these agricultural customers' systems to increase flexibility in SWP deliveries.

summer, and recharge their wells with imported SWP water during other times of the year. This groundwater production and recharge could be coordinated to create seasonal load-shifting.[111]

- Increase use of recycled water. While use of recycled water has nearly tripled since 1970, it still accounts for a very small percentage of the state's water supplies.[112] At a minimum, recycled water should be used wherever possible for landscape irrigation, though the high cost of dual distribution networks has been a major barrier.[113] When viewed from a societal perspective, significant investment in programs to reduce landscape irrigation is warranted on the basis of their energy benefits alone.

- Capture energy in water systems. Water utilities purchase significant amounts of energy to transport water though their systems. There are opportunities to recapture some of this energy through in-conduit turbines. The effect of this in-conduit hydropower production would be to decrease a water utility's net energy requirements. While opportunities exist to capture this energy, there are few incentives (and many disincentives) for development. Viewed on a holistic basis, the efficient utilization of energy within an existing pipeline or conduit would be viewed as an efficiency retrofit that qualifies for funding support by energy utilities.[114]

- Reduce energy for water pumping. Oversizing and/or lining pipelines can reduce friction and the amount of energy needed to transport water.

- Reduce energy for treatment. Both potable and wastewater systems could be reconfigured to incorporate storage, allowing treatment to be deferred to off-peak periods.

In addition to opportunities for reducing and shifting water utilities' energy consumption, stakeholders identified an important new opportunity – saving energy by saving water. When a unit of water is saved, so too is the energy required to convey, treat, deliver, and safely dispose of that unit of water.

In order to employ this value in designing cost-effective programs, this water ***energy intensity*** must take into account all of the steps in the water cycle. The energy

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[111] The state's highest electric demand is on hot summer days. If significant water activities could be shifted to other months, the state may need to build less generation and transmission capacity. In addition, electric reliability would be increased, and the adverse public health, safety, and economic impacts of rotating outages avoided.

[112] *California Water Plan Update* 2005, public review draft, April 2005.

[113] During summer months, as much as 50-70 percent of residential water use in Central and Southern California is for landscape irrigation.

[114] In-conduit hydropower does not presently qualify as an energy efficiency retrofit for purposes of energy utilities' programs. While in-conduit hydropower is RPS-eligible and could qualify for supplemental energy payments (SEPs), it would not be feasible to develop mini- and micro-hydro under the same rules as utility-scale generation.

intensity of cold-water energy savings is presently not considered in water or energy efficiency program planning. When a saved unit of water is valued from a societal cost perspective, significant energy-efficiency, embedded in water efficiency, is clear. The following example shows the electric energy resource value of just one water efficiency measure, BMP14[115]:

> An ultra-low-flow toilet saves 11,340 gallons of water per year and has a service life of 25 years. This results in potable cold-water energy savings of 91 kilowatt hours (kWh) per year, or 2,275 kWh over its useful life. The present value of electricity's avoided cost is $141. In 2004, water utility programs installed 1.8 million ultra-low-flow toilets in California residences, resulting in cold water savings of 60 million kWh per year, or 1.5 billion kWh over the program's life. The present avoided cost value through this single BMP is $119 million[116].

This simple analysis shows how energy can be saved by saving water. However, energy utilities are not currently authorized to invest in cold water savings. This raises some important questions:

- How much water or energy could be saved with existing technology, without basing their cost-effectiveness upon a single resource like the avoided cost of water or electricity, natural gas, or diesel?

- What incremental energy benefits would be realized if saved water were valued on a societal basis, and energy utilities were allowed to participate in programs that save energy by saving water?

Regarding a comprehensive statewide water and energy program:

- How can programs and incentives be structured to both encourage collaboration across utility systems and boundaries and allow energy utilities to share the costs of water conservation and efficiency programs (to access water savings not deemed cost-effective on a single utility resource cost test)?

The following table describes some actions that could facilitate a statewide shift toward integrating the water and energy resource planning and management needed to achieve incremental societal benefits.

[115] See discussion of water conservation and efficiency "best management practices" (BMPs) in Appendix C.
[116] See Appendix C for full discussion of this issue and information source references.

ENERGY OBJECTIVE	APPROACH	OPTIONS
Optimize the state's water and energy resources & assets on an integrated basis	Build policy framework & infrastructure	1. Identify synergistic benefits that make business sense to both water & energy stakeholders. 2. Revise both water & energy utilities' investment criteria to incorporate a societal perspective. 3. Adjust resource pricing methodologies to reflect total societal values. 4. Authorize energy utilities to invest in programs for cold water savings. 5. Structure funding & incentives to attain targeted responses. 6. Provide low-interest loans & grants for incremental water infrastructure that produce benefits to the electric grid. 7. Create a joint agency task force to establish protocols for sharing costs, benefits and responsibilities among multiple stakeholders subject to different jurisdictional rules and regulations. 8. Coordinate water and energy capital programs to maximize infrastructure investments for benefit of both resources.
Increase energy supplies	Support development of additional hydropower capacity	1. Resolve conflicts with FERC relicensing process. 2. Modify Renewable Portfolio Standards to include all new and increased hydropower capacity. 3. Provide access to Supplemental Energy Payments. 4. Establish incentives for re-powering for incremental pumped storage capacity.[117] 5. Allow in-conduit hydropower to qualify for funding as an energy recovery facility, qualified as an energy efficiency retrofit.
	Remove disincentives to energy self-sufficiency	1. Allow water utilities to wheel self-produced power to themselves, anywhere on their systems. 2. Streamline the interconnection process and reduce costs. 3. Remove net metering caps.
	Encourage production of excess power	1. Provide technical & funding support for development of renewable resources & distributed generation. 2. Encourage partnering between water & energy utilities in power development. 3. Establish long-term power purchase agreement for such excess production that exceeds bulk wholesale markets and

[117] Hetch Hetchy implemented system improvements that increased peak hydropower capacity by 48 MW at a capital cost of $8 million, 83 percent less than the cost of installing a new unit of comparable capacity.

ENERGY OBJECTIVE	APPROACH	OPTIONS
		assures payments that support project financing. 4. Provide a ready market for purchasing any over-production of power (e.g., require investor-owned utilities to include in their energy supply portfolios).
Increase energy efficiency and demand side management	Help water utilities develop & implement comprehensive energy management	Provide technical, funding & other support.
	Reduce peak energy consumption (seasonal & time-of-use)	Increase system & operating flexibility (e.g., increase capacity for pumping groundwater during summer, deferring water imports to fall and winter).
	Establish incentives for shifting seasonal use	Compensate water utilities for deferring water imports from summer to fall.[118]
Increase operating flexibility	Maximize ancillary services benefits of the state's hydropower resources	1. Increase pump storage capacity. 2. Use hydro to shape wind & other intermittent resources (e.g., solar).
	Increase storage	Support development of new and incremental storage wherever possible.[119]
Increase water conservation & efficiency	Increase investments that attain statewide energy benefits	1. Incorporate a societal perspective into water utilities' investment criteria. 2. Allow energy utilities to invest in water system improvements that attain benefits for energy ratepayers. 3 Create a Public Goods Charge equivalent for water utilities.

A Conceptual Road Map

Following is a conceptual road map for a five-year program structured to achieve the above objectives. The plan considers a three-phase approach:

Phase 1 – Policy Framework and Infrastructure
Phase 2 – Pilot Programs
Phase 3 – Implementation

The process of building the policy framework and infrastructure needed to support a major policy shift of this kind would begin in *Phase 1*. *Phase 2* would be triggered by adoption of interim policies and pilot programs by energy utilities, and their regulator(s), in recognition of the energy value of saved water. *Phase 3* would begin with adoption of permanent policies and programs by energy utilities and their regulator(s) that will invest in saving water to save energy.

[118] Incentives already exist to encourage shifting loads from on-peak to partial- and off-peak periods.
[119] Water remains the most effective means of storing energy.

The work in each phase is generally described below.

Phase 1 – Policy Framework and Infrastructure [8-12 months]

During the initial phase, three distinct activities would proceed concurrently:

- Task 1: Increase access to existing energy programs and resources by water and wastewater utilities.

- Task 2: Develop a policy roadmap for statewide integrated water and energy planning and management.

- Task 3: Conduct studies of California's water-energy relationships.

Activities included in each task could include, but are not limited to, the following:

Task 1: Increase access by water and wastewater utilities to existing energy programs and resources. Energy utilities already offer programs where water utilities can participate. These include traditional energy efficiency programs such as retrofits of lighting and HVAC and programs for increasing the efficiency of pumps and motors. In addition, the state's investor-owned utilities (IOU) offer energy-performance contracts (EPCs) that provide customized cash incentives for projects that demonstrate real energy savings.

The following tasks are designed to increase access to existing programs and resources, identify additional resources, and facilitate identification of opportunities for attaining incremental benefits through increased collaboration, and, potentially, the joint operation of multi-utilities' systems, resources, and assets.

1.1 Develop a clearinghouse of water-related energy information for water professionals and others concerned about energy and water use in California. The clearinghouse should include the leading references and studies that highlight energy best practices for water utilities; creative approaches to system design and operations that provide operating flexibility to moderate peak energy consumption; opportunities to become energy self-sufficient; and sources of technical, funding and other types of support.

1.2 Develop a pilot assistance program for water utilities to help individual water agencies integrate comprehensive energy planning and management into their activities.

1.2.1 Establish the baseline of current practices. Provide direct and active technical assistance for best practices for reducing energy consumption by water systems and processes. Encode these best practices into benchmarking tools and make them available to practitioners, enabling them to compare their current practices with what is possible. Develop a clearinghouse of information on a range

from current to best practices. Establish measurement and evaluation protocols to verify savings and share lessons learned.

1.2.2 Provide incentives for incremental and/or joint infrastructure improvements that reduce total and peak energy requirements for water transport and processing. These incremental facilities would likely include storage (reservoirs, groundwater wells, and oversized pipelines) that both increases system flexibility and facilitates time-of-use (TOU) and/or seasonal load shifting.

1.2.3 Identify long-term funding opportunities for both ongoing existing programs and for funding retrofits that exceed single utility resource cost-effectiveness tests.[120]

1.2.4 Assist in identifying opportunities for peak-load reductions and seasonal load shifting.

1.2.5 Provide technical and funding assistance in identifying and implementing self-generation opportunities, especially renewable resources and emerging technologies.

1.2.6 Facilitate opportunities for collaborating with local energy distribution companies on all aspects of energy management and energy self-sufficiency, including strategies to meet projected load growth.

Depending upon the results of the pilot, successful programs could be quickly ramped up to provide assistance to water agencies statewide.

Task 2: Develop a policy roadmap for statewide integrated water and energy planning and management. A policy shift of this magnitude requires thoughtful consideration of the barriers and hurdles that need to be overcome before successful implementation. A policy roadmap identifying key changes to laws and regulations that would help facilitate the shift would be very beneficial when embarking upon this effort. The types of activities within this task could include:

2.1 Establish a statewide multi-agency Water-Energy Task Force. This task force would provide consistent, long-term leadership, policy direction, and technical and resource support for a comprehensive statewide water-energy program. The Water-Energy Task Force would include staff from the Energy Commission, Department of Water Resources, California Public Utilities Commission, Air Resources Board, State Water Resources Control Board, and the California Department of Health Services.

The goal of the task force would be to achieve the benefits of *statewide integrated planning and management of the state's water and energy resources*. Specific tasks include the following:

[120] Long-term funding was identified as an important factor in gaining support from water utilities.

- Collaboratively build a knowledge base of water and energy interdependencies. Investigate beneficial statewide integrated water and energy planning and management practices and recommend policies, programs, and funding for successful programs.

- Expand the Water-Energy Relationship (WER) Working Group created through this process to include strong participation by all key stakeholder groups needed for successful implementation of the program. The WER Working Group will provide technical advice to the Water-Energy Task Force.

- Designate a Water-Energy Liaison at the Energy Commission. This person or group would be responsible for coordinating policy, research, and programmatic efforts within the Energy Commission and act as liaison to the Water-Energy Task Force, other state agencies, local jurisdictions, and water, wastewater, and energy utilities. Similar people or groups should be identified at other agencies on the Task Force.

- Collaborate with other parties and entities with compatible goals. These include DWR's Office of Water Use Efficiency, the Recycling Task Force, and the Desalination Task Force.

- Develop a roadmap that establishes goals for increasing water efficiency and demand-side management. Among other things, the roadmap should prioritize investments in programs and measures that have the highest resource value and impact. In recognizing that every unit of water saved allows displacement of higher-energy intensity water supplies, high priority should be assigned to reductions in agricultural water use and urban landscape irrigation, both residential and commercial.

- Charge the Water-Energy Task Force with monitoring technology changes that affect the energy intensity of the water cycle, and identify potentially feasible and cost-effective applications.[121] A mechanism should be established to continually identify and incorporate new technologies wherever beneficial and feasible.

2.2 *Build the policy framework and infrastructure.* The concept that there are statewide benefits from "saving water to save energy" needs to be emphasized and regularly underscored*. Energy Report* findings and recommendations should be presented to the CPUC, water and energy utilities, key water and energy

[121] For example, new tunneling equipment and techniques may one day make it possible to drill through mountains instead of transporting water over mountains, significantly reducing energy used for water pumping. In addition, improvements in desalination and other water supply development techniques may become more cost-effective than transporting water from Northern California to Southern California. Further, technologies such as cloud seeding may become more successful in producing local supplies that could reduce Southern California's need for water imports.

policymakers, and other key stakeholders. The bases for computing potential benefits needs to be widely and clearly understood.

Policies, procedures, business processes, analytical methods, investment criteria, and decision making tools all need to be adjusted to support a policy and planning shift of this magnitude. To support this shift, the importance of the state's water-energy relationship needs to be better understood. Preliminary studies show the complexities of the water supply balance and cycle, and geographic, source, end user and other diversities – all of which must be documented, quantified, and modeled to assure that programs and strategies achieve their intended results. Thereafter, policies, rules, regulations, protocols, methodologies, programs, and funding need to be brought into alignment.

- Establish a valuation methodology for the societal value of water. We are just beginning to understand the water-energy relationship. Preliminary studies of the water supply-use-disposal cycle and overall water supply balance show distinctly different energy intensities of water in various regions of the state, depending upon climate, topography, and water storage/recovery/delivery options and methods. In addition, different uses have different energy intensities. A valuation methodology is needed to capture these diversities in a manner that will help planners prioritize their investments.[122]

- Leverage developmental work already in progress by others, including the U.S. Department of Energy National Laboratories' Water-Energy Nexus Program, Pacific Institute, California Urban Water Conservation Council, and the Irrigation Training and Research Center. Collaborate with these (and other) entities, to:

    - Inventory, characterize, and measure California's types of water and energy interdependencies.

    - Develop pilot programs to test tools and methodologies for evaluating tradeoffs among these interdependencies.

    - Develop analytical models for policymakers, regulators, utilities, and other key stakeholders in developing cost effective joint water and energy programs.

- Facilitate joint investment to attain societal benefits. As opportunities are identified that could produce incremental energy benefits but are not deemed

[122] For example, while it may be possible to increase total groundwater capacity in Southern California, unique geological characteristics create uncertainties as to both ultimate capacity (groundwater doesn't behave predictably) and impacts on production capacity of other wells in the vicinity. Similarly, displacing SWP imports with increased seawater desalination in Southern California may not produce a net benefit; nor would over-pumping of groundwater supplies and reducing drought reserves be desirable. All of the interdependencies – water to energy, energy to water, and water to water -- need to be evaluated to determine how best to attain positive net benefits.

cost-effective on a single utility resource cost test, mechanisms are needed that facilitate joint investment to attain those incremental benefits.

- Incorporate a societal valuation approach in both water and energy utilities' resource pricing methodologies, water and energy efficiency program portfolios, and investment criteria.

- To facilitate early results, establish a proxy for the societal value while a detailed methodology is developed.

- Establish a water resource loading order that incorporates the societal value of an avoided unit of water consumption and that mirrors the preferred energy resource loading order in the Joint Agency Energy Action Plan for energy.[123]

- Establish a public goods charge equivalent for public purpose water conservation and efficiency programs.

- Provide incentives for water, wastewater, and energy utilities to optimize their joint resources beyond traditional discrete single utility service boundaries (water or energy).[124]

- Require the state's energy and water planners to collaborate on plans and strategies to reduce net water sector energy consumption and to meet projected energy load growth.

2.3 Identify changes to existing laws and regulations. Examples of some proposed changes are provided in the table of potential actions on pp. 4-5.

2.4 Request that DWR provide input to the IEPR with respect to projected energy load growth in the water sector and potential energy impacts of drought risk mitigation measures. Similarly, request Energy Commission's participation in DWR's Water Plan Update process to provide assumptions as to energy supply availability and price forecasts.[125] Energy Commission and DWR should also synchronize planning assumptions for dry, wet and average hydrology years, as well as

[123] The California Water Plan Update 2005 already identifies a prioritized resource strategy. In order to attain results that optimize the state's water and energy resources on a joint basis, societal values should also be considered in the resource loading order. For example, least-cost water supply options at low electricity prices (e.g., desalination and water transfers) may become expensive when electricity prices are high. Since high electricity prices typically coincide with electricity supply shortages, water resource planning that does not consider energy impacts during times of shortage can create electric reliability risks that affect all California ratepayers. Integrated planning of water and energy resources provides the policy perspective needed to develop contingency plans and strategies for mitigating these types of risks.

[124] For example, the SWP could work with the water agencies that take water from the aqueduct to identify incremental infrastructure and changes to operations that can shift more water pumping to off-peak periods and/or non-summer months.

[125] This could result in a water supply equivalent of the state Energy Action Plan's resource load order.

assumptions as to the duration and magnitude of a multi-year drought for contingency planning purposes.

2.5 Expand the 14 water conservation best management practices (BMPs) to include new measures that meet the broader goals of statewide integrated water and energy planning and management.[126] Prioritize investments in BMPs in accordance with cost-effectiveness from a societal perspective.

2.6 Resurrect long-term purchase commitments (e.g., "standard offer contracts") that provide a ready market for excess power produced by water agencies after meeting all of their own energy requirements. One option might be to merely include such default purchase mechanisms in investor-owned utilities' procurement baselines.

2.7 Increase collaboration among state agencies to assure a consistent policy perspective. Unintended consequences result when multiple regulators seek to discharge their separate responsibilities in absence of a consistent policy framework. For example, while the state is encouraging increased energy production, the Department of Fish and Game restricted operational flows at Silverwood, a man-made reservoir, to protect non-native fish. The WER Working Group identified a need for consistent policy in which state agencies collaborate regularly to assure that energy, water and environmental benefits are continually balanced.

Task 3: Conduct studies of California's water-energy relationships. There is a near-term opportunity to access California ratepayer funds to support the policy shift to statewide integrated water and energy planning and management. Specifically, the state's investor-owned utilities are challenged to attain the targeted energy efficiency goals established by the CPUC for the 2006-2008 round of ratepayer investments. The opportunity to save water to save energy has significant promise to deliver, and potentially to exceed, system benefits targeted by the CPUC. In fact, water-energy programs may well represent the most promising opportunity for "second generation" energy efficiency measures.

The purpose of this task is to establish the foundation for an interim water-energy program that will demonstrate the expected benefits of statewide integrated water and energy resource management, prior to establishing permanent programs. The following work will need to be accomplished to support design of one or more interim programs.

3.1 Establish an interim methodology and proxy for the societal value of a unit of water saved. Design of cost effective programs requires computation of the societal value of a saved unit of water. The computation needs to be performed over the

[126] See Appendix C for a discussion about water conservation BMPs.

entire water use cycle (i.e., the total costs of water, externalities and energy incurred during the entire life of a unit of water[127]).

Ultimately, a comprehensive methodology is needed that recognizes the diversity of water supplies, treatment processes, types of end use, and other factors. The number and complexity of variables will need to be analyzed to determine which are most significant in computing the societal value. In the meantime, a proxy can be employed to allow interim water-energy programs to go forward while detailed studies of the water-energy relationship continue in parallel. There is precedent at the CPUC for utilizing proxies while formal methodologies are being debated and refined.[128]

[Note: The "triple bottom line" concept captures the full spectrum of economic and societal values that today's organizations must address. In developing the proxy, it may be desirable to consider aligning the components of the societal value of water with this evolving concept that is gaining increased acceptance.]

3.2 Inventory needs. Prior to designing the studies, a needs assessment should be conducted to inventory the spectrum of primary water-energy relationships in California, and the current body of data, models, tools, policies, programs, practices, funding, legislation and regulations. Water-related energy consumption will be benchmarked by type of water system, function, and end use. Water-related energy consumption will then be mapped from source through various categories of end use to develop a comprehensive understanding of the points and relative magnitudes of energy consumption along the supply chain, and the types of systems, processes, equipment and measures that could reduce energy consumption at these points.

3.3 Conduct detailed studies. The final task under Phase 1 is to conduct detailed studies of California's water-energy interdependencies and to integrate these data into analytical models and tools that can help both water and energy utilities develop cost-effective joint water-energy programs. The scope of these studies will include establishing baseline water use by all sectors and then linking this to the energy baseline. In addition, technologies will be researched for their water and energy savings potential, and the associated environmental benefits.

Studies will proceed in parallel with commencement of Phase 2 – Pilot Programs. The Pilot Programs will employ a proxy until more detailed data and methods become available to support adoption of a formal methodology for valuing the energy and societal value of an avoided unit of water. The types of studies needed are described more fully at the end of this appendix.

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[127] Water collection, transmission, treatment, distribution, wastewater treatment, and ultimate disposal or recycling.

[128] In recent years, for example, proxies were established and relied upon by the CPUC for both the market price referent and avoided costs of energy.

Phase 2 – Pilot Programs [12-24 months]

During Phase 2, a proxy will be adopted and applied to develop pilot water-energy programs in which the projected incremental benefits of joint water and energy planning and management can be verified. Concurrently, Phase 1 studies to perfect the data, methods, and tools needed to establish a reliable methodology for supporting development of cost effective programs on an ongoing basis will continue in parallel.

Several water-energy pilot programs are recommended:

- A pilot for investor-owned and municipal utilities that targets specific types of water use reduction to demonstrate and measure the expected economic and reliability benefits to energy ratepayers and the California electric grid. The pilot would employ a proxy for the societal value of each type of water use reduction based on a preliminary methodology, pending completion of further studies and analyses. The scope of such a pilot could include:

    - Direct co-investment by energy utilities in water conservation and efficiency programs with high potential for energy savings. (The Pacific Institute, in its November 2003 study "Waste Not, Want Not: The Potential for Urban Water Conservation in California", estimated a remaining annual potential for cost effective urban water conservation as high as 2 million acre feet (651.7 billion gallons). Assuming a conservative estimate of 5,000 kWhrs/mg[129], this quantity of saved water could reduce energy consumption by 3,258 Gwh per year. This is about 1.8% of the state's total energy consumption.)

[129] Refer Appendix C, Energy Impact Analysis of Existing Water Management Practices. For the sole purpose of illustrating the potential magnitude of impacts, we have assumed a statewide average value of 5,000 kWhrs/mg.

California Urban Water Use in 2000
and the Potential to Improve Efficiency and Conservation

California Urban Water Use by Sector	Current (2000) Water Use (AF/year)	Best Estimate of Conservation (AF/year)	Potential to Reduce Use (%)	Minimum Cost-Effective Conservation (AF/year)
Residential Indoor	2,300,000	893,000	39	893,000
Residential Outdoor	983,000 to 1,900,000 (b)	360,000 to 580,000 (c)	25 to 40	470,000
Commercial/ Institutional	1,850,000	714,000	39	Combined CII: 658,000
Industrial	665,000	260,000	39	(e)
Unaccounted-for Water	695,000	(d)	(d)	(d)
Total	**6,960,000** (+/- 10%)	2,337,000	34	2,020,000

Source: "Waste Not, Want Not: The Potential for Urban Water Conservation in California", The Pacific Institute, November 2003.

- Subsidized investments in incremental water infrastructure that are expected to attain significant energy benefits (e.g., increasing capacity of, or adding new reservoirs, pipelines, and groundwater wells).

- A pilot that investigates the potential incremental benefits attainable by optimizing joint water and energy resource management of the state's largest water utilities on a combined basis. For example, the pilot could investigate incremental water and/or energy infrastructure (water storage, delivery, power production, etc.) that could increase the operating flexibility of combined large water systems (SWP, SWC, CVP and/or the Colorado River System, as well as other large water systems that are now or could become interconnected).

<u>Phase 3 – Implementation</u>
Phase 3 will be defined by completion of most of the detailed studies of the state's water-energy interdependencies, and of the analytical models and tools that employ these data to design cost effective joint water-energy efficiency programs. During Phase 3, proxies for the societal value of saved water will be replaced with permanent methodologies, and long-lived (5-10 years) water-energy programs will be established and funded.

Implementation Challenges

While some opportunities could be accessed now for early results, there are some challenges to implementation of joint investments that attain the incremental energy resource and reliability benefits of fully integrated water and energy resource planning and management.

1. Water and energy utilities are regulated, operated and managed separately. Short of a few programs in which end users can earn energy incentives for reducing consumption of hot water, there presently is little incentive for water, wastewater, and energy utilities to even coordinate their resource planning activities and much less to share investments in programs and infrastructure.

2. Program goals and incentives will need to be aligned. Societal values are derived from reducing or avoiding the buildup of costs along the water cycle. In this case, water and wastewater utilities and their ratepayers will need to make the investments that attain energy resource and reliability values that benefit other ratepayers and the state overall. This presents challenges with respect to equitable sharing of joint program costs. For example:

    - Increasing use of recycled water in Southern California to reduce high-energy water imports from Northern California may well provide a benefit to all water and energy ratepayers.[130] However, the incremental investment in recycled water distribution facilities needs to be made by a local government or wastewater utility that must then seek recovery of its investment. If the costs of such incremental facilities are allocated only to users of that recycled water, the cost of recycled water may far exceed the cost of potable water.

    - During summer months, as much as 50 to 70 percent of residential water use in central and Southern California is for landscape irrigation. When viewed from a societal perspective, significant investments in programs to reduce landscape irrigation are warranted on the basis of the energy benefits alone. However, water utilities' investments are limited to those that benefit their own ratepayers (i.e., not on the basis of benefits that may accrue to the entire water supply chain or to other stakeholders). Further, there presently is no mechanism that allows energy utilities to invest in programs that reduce water use to save energy.

Allocating incentives to the stakeholder(s) who need to make the investment on behalf of all California ratepayers, both water and energy, is not a trivial task.

[130] Water ratepayers benefit by avoiding investments in higher cost water supplies and increasing water supply reliability. Energy ratepayers benefit from associated reductions in energy procurement, as well as by avoiding investments in additional electric infrastructure and by increased electric system reliability.

Additional Needs for Research and Assistance

Integrating water and energy resource management will require additional knowledge in a number of key areas to develop the analytical methods, tools, and data needed to develop and implement cost effective water-energy projects and programs.

Building on Present Knowledge

Considerable work is already being performed in this area. Some current efforts are described in Appendix A.

Additional information is needed to facilitate a statewide policy shift to comprehensive planning and management of the state's water and energy resources. In particular, more accurate information about the nature and magnitude of the state's water and energy relationships -- including the spectrum of opportunities for realizing the synergies of integrated water and energy resource management, the amount of needed investments, and the relative costs vs. benefits of each type of measure – is needed to prioritize investments and develop methods, models, and tools that support cost-effective program design.

The following ***conceptual*** research and development plan describes the primary research activities needed to support the program objectives identified in the table in the first section of this appendix. The plan is structured to allow near- and long-term initiatives to proceed in parallel to provide opportunities for early benefits.

CONCEPTUAL Research and Development Plan

R+D Program Objectives	Near-Term Strategies	Long-Term Strategies
1. Proactively manage water-related energy consumption	Synchronize the state's water & energy planning assumptions and strategies to meet projected energy load growth	Develop comprehensive programs for technical & resource assistance that attain water utilities' energy management best practices
2. Increase understanding of the state's water-energy relationship	Demonstrate primary water-energy interdependencies; develop prototypical values by Forecasting Climate Zones	Inventory, document & quantify the state's primary water-energy interdependencies for input to detailed models & tools
3. Implement statewide integrated water and energy resource management	Develop proxy for interim societal valuation methodology for cold water savings for discussion with CPUC[131], policymakers, other interested stakeholders	Develop data, analytical tools and methodology for computing the societal value of saved water for different water sources, end uses, climate zones, etc. for valuation of societal costs in long-term cold water savings programs
4. Increase water utilities' energy self-sufficiency	Investigate potential for revising existing programs, policies, methods & practices to reduce water utilities' net energy consumption ('net' of power production)	Develop studies, methods, tools & techniques to assist water utilities in becoming energy self-sufficient, and potentially becoming net exporters of power
5. Increase water efficiency and demand-side management	Develop preliminary valuation of existing cold-water efficiency measures	Identify & evaluate new cold-water measures; develop cost-effective programs

Primary research and assistance needs identified to-date are described in more detail below by program objective.

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Objective 1: Proactively manage water-related energy consumption.

1. Establish baseline of current practices. Research "best practices" for reducing energy consumption by water systems and processes. Encode "best practices" into benchmarking tools and make them available to practitioners, enabling them to compare their current practices to what is possible. Populate the "Clearinghouse" with information on the range from current to best practices. Establish measurement and evaluation protocols to verify savings and provide lessons learned.

2. Conduct an assessment of the penetration and adoption of "best energy practices" by water and wastewater utilities, and barriers and hurdles that prevent or restrict adoption, to support development of targeted assistance programs that incorporate workarounds to identified barriers and hurdles.

3. Track and evaluate energy use by function to enable development of targeted measures and retrofits with high benefit potential. For example, a better

[131] CPUC could adopt a proxy for the societal value of cold water savings that would allow pilot programs to go forward in the 2006-2008 energy efficiency funding cycle.

understanding is needed as to how recycled water fits into the water supply portfolio and water balance. While increasingly stringent federal discharge rules are pressing water utilities to upgrade secondary treatment to higher energy intensive tertiary treatment, incremental energy consumption attributable to the higher level of treatment should be offset (at least in part) by using recycled water to displace higher energy intensity water supplies.

4. Continue to monitor and plan for projected changes in energy usage by water systems and treatment processes. Continue to study the projected energy requirements of changed federal water treatment and discharge regulations as these evolve, and develop approaches to help energy and water utilities manage the energy impacts of these changes.

5. Continue to identify and evaluate opportunities to reduce energy consumption in targeted high-use sectors, such as agriculture. Work with interested stakeholders to identify and evaluate opportunities to reduce energy use by the agricultural sector and to conduct various studies. Potential projects might, for example, include tracking energy-use trends associated with changes in crop-planting and harvesting patterns; evaluating impacts of pressurized irrigation systems (drip and spray) on fields now irrigated by gravity; and converting diesel-engine pumps to motor-driven pumps.

6. Evaluate the potential energy impacts of increased water transfer transactions. Little is known about whether changes in conveyance patterns will have a noticeable impact on water-related energy consumption. The Energy Commission could work with water utilities involved in contracting for or providing conveyance services, to first determine the likely extent of such transactions, and make a rough estimate of the magnitude of change in electricity use patterns. If warranted, staff could recommend further study of methods to track such transactions, and determine and prepare for their expected energy impact.

7. Continue studies with AwwaRF and others to reduce energy consumption by desalination technologies, and to coordinate water and energy planning for dry years. Though the WER Staff Paper identified only fairly modest impacts on the electric system from known planned desalination plant development, the number of planned facilities could increase quickly if one or both of two things occur: an extended drought or other scenario that significantly curtails surface water deliveries, and/or a significant decrease in the cost of operating such facilities.

8. Develop a comprehensive program to study groundwater-related energy use. Groundwater is a particularly significant area of study, since use of groundwater storage has potentially significant impacts, both positive and negative, on water-related energy consumption. On one hand, increased groundwater storage provides significant operating flexibility that could allow

more SWP water deliveries to be shifted from summer to fall. On the other hand, over-pumping groundwater basins could increase energy consumption at undesirable times and also reduce critical drought supplies.

Less is known about groundwater than any other water source. This is due to the fact that each groundwater basin is unique, and production characteristics of wells are often interlinked. Further, since use of groundwater is largely unregulated, the actual quantity of energy used for groundwater pumping statewide is undeterminable. The complexities of groundwater warrants a comprehensive monitoring approach that tracks groundwater levels, pump production, electricity use, and other data over multiple years.[132]

9. Assist water utilities in developing less energy intensive water supplies. For example, increased reliance on recycled water to displace need for desalted water.

10. Continue to build on PIER/AwwaRF's Water and Wastewater Technology Roadmap.

Objective 2: Increase understanding of the state's water-energy relationship.

1. Conduct pilots and studies that document and quantify the state's primary water-energy interdependencies. The information being developed by UCSB and Pacific Institute will help develop a proxy that can be relied upon to develop pilot water-energy programs while more detailed studies are being conducted. In particular, while studies of urban water uses indicate significant energy can be saved by reducing water consumption, the drivers for such opportunities are not well understood. A comprehensive inventory, characterization, and assessment of the primary types of water-related energy consumption by type of water

[132] The Irrigation Training and Research Center (ITRC) study on agricultural energy requirements perhaps goes farther than any other, and bases much of its information on real-world geographical information system (GIS) data; but it must make many assumptions concerning average pump lift (groundwater levels), distribution uniformity, surface water availability (timing factor), irrigation type, average drawdown, discharge pressure, and so forth. It uses the real-world results of the pump efficiency tests conducted for the Agricultural Peak Load Reduction Program by the Center for Irrigation Technology, but those data did not include static or pumping water levels and primarily covered only wells in PG&E's territory.

Considerable additional study is needed in order to facilitate detailed modeling of groundwater supplies. The ITRC study also is the result of at least two levels of computer modeling: that by Department of Water Resources to estimate groundwater levels in Northern California and ITRC's own crop water model, which produced the energy use estimates in its groundbreaking study. Much of ITRC's results are based on what can only be described as rough calculated estimates by DWR for Central and Southern California groundwater volumes, which is especially critical in the Kings and Kern River Basins, where more than 50 percent of the energy used for agriculture-related groundwater pumping occurs. (A detailed discussion of ITRC's model can be found in their report No. 02-001, available on their Web site at www.itrc.org)

source, system, function, and end use will eventually be needed to develop the detailed methodologies on which cost-effective programs can be based.

Water-related energy consumption can then be mapped from the source through various categories of end use to develop a comprehensive understanding of the points and relative magnitudes of energy consumption along the water supply chain, and the types of systems, processes, equipment, and measures that could reduce water and energy consumption at these points. Ideally, a sampling of water utilities that collectively represent most of the primary types of water-energy interdependencies in California would be included in such a pilot. Several water utilities have already indicated interest in participating in such a pilot. These include MWD, IEUA, LADWP, Palo Alto Utilities, Sonoma County Water Agency, and Semitropic Water District.

2. Construct a valuation methodology that accounts for the societal cost (water, energy and externalities) of avoided water consumption for various types of water sources and end uses. Relying upon the data and knowledge gained from detailed studies, quantify the water-energy tradeoffs of various resource decisions through computation of the "Regional Cold-Water Energy Intensity".

    - Research and develop regional cold-water energy intensities (or co-opt existing research), adopt prototypical values, and establish linkage to Forecasting Climate Zones;

    - For existing "cold-water measures" develop base case Unit Energy Consumption (UEC), High-Efficiency (HE) UEC, Base and HE Peak watt and demand savings, volume-sensitive installed measure costs and expected useful life values;

    - Identify and evaluate new cold-water measures targeted to create resource value specifically suited to integrated water/energy resource planning not previously addressed under the discrete/isolated water/energy resource management regime;

    - For new cold-water measures deemed viable, develop planning data identified for existing cold-water measures, and;

    - Incorporate research elements into the Database for Energy Efficiency Resources (DEER) for use by energy-efficiency program planners consistent with program planning protocols enunciated in CPUC Rulemaking 01-08-028, Decision 05-04-051.

The above described methodology is consistent with that employed by the CPUC in its regulation of investor-owned utilities' energy efficiency programs, thus allowing proposed investments in water saving measures to be considered on an equivalent basis.

Objective 3: Implement statewide integrated water and energy resource management.

1. Develop tools and techniques for identifying potential infrastructure upgrades that extend beyond a single utility's service boundaries. The goal of implementing statewide integrated water and energy resource planning and management opens up new opportunities that heretofore have not been considered. Specifically, water and energy utilities presently attempt to optimize their separate resources and systems. Many of these utilities have calibrated their models and tools to simulate their own systems' operations. New analytical models, tools, and methods will be needed to help water and energy utilities look beyond their system boundaries, looking for opportunities to optimize their systems and resources on a joint basis with other water and energy utilities with which they may now be interconnected (or potentially could be interconnected). The underlying premise of joint optimization is that it is at this level of fully integrated planning – i.e., the "nexus" – that the most beneficial incremental benefits will be found.

   Potential opportunities include optimizing the systems and operations of the SWP and the 29 member agencies that comprise its sole customer, the SWC, as well as the CVP, the Colorado River system, and any other points of interconnection along the way.

2. Develop analytical models and tools that:

   - Assist both water and energy utilities in developing joint programs that are cost-effective from a societal point of view;

   - Assist wholesale water utilities in evaluating the net benefits of system reconfigurations or retrofits that exceed their own boundaries[133];

   - Assist both water and energy utilities in assessing the net water supply and associated energy and externalities benefits of proposed measures and retrofits (e.g., assessing the net impact on the water supply balance);l

   - Other analytical models and tools needed to support development and implementation of cost-effective joint water-energy programs.

[133] These may include those that assist the State Water Project operator in making determinations as to how to optimize energy consumption for itself and its customer, the SWC, (and potentially other interconnected systems such as CVP and the Colorado River system) on a combined basis.

Objective 4: Increase water utilities' energy self-sufficiency.

Reduce Energy Consumption:

1. Identify opportunities to reduce conveyance-related peak demand reduction (State Water Project and other large water systems). The State Water Contractors and DWR observed that it might be possible to increase off-peak pumping at Edmonston Pumping Station; however, additional pumping capacity would be needed. In addition, they noted that while there may be opportunities to further increase operational flexibility, additional storage would be needed at points along the aqueduct.[134] In order to assess the statewide opportunity to support such incremental capital expenditures that may be beneficial to the state overall, but are not deemed cost-effective from the perspective of a single entity, the Energy Commission could:

    - Assess and report incremental cost-effective measures that can be implemented to increase pumping capacities and storage to reduce peak energy demands that are cost effective based upon a more comprehensive societal cost-benefit evaluation.

    - Evaluate opportunities to reduce peak demands through coordinated operation of federal and state water projects.

2. Assist water utilities in identifying methods to increase operational flexibility such that energy intensive pumping and water treatment processes could be shifted from on-peak periods, to partial- and off-peak periods.

    - According to ACWA, installation of sensors and other equipment could substantially increase water utilities' flexibility in operating their systems. This flexibility could allow water utilities to maintain minimal pumping loads during peak periods, either by delaying such use into the evening hours or at least by cycling such loads sequentially to minimize peak use.

[134] Reservoirs, depending on location and size, including intake and discharge capacities, provide opportunities for pumping load and generation time-shifting -- hourly/daily shifts for small reservoirs, and sometimes monthly/seasonal shifts for larger reservoirs. For large river reservoirs, like Lake Mead, a downstream re-regulation reservoir such as Lake Mojave could support optimum water deliveries and peak generation. However, Lakes Mead and Mojave increase evaporative losses and incur greater costs and environmental concerns.

Urban hillside tank storage reservoirs that provide system pressure for urban retail water users can be oversized to emphasize off-peak pumping to fill the reservoirs if the pumping capacity in the supply system (say, groundwater wells) is simultaneously increased to produce needed water yield in the less-than-24-hours window. (Note: the pumps can wear out sooner and incur increased operations and maintenance costs if the frequency stop/starts increase to match daily Flex-Your-Power objectives.)

- IEUA has designed its systems to allow water to be “detained” during critical peak periods and held for processing during partial- and off-peak periods.

3. Explore increased use of groundwater storage to allow shifting of summer SWP deliveries to fall. In Southern California, groundwater pumping uses approximately 30 percent of the energy required to import water from Northern California. Groundwater aquifer source production and recharge requirements are fixed and finite. During periods of seasonal peak energy demand, water agencies might rely on groundwater sources and recharge the aquifers using imported water months later in the off-peak season. As noted previously, some Southern California water utilities already choose to pump groundwater during summer and recharge groundwater wells during fall. In this manner groundwater storage capacities could be employed to affect large-scale and long-term seasonal peak demand shifting.

   The potential of increasing groundwater storage capacity to further defer seasonal deliveries should be studied. These studies are complicated, due to unique hydrogeology of groundwater basins and potential linkages among wells. The scope would include:

   - Identification of groundwater aquifers where groundwater pumping and recharge is being performed by water utilities;

   - Identification of groundwater aquifers that are not currently being tapped for groundwater pumping that could be used to affect the aforementioned, and;

   - Assessment of the operational feasibility and associated costs and benefits of potential incremental seasonal demand shifting.

   Analytical tools and techniques will be needed to help determine the efficacy and relative costs vs. benefits of this approach. The study should include consideration of who should develop, fund, own, and operate such assets, which potentially may be constructed primarily for energy benefits (i.e., the value of shifting summer demand to other months).

Increase Power Production:

1. Conduct studies of potential for incremental power production through in-conduit hydropower, pumped storage, and repowering. In-conduit hydropower is a very attractive option since it produces energy as a by-product of water operations. Pumped storage has unique capabilities to produce power during peak periods. The Hetchy Hetchy example illustrated a potential for increasing the state’s hydropower capacity by as much as 10 percent at a fraction of the cost of installing new units and much more quickly.

There are multiple barriers to water utilities' energy self-sufficiency. The statewide potential for increased hydropower and pumped storage capacity should be assessed, and a roadmap developed for attaining this potential that includes potential work-arounds to the policy, regulatory, economic, technical, and other barriers that will need to be overcome.

2. Develop mitigation strategies to reduce lost hydropower capacity during FERC relicensing. As discussed previously, the National Hydropower Association reported that an average of 8 percent of the nation's total hydropower capacity is being lost through relicensing. The Energy Commission could evaluate causes and identify potential mitigation strategies that consider the societal value of associated hydropower capacity.

3. Develop models and tools to evaluate the energy water tradeoff for reservoir storage. Detailed modeling studies of reservoir operations should be performed to evaluate the additional hydropower generated by changing average year reservoir releases. Similarly, conduct studies detailing the decrease in groundwater pump electricity demand associated with a change in average and dry-year reservoir releases.

4. Develop analytical models and tools that assist both water and energy utilities in assessing power production potential by water utilities including, but not limited to:

    - Self-generation utilizing local renewable resources (digester gas[135], agricultural wastes and other biomass, solar,[136] and hydropower).

    - Renewable resource potential for utility scale generation facilities on watershed lands and rights-of-way.[137]

5. Conduct demonstration projects that allow testing of workarounds to barriers and hurdles and verification of net energy and other benefits of water projects that produce energy. In particular, demonstrate means for water utilities to produce energy as a by-product of water delivery and treatment processes (e.g., in-line conduit applications for water and wastewater utilities), and extrapolate statewide potential for these types of opportunities.

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[135] Biogas potential need not be restricted to that produced by sewage digesters. Studies are underway to test the energy potential of blending sewage sludge with other biosolids, such as dairy animal waste and food refuse. In addition to increasing power production, this process provides an attractive means for disposing of other types of waste products. In addition, some parties are investigating development of a sludge-derived solid fuel that could be burned in power plants.

[136] Solar power is well suited to meeting small pumping loads in water distribution systems.

[137] Water utilities' extensive watershed land holdings could provide good opportunities for utility-scale wind and concentrating solar power development.

6. Conduct a comprehensive resource assessment of the renewable resource potential of watershed lands and rights-of-way and determine the barriers and hurdles that would need to be overcome.

Objective 5: Increase water efficiency and demand-side management.

1. Develop a pilot program that evaluates societal benefits of water conservation and efficiency programs presently deemed non-cost-effective under traditional water utility planning criteria. Potential items include: new balanced irrigation systems, weather based-irrigation systems, drought tolerant plant/low runoff landscape retrofits, synthetic turf retrofits, free water brooms for every school, connectionless water steamers, digital x-ray machines or x-ray water recirculation systems for doctors and hospitals, free cooling tower conductivity controllers for all public schools and buildings (may be commercial uses too), small scale water recycling projects for communities and golf courses, incentives for new home owners to buy water/energy efficient new homes, large-scale irrigation controllers and landscape retrofits for parks and greenbelts, water softeners[138], etc.

2. Expand the 14 BMPs to include other water conservation measures that meet the more comprehensive "societal" resource test. Building on the important work by CUWCC and its members, Pacific Institute, and other key stakeholders, identify and value incremental measures that can help meet the goals for a comprehensive statewide water-energy program. These measures should then be ranked alongside other feasible water and energy efficiency options on the basis of highest benefit:cost ratio, and then incorporated into joint water-energy programs.

3. Continually improve agricultural water use efficiency.
   - Continue to implement the PIER Agricultural Irrigation Technology Roadmap calling for research and development efforts improve irrigation efficiency. Possible studies include:

     - Reduce the total pressure required to operate drip irrigation technologies; this includes the filter system as well as the pipe and micro-sprayer technologies.

     - Advance the use of longer lasting materials for pump components.

     - Work with the SWP, the CVP and the irrigation districts to increase the flexibility of water deliveries to farms.

[138] One California water agency performed an analysis of retrofits of water softeners. The program did not meet the cost-effectiveness threshold on water alone, but the societal benefits are potentially large.

- Learn more about the increasing trend to adopt drip/micro systems, the implications to energy consumption, and the energy management benefits the systems provide.

- Work with irrigation districts to understand the ramifications increased reliance on groundwater.

- Work with the CPUC to ensure appropriate implementation of Critical Peak Pricing and other TOU rates.

- Work with the CPUC, the utilities, the irrigation districts, and the farmers to ensure widespread use of available energy efficiency programs.

4. Reduce outdoor water consumption. In the context of greatest near-term benefit, there is no dispute among stakeholders: The single largest opportunity for saving a lot of water quickly is through reductions of outdoor water use, both in agricultural and landscape irrigation.

    - Pacific Institute stated that more than 75 percent of the state's total water consumption is used by agriculture.

    - IEUA stated that during summer, outdoor water use for landscape irrigation accounts for 50 to 70 percent of all water consumed by the residential sector. Regions along the coast tend to use less; hotter interior uses more. Seasonal factor translates into even bigger impacts. Overall, reducing residential usage from 200 gal per capita daily down to 80 gal per capita daily (SF/LA numbers).

    - MWD stated that the biggest opportunity for outdoor water savings is in landscape replacement with native plants and synthetic turf.

5. Reduce industrial water use. Pacific Institute estimates that as much as 658,000 AF/year could be saved by the commercial and industrial sectors. Opportunities include joint investment in existing water savings programs, as well as potential joint investment in new technologies. MWD, for example, suggests joint investigation of innovative conservation program investments in industrial process water improvements, such as optimal approaches to industrial recirculation. In addition, this program could include investigation of new water efficiency technologies for various types of industrial processes.

6. Explore a "Golden Carrot" equivalent for water conservation programs. Develop joint investment opportunities in use funds to conduct innovative conservation program investigations into new technology and to kick start methods of obtaining water customer responses to these opportunities. One or more cash and other prizes could be awarded through a competitive innovation program that includes, for example, a call for water and energy-efficient home water heating systems and improvements.

Glossary

acre-foot (AF) - a quantity or volume of water covering one acre to a depth of one foot; equal to 43,560 cubic feet or 325,851 gallons.

active storage capacity - the total usable reservoir capacity available for seasonal or cyclic water storage. It is gross reservoir capacity minus inactive storage capacity.

adjudication - the act of judging or deciding by law. In the context of an adjudicated groundwater basin, landowners or other parties have turned to the courts to settle disputes over how much groundwater can be extracted by each party to the decision.

afterbay - a reservoir that regulates fluctuating discharges from a hydroelectric power plant or a pumping plant.

alluvium - a stratified bed of sand, gravel, silt, and clay deposited by flowing water.

aquifer - a geologic formation that stores and transmits water and yields significant quantities of water to wells and springs.

artificial recharge - the addition of water to a groundwater reservoir by human activity, such as putting surface water into dug or constructed spreading basins or injecting water through wells.

average annual runoff - the average value of annual runoff amounts for a specified area calculated for a selected period of record that represents average hydrologic conditions.

brackish water - water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Considerably less saline than sea water.

conjunctive use - the coordinated and planned management of both surface and groundwater resources in order to maximize the efficient use of the resource; that is, the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin for later and planned use by intentionally recharging the basin during years of above-average surface water supply.

contaminant - any substance or property preventing the use or reducing the usability of the water for ordinary purposes such as drinking, preparing food, bathing washing, recreation, and cooling. Any solute or cause of change in physical properties that renders water unfit for a given use. (Generally considered synonymous with pollutant.)

conveyance - provides for the movement of water and includes the use of natural and constructed facilities including open channels, pipelines, diversions, fish screens distribution systems, and pumplifts.

cost-effective - means that the benefit-to-cost ratio of a proposed program or measure exceeds 1.0. As applied to this test, both costs and benefits are measured either over the life of the program or in terms of societal cost. Water and energy utilities currently include only costs and benefits that affect their respective ratepayers in their cost-effectiveness computations. The conclusion of this staff paper is that a cost-effectiveness test should expand to include all economic, environmental, and societal costs and benefits over the entire water use cycle - even those extending beyond the boundaries of a utility's service territory, resources, and assets - in order to identify opportunities to benefit the state as a whole.[139]

desalination - water treatment process for the removal of salt from water for beneficial use. Source water can be brackish (low salinity) or seawater.

drainage basin - the area of land from which water drains into a river; for example, the Sacramento River Basin, in which all land area drains into the Sacramento River. Also called, "catchment area," "watershed," or "river basin."

drip irrigation - a method of microirrigation wherein water is applied to the soil surface as drops or small streams through emitters. Discharge rates are generally less than 8 L/h (2 gal/h) for a single outlet emitters and 12 L/h (3 gal/h) per meter for line-source emitters.

drought - the magnitude and probability of economic, social or environmental consequences that would occur as a result of a sustained drought under a given study plan. Measures the "drought tolerance" of study plans.

energy consumption - the energy consumption required to facilitate water management-related actions such as desalting, pump-storage, groundwater extraction, conveyance, or treatment. This criterion pertains to the economic feasibility of a proposed action in terms of O&M costs.

energy costs - refers to the cost of energy use related to producing, conveying and applying water. It also refers to the cost of energy use for processes and inputs not directly related to water, but which can affect the demand for water (e.g., the cost of nitrogen fertilizer, tractor manufacturing, etc.).

energy production - both instantaneous capacity (megawatt) and energy produced (kilowatt hours).

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[139] Eventually, the issue as to who pays for such incremental statewide benefits will also need to be addressed.

energy self-sufficiency – Refers to an entity that self-supplies its own energy requirements. This would typically be done through a combination of energy efficiency and self-provision of power, whether purchased or produced. Current regulatory barriers prevent water and wastewater utilities from becoming energy self-sufficient.[140]

effluent - wastewater or other liquid, partially or completely treated or in its natural state, flowing from a treatment plant.

end use – the use of energy or water for specific activities such as heating, cooling, toilets, or irrigation.

end users – the consumers of energy or water.

estuary - the lower course of a river entering the sea influenced by tidal action where the tide meets the river current.

evapotranspiration (ET) - the quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces. Quantitatively, it is usually expressed in terms of depth of water per unit area during a specified period of time.

forebay - a reservoir or pond situated at the intake of a pumping plant or power plant to stabilize water levels; also a storage basin for regulating water for percolation into ground water basins.

gigawatt (GW) - one thousand megawatts (1,000 MW) or one million kilowatts (1,000,000 kW) or one billion watts (1,000,000,000 watts) of electricity. One gigawatt is enough to supply the electric demand of about one million average California homes.

gigawatt-hour (GWh) - one million kilowatt-hours of electric power. California's electric utilities generated a total of about 250,000 gigawatt-hours in 2001.

gross reservoir capacity - the total storage capacity available in a reservoir for all purposes, from the streambed to the normal maximum operating level. Includes

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[140] Barriers to energy self-sufficiency include:
(a) Long lead-time, complicated and costly interconnections;
(b) Prohibitive stand-by charges for grid-connected self-generation facilities:
(c) Net metering caps that discourage self-production of power at any site in an amount greater than 1MW (or the then current cap);
(d) Inability to “wheel” self-produced and/or purchased power to themselves anywhere on their own system (causing excess power to be either “lost” or sold at uneconomic wholesale prices that do not recover costs;
(e) Lack of standardized contracts, rates and terms for purchasing self-produced power that exceeds water and wastewater utilities’ needs at prices that at least recover costs; and
(f) Prohibitive exit fees assessed to entities departing from bundled electric utility service.

dead (or inactive) storage, but excludes surcharge (water temporarily stored above the elevation of the top of the spillway).

groundwater - water that occurs beneath the land surface and completely fills all pore spaces of the alluvium, soil or rock formation in which it is situated. It excludes soil moisture, which refers to water held by capillary action in the upper unsaturated zones of soil or rock.

groundwater basin - a groundwater reservoir, defined by an overlying land surface and the underlying aquifers that contain water stored in the reservoir.

groundwater overdraft - the condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average.

groundwater recharge - increases in groundwater storage by natural conditions or by human activity.

groundwater table - the upper surface of the zone of saturation, except where the surface is formed by an impermeable body.

hydraulic barrier - a barrier developed in the estuary by release of fresh water from upstream reservoirs to prevent intrusion of sea water into the body of fresh water.

hydrologic balance - an accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period of time.

hydrologic basin - the complete drainage area upstream from a given point on a stream.

hydrologic region - a study area, consisting of one or more planning subareas.

infiltration - the flow of water downward from the land surface into and through the upper soil layers.

irrigation efficiency (IE) - the efficiency of water application and use, calculated by dividing a portion of applied water that is beneficially used by the total applied water, expressed as a percentage The two main beneficial uses are crop water use (evapotranspiration, etc.) and leaching to maintain a salt balance.

kilovolt (kV) - one-thousand volts (1,000). Distribution lines in residential areas usually are 12 kv (12,000 volts).

kilowatt (kW) - one thousand (1,000) watts. A unit of measure of the amount of electricity needed to operate given equipment. On a hot summer afternoon a typical

home, with central air conditioning and other equipment in use, might have a demand of 4 kW each hour.

kilowatt-hour (kWh) - the most commonly-used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumes 534 kWh in an average month.

land subsidence - the lowering of the natural land surface due to groundwater (or oil and gas) extraction.

maximum contaminant level (MCL) - the highest drinking water contaminant concentration allowed under federal and State Safe Drinking Water Act regulations.

megawatt (MW) - one thousand kilowatts (1,000 kW) or one million (1,000,000) watts. One megawatt is enough energy to power 1,000 average California homes.

methane (CH_4) - the simplest of hydrocarbons and the principal constituent of natural gas. Pure methane has a heating value of 1,1012 Btu per standard cubic foot.

methanol (also known as Methyl Alcohol, Wood Alcohol, CH_3OH) - a liquid formed by catalytically combining carbon monoxide (CO) with hydrogen (H_2) in a 1:2 ratio, under high temperature and pressure. Commercially it is typically made by steam reforming natural gas. Also formed in the destructive distillation of wood.

microirrigation - the frequent application of small quantities of water as drops, tiny streams, or miniature spray through emitters or applicators placed along a water delivery line. Microirrigation encompasses a number of methods or concepts such as bubbler, drip, trickle, mist, or spray.

minimum pool - the reservoir or lake level at which water can no longer flow into any conveyance system connected to it.

natural recharge - natural replenishment of an aquifer generally from snowmelt and runoff; through seepage from the surface.

percolation - process in which water moves through a porous material, usually surface water migrating through soil toward a groundwater aquifer.

photovoltaic cell - a semiconductor that converts light directly into electricity.

public water system - a system for the provision of water for human consumption through pipes or other constructed conveyances that has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year.

recharge - water added to an aquifer or the process of adding water to an aquifer. Groundwater recharge occurs either naturally as the net gain from precipitation or artificially as the result of human influence.

recycled water - the process of treating municipal, industrial, and agricultural wastewater to produce water that can be productively reused.

riparian right - a right to use surface water, such right derived from the fact that the land in question abuts the banks of streams.

runoff - the volume of surface flow from an area.

salinity - generally, the concentration of mineral salts dissolved in water. Salinity may be expressed in terms of a concentration or as electrical conductivity. When describing salinity influenced by seawater, salinity often refers to the concentration of chlorides in the water.

seawater intrusion barrier - a system designed to retard, cease or repel the advancement of seawater intrusion into potable groundwater supplies along coastal portions of California. The system may be a series of specifically placed injection wells where water is injected to form a hydraulic barrier.

single utility resource cost test - refers to resource optimization from the perspective of a single utility - for example, a water utility already seeking optimization of its own water resources. Energy costs embedded in delivered wholesale water are included when considering cost-effectiveness. However, the single utility resource cost test does not evaluate the impact of these water resource decisions on either water or energy utilities, or on statewide water and energy resources and infrastructure. Similarly, neither water nor energy utilities consider the energy intensity embedded in a unit of avoided water over the entire water use cycle.

societal cost or societal value - refers to the total resource cost, including water and energy and externalities, embedded in a unit of water. For purposes of this staff paper, this term is consistent with that used by the California Public Utilities Commission when determining the cost-effectiveness of energy efficiency programs and measures, and by water utilities when determining the cost-effectiveness of their water conservation incentive programs.[141]

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[141] The CPUC's Energy Efficiency Policy Manual, Chapter 4 Cost-Effectiveness Methodology, relies upon a "Total Resource Cost (TRC) test - Societal Version" as "articulated [in] the California Standard Practices Manual: Economic Analysis of Demand-Side Management Programs." The California Standard Practices Manual states that "The Total Resource Cost Test measures the net costs of a demand-side management program as a resource option based on the total cost of the program, including both the participant's and the utility's costs." "A variant on the TRC test is the Societal Test. The Societal Test differs from the TRC test in that it includes the effects of externalities, excludes tax credit benefits, and uses a different (societal) discount rate." Water conservation incentives are typically valued in accordance with the February 1994 EPA manual, "A Guide to Customer Incentives

surface supply - water supply obtained from streams, lakes, and reservoirs.

surplus water - water that is not being used directly or indirectly to benefit the environmental, agricultural or urban use sectors.

tailwater – the excess water that was applied for agricultural irrigation water. This water is either returned to the environment or reused for irrigation.

transpiration - an essential physiological process in which plant tissues give off water vapor to the atmosphere.

Urban Water Management Planning Act – Sections 10610 through 10657 of the California Water Code. The Act requires urban water suppliers to prepare urban water management plans which describe and evaluate sources of water supplies, efficient uses of water, demand management measures, implementation strategies and schedules, and other relevant information and programs within their water service areas. Urban water suppliers (CWC Section 10617) are either publicly or privately owned and provide water for municipal purposes, either directly or indirectly, to more than 3,000 customers or supply more than 3,000 acre-feet of water annually.

volt - a unit of electromotive force. It is the amount of force required to drive a steady current of one ampere through a resistance of one ohm. Electrical systems of most homes and office have 120 volts.

water balance - an analysis of the total developed/dedicated supplies, uses, and operational characteristics for a region.

water quality - description of the chemical, physical, and biological characteristics of water, usually in regard to its suitability for a particular purpose or use.

watershed - the land area from which water drains into a stream, river, or reservoir.

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for Water Conservation" which incorporates by reference the societal valuation approach adopted in the California Standard Practice Manual.

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Get a CLWUE!

The Comprehensive Landscape Water Use Efficiently Program

October 3, 2013

Melissa Baum-Haley, Ph.D.
Water Use Efficiency Programs Programs Specialist
Municipal Water District of Orange County

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Municipal Water District or Orange County

WHO WE ARE

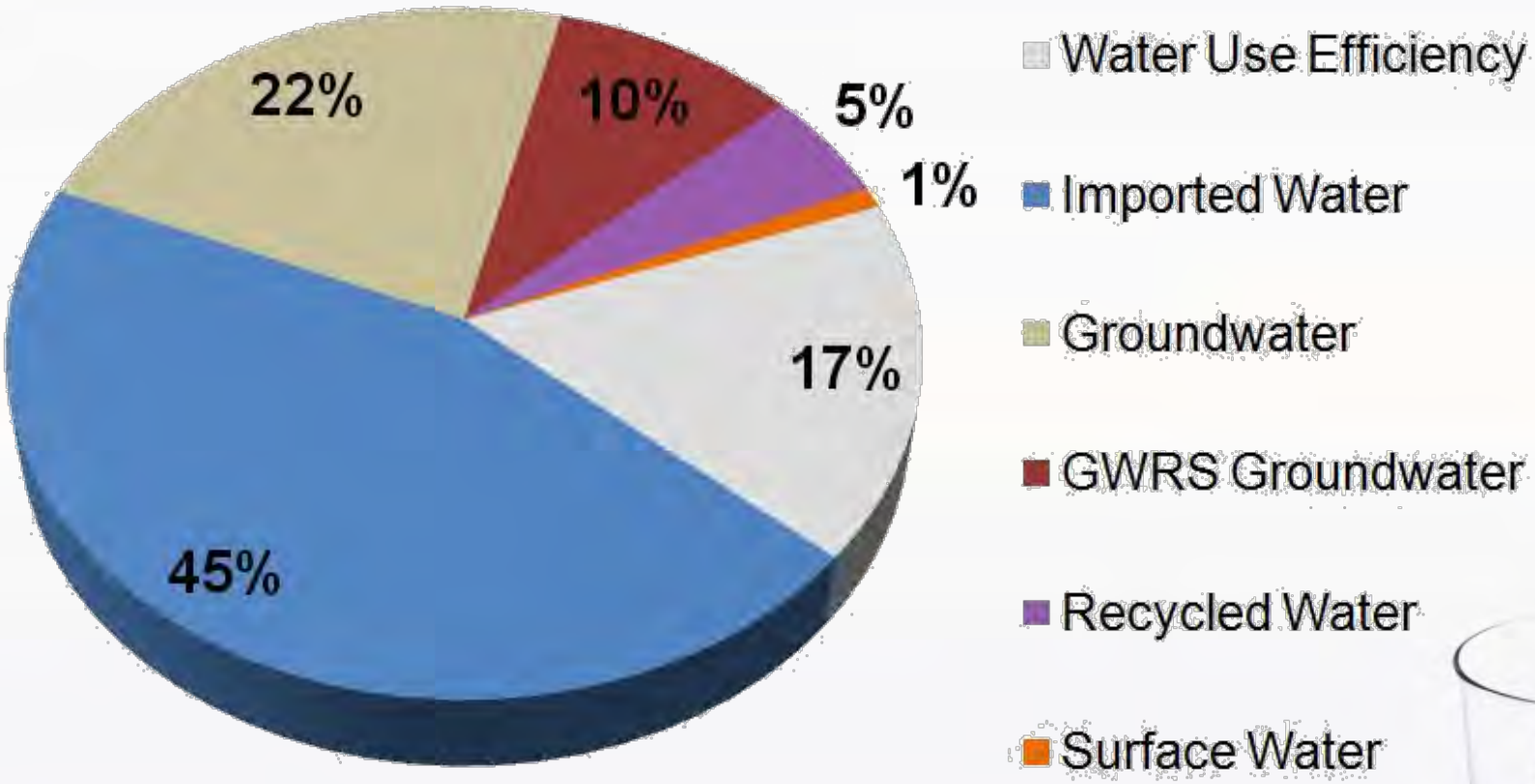
MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Municipal Water District of Orange County

- Wholesale supplier and regional planner to 28 client cities and water agencies
- Governed by seven-member elected board of directors
- Member agency of Metropolitan Water District of Southern California
- Service area: 600 square miles
- Water demand: 668,000 AFY
  - Imported supply
  - Local supplies
- Population: 2.3 million

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Where Orange County Gets its Water



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Program Funding Provided By:

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DEPARTMENT OF WATER RESOURCES
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BUREAU OF RECLAMATION

The Family of Orange County Water Agencies

MWD
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

The Problem

Too much excess water!

System inefficiencies!

Too much runoff!

Lack of maintenance!

Lack of management!

Lack of communication!

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

The Solution

REBATES & INCENTIVES

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

SMARTIMER™
REBATE PROGRAM

Receive money back when you upgrade to "smart" technology that fully automates landscape watering, based on the weather and water needs of your plants.

Smart Timer Rebate Program

- **Provides rebate incentives to install automated self-adjusting weather based irrigation controllers & soil moisture sensors**

- **Residential Smart Timer Rebate Levels:**
  - **$80 to $380 per controller installed**
- **Commercial Smart Timer Rebate Levels:**
  - **$25/station up to clock capacity**

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Rotating Nozzle Rebate Program

- Distribution Uniformity Improvement Incentive
- Replacement nozzle for spray heads
- Save 6,600 gallons per nozzle over 5 years
  - $4 to $5 per nozzle
- 15 nozzle minimum per site for common areas (commercial)

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Turf Removal Rebate Program

- Turf removal with replacement by California Friendly plants and permeable surfaces
- Rebate amount in Orange County
  - $1.00 to $2.00 per square foot
- Water savings are estimated at 44 gallons per square foot per year
- For more information visit:
  - www.mwdoc.com/services/turf-removal

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Spray to Drip Pilot Program

- Spray irrigation with replacement by embedded emitter drip tubing
  - Criteria includes pressure regulation and filters
- Rebate amount in Orange County
  - $0.20 to $0.40 per square foot
  - can be in addition to turf removal

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Public Spaces WSL

- **The Program specifically targets the implementation of comprehensive landscape improvements for publicly owned and other commercial landscape properties**
  - Highly visible sites
  - Encourage the new norm
  - Cost share program

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Pay for Performance Programs

- Water Savings Incentive Program
- Hotel Program
- CII Pay-for-Performance

- Focuses on Large landscapes
- Incentive amount paid based on actual water savings during a one year monitoring period
  - Can include a suite of device changes, plant changes, increased management, or any other practice

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

INFORMATION TOOLS
&
EDUCATIONAL OUTREACH

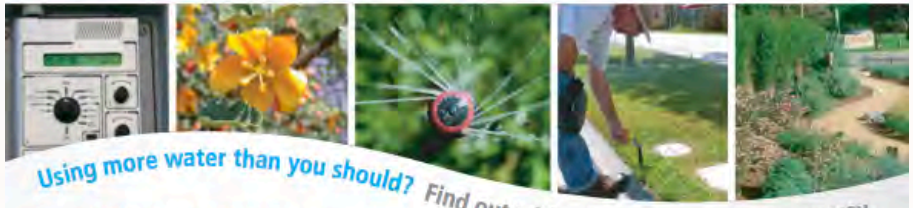
MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Landscape Surveys

THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Landscape Irrigation Survey

For Commercial, Industrial, Institutional and Common Area Landscapes



Using more water than you should? Find out with a landscape irrigation survey.

HOW IT WORKS

A certified landscape irrigation auditor will survey and provide written recommendations for qualifying non-residential properties within Metropolitan's 5,200 square-mile service area **at no cost**. To participate, properties must have a minimum of one acre of irrigated land. Eligible landscapes include commercial and industrial sites, homeowner association common areas, and institutional sites like schools, parks and government facilities.

Surveys are scheduled on a first-come, first-served basis. To request a survey, please complete the online application at bewaterwise.com®. Funding is limited and submitting an application does not guarantee a survey will be provided.

CONTACT

Deneice Cotton
Metropolitan Water District of Southern California
(213) 217-6616
dcotton@mwdh2o.com

WHAT TO EXPECT

The property owner, manager or authorized representative with access to the irrigation controllers must be present during the survey. The certified landscape irrigation auditor will conduct a comprehensive review of the irrigation system including:

- System pressure
- Controllers
- Site conditions and irrigation scheduling
- Issues that cause higher water use, such as valve malfunctions, high or low pressure, sprinkler misalignment, poor drainage, breaks and leaks, runoff, etc.

Participants will receive a written report that includes:

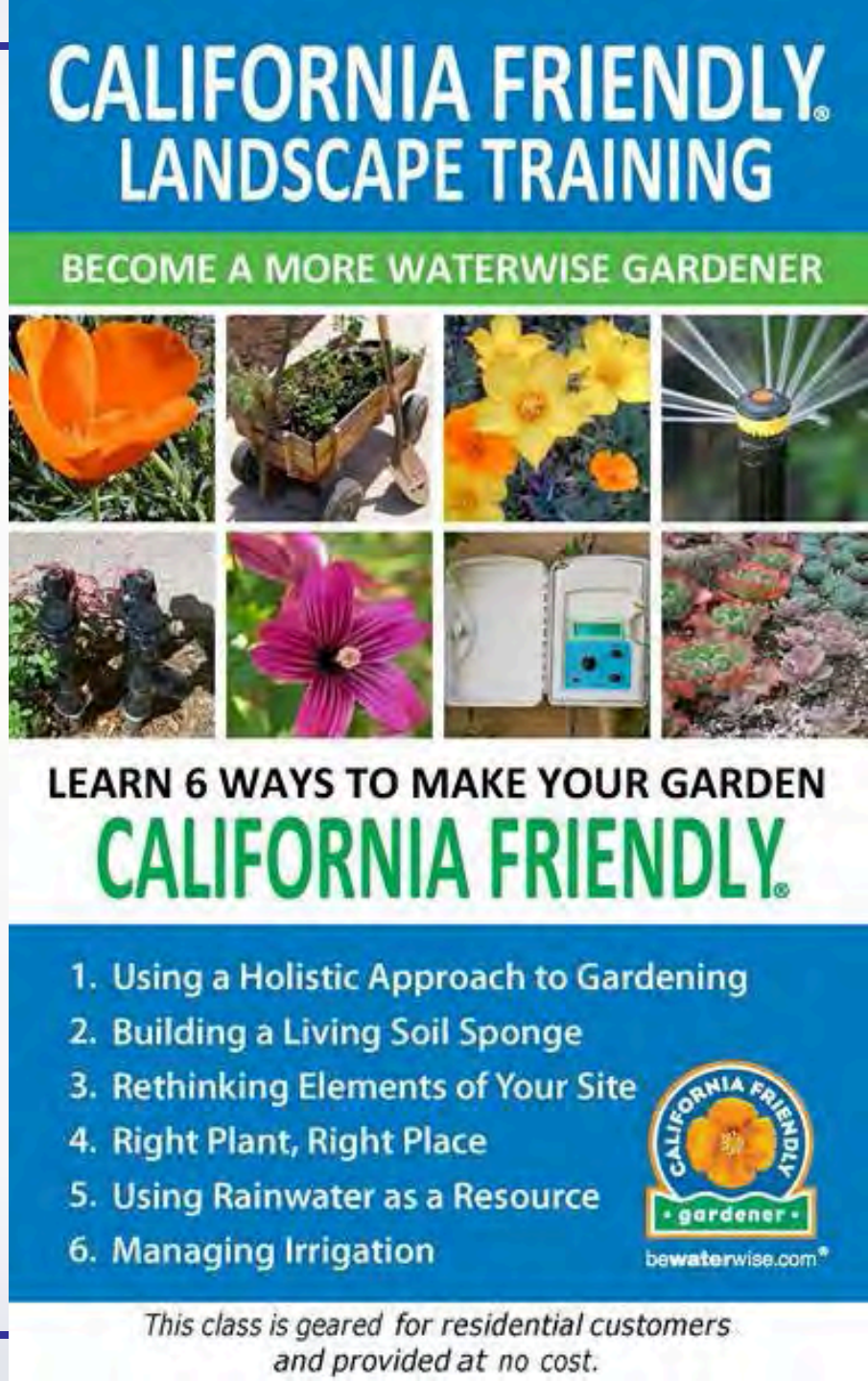
- Data collected during the survey
- Recommendations for improving the site's irrigation efficiency including system repairs, equipment updates, and irrigation scheduling
- Information about available financial incentives to help with the cost of recommended improvements

bewaterwise.com®

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

California Friendly Landscape Classes

- Encourage participants to think of their property as a watershed
- Introduction to water use efficiency in the landscape
- Great opportunity to "show & tell"



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Rain Barrels

- Encourage the perspective that rain is a water source
- Gateway product
- Visual prompt
- Rebate amount
  - $75 per barrel

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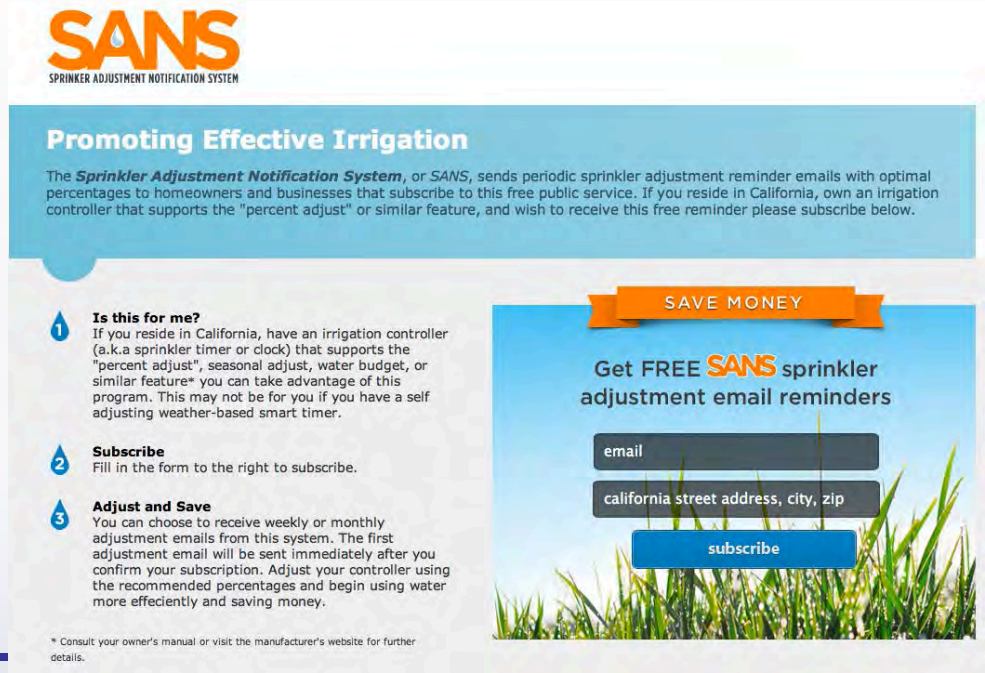
Water Smart Home Certification Program

- Participating in a free home water survey will score the home's water use efficiency and identify potential water savings needed.
- Recommendations will include money- and water-saving rebates and no-cost activities that can help participants become more water efficient.

California Sprinkler Adjustment Notification System

- Sends periodic sprinkler adjustment reminder emails
  - with optimal percentages for conventional timers with the percent adjust feature
- Free public service
- Avenue for marketing other programs and education



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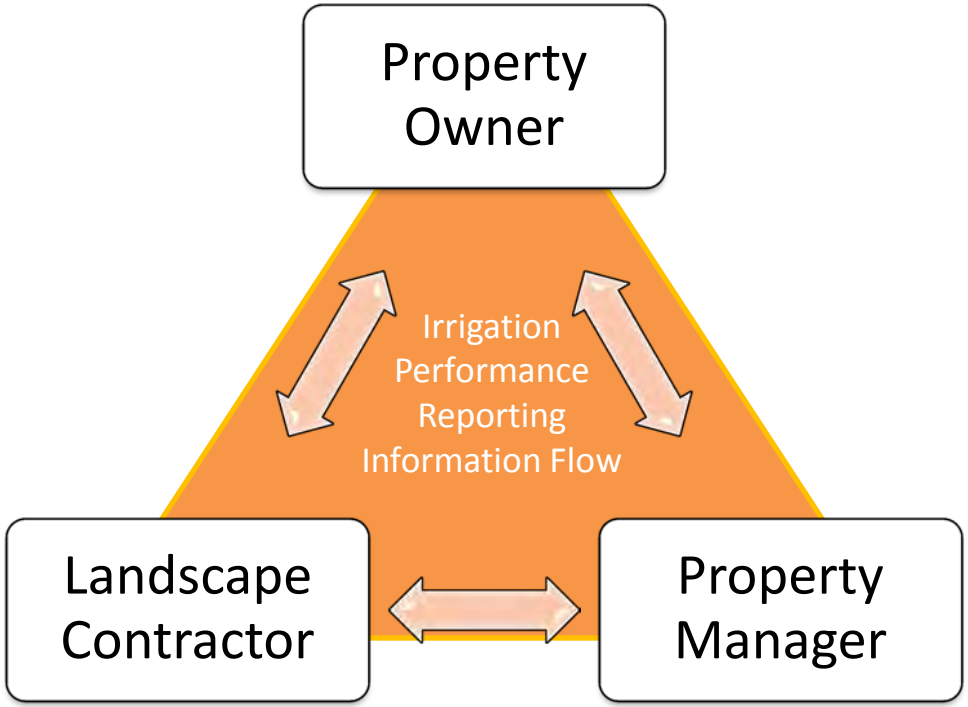
Stormwater Partnership

- **MS4 Permit Compliance**
- **Public Educational Informational Campaign Partnership**

Communication Tools



Water Smart Landscape Program (WSLP)

Formerly: Landscape Performance Certification Program

- A Free Program that establishes Landscape Irrigation Budgets for dedicated landscape meters
  - Scientific calculation of the annual, monthly or weekly water requirements
- Provides monthly irrigation performance reports to landscape contractors, property managers and property owners

Performance-Based Irrigation Management Contract

An outcome based approach to contracting that uses irrigation scheduling performance measures to define the minimum irrigation efficiency standards that must be met by the contractor.

Intended Users

- Commercial Property Owners
- Home Ownership Associations
- Landscape Maintenance Contractors
- Community Managers
- Municipalities

Adaptable/Customizable/Flexible

ROI Calculator

- Technical education
- Help prioritize sites for upgrades
- Identify potential expense reductions
  - O&M and Capital
- Facilitate communication among stakeholders
- Provide a financial analysis for landscaping and water management

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

INSPECTIONS, MONITORING & IMPACT EVALUATIONS

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

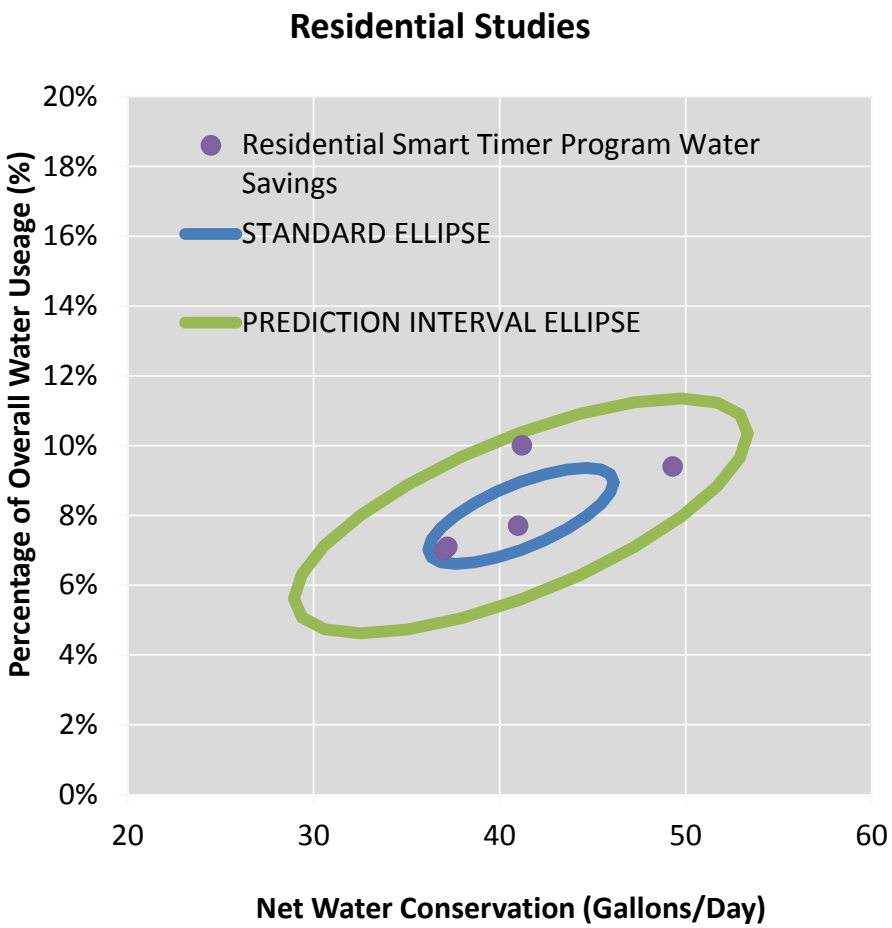
Inspections, Monitoring, & Evaluations

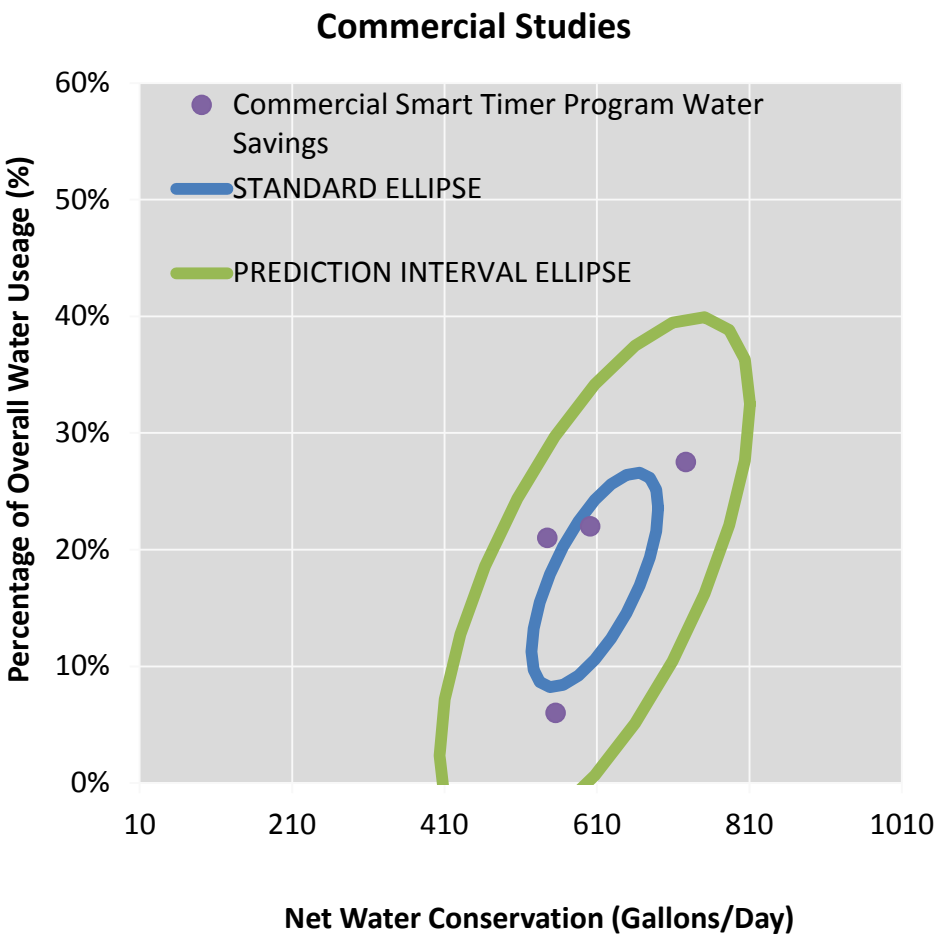
- The majority of our rebates require 100% site inspections to verify installation
- Pay for performance projects are monitored
- Each program has an Evaluation
  - Process – how the program functions
  - Impact – effectiveness of program (water savings, reduction of runoff, etc.)

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Impact Evaluation Results

Smart Timers





Water Use Efficiency Master Plan

- Comprehensive look at all programs offered in Orange County
  - Benefit-cost ratio
  - Productions levels
- How to best meet our conservation goals

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Where do we go from here?

- Can't look ahead without looking back
  - Follow-up surveys
  - Determining retention rates
  - What's next time?

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Questions?

Contact: Melissa Baum-Haley
Water Use Efficiency Programs Specialist
Municipal Water District of Orange County
714-593-5016
mbaum-haley@mwdoc.com

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The Metropolitan Water District of Southern California

NEWS RELEASE

P. O. Box 54153, Los Angeles, California 90054-0153 • (213) 217-6485 • www.mwdh2o.com

Contact: Bob Muir, (213) 217-6930; (213) 324-5213, mobile

May 14, 2014

METROPOLITAN EXPANDS INCENTIVE PROGRAMS TO
BOOST REGION'S CONSERVATION IN RESPONSE TO DROUGHT
Modifications to water-saving incentive programs approved
in response to Gov. Brown's call for a redoubled statewide effort

If money talks, then Southern California consumers should hear a louder call for water conservation with increased financial incentives being offered by the Metropolitan Water District.

Metropolitan's Board of Directors Tuesday doubled the incentive for turf removal, as well as extended rebates for rain barrels and high-efficiency toilets to further entice Southern Californians to institute water-saving practices at home and in businesses.

The new measures were adopted in response to Gov. Edmund G. Brown's Jr.'s emergency drought declaration calling on all Californians to redouble their conservation practices. The changes will go into effect before the expected summer period of peak water demands.

"Southern Californians have time and again responded to the call for conservation," said Metropolitan board Chairman Randy A. Record. "By encouraging them with even more financial incentives, we hope to boost participation in region-wide conservation programs."

Incentive changes include doubling the per-square-foot rebate for turf removal from $1 to $2, extending funding for rain barrels and the residential high-efficiency toilet program, and increasing funding for private and public property owners to convert potable water irrigation or industrial water systems to recycled water as part of a pilot program launching July 1.

Participation in the turf removal program increased by more than 50 percent in the areas where member agencies offered higher incentives. The program promotes the substitution of California Friendly® plants and alternative landscape material in place of turf.

"The popularity of both the rain barrel and residential high-efficiency toilet rebate programs, offered in cooperation with our member agencies, warranted the extension of the programs at least until we see a change in drought conditions," said Metropolitan General Manager Jeffrey Kightlinger.

more . . . . .

"To be both responsive to our member agencies and our shared water consumers, it makes sense to extend these effective and popular programs and showcase other water-saving opportunities."

Private or public business owners who convert to recycled systems will now be paid for water savings up to five years, replacing the previous two-year cap instituted when the on-site retrofit pilot program was initially approved by Metropolitan's board in February 2014.

In addition to the longer period for incentivized savings, the board approved a higher program cap to allow for a larger amount of annual recycled water use. All of the newly approved incentive changes will be managed within the previous board-approved conservation budget.

For a full listing of Metropolitan's commercial and residential incentives, consumers are encouraged to visit www.bewaterwise.com®.

###

The Metropolitan Water District of Southern California is a cooperative of 26 cities and water agencies serving nearly 19 million people in six counties. The district imports water from the Colorado River and Northern California to supplement local supplies, and helps its members to develop increased water conservation, recycling, storage and other resource-management programs.

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POLICY ANALYSIS
FOR THE
PUBLIC AND PRIVATE
SECTORS
M.CUBED

Evaluation of East Bay Municipal Utility District's Pilot of WaterSmart Home Water Reports

Prepared by

David L. Mitchell
M.Cubed

Thomas W. Chesnutt, Ph.D., CAP™
A&N Technical Services, Inc.

Prepared for

California Water Foundation
&
East Bay Municipal Utility District

December 2013

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EXECUTIVE SUMMARY

This report presents the results of an independent evaluation of the East Bay Municipal Utility District's (EBMUD) year-long pilot project (Pilot) of WaterSmart Software's Home Water Reports (HWRs) service. HWRs provide households with periodic information on their current water use and compare it to their past use, the average use of similar households, and the use of the most efficient similar households. This data is coupled with actionable information on ways to use water around the home more efficiently. HWRs aim to motivate households to reduce their water use through changes in behavior or adoption of more water efficient technology. The approach is based on research on social norms marketing coming out of the field of social psychology and for this reason we refer to these type of programs as social-norms-based (SNB) efficiency programs. While SNB efficiency programs have been broadly adopted by energy utilities across the United States in recent years, they are new to water utilities.

The EBMUD Pilot is the first relatively large-scale implementations of an SNB efficiency program by a large urban water utility, providing HWRs to 10,000 homes over a twelve-month period. The pilot was comprised of two experiments. The first we call the Random Group Experiment. The second we call the Castro Valley Group Experiment. In both experiments, households were selected to be in either a treatment group or a control group. Households in the treatment groups received HWRs while households in control groups did not. The Pilot ran from June 2012 through June 2013.

The Random Group Experiment consists of households representative of EBMUD's overall service area. The Castro Valley Group Experiment is comprised of a much more homogenous group of homes with characteristics thought to make them good candidates for HWRs. The goal of having two experiments was to provide insight into the effectiveness of HWRs directed at a targeted group of homes (Castro Valley Experiment) as well as into what the average effectiveness of HWRs might be if the program were expanded across EBMUDs whole service area (Random Group Experiment).

The Pilot was intended to address three primary questions:

1. First, would an SNB efficiency program like WaterSmart result in measurable reductions in household water use?
2. Second, would it increase rates of participation in other EBMUD conservation programs?

3. Third, would it increase household knowledge and awareness of water consumption and ways to use water more efficiently?

Within the context of each of the primary questions, EBMUD hoped the Pilot would yield information to address a number of additional questions of interest. These included:

1. Are households that are above (below) the norm more (less) likely to reduce their consumption of water?
2. Does whether the household receives a paper or electronic HWR affect the level of savings?
3. Is there a seasonal shape to water savings?
4. If HWRs increase participation in other conservation programs, which programs receive the greatest boost? Are households receiving HWRs that are above (below) the norm more (less) likely to participate in other conservation programs?
5. Are HWRs cost-effective? What is the expected cost of saved water from HWRs relative to other conservation program options or the cost of new water supply?

To address these questions we employ a range of statistical techniques, including robust panel data regression and dichotomous choice logit models. The following is a summary of our primary findings.

1. We find strong evidence that households in the Pilot's treatment groups reduced their water use in response to the HWRs. We estimate mean treatment effects on residential water use of 4.6% and 6.6% for the Random Group and Castro Valley Group experiments, respectively. We reject the null hypothesis of no treatment effect with better than 99% statistical confidence. Our estimates of mean treatment effect bracket the 5% mean effect estimated by WaterSmart using a less robust difference-in-differences methodology. The consistency between the WaterSmart estimates and our results is useful corroborating information.
2. We also find evidence that the magnitude of the water savings scales with level of household water use. Households in the top quartile of water use save, on average, 1% more, while households in the bottom quartile of water use save, on average, 3% less, than households in between these two categories. This suggests that if HWRs are not

going to be universally provided, utilities should consider giving households in the bottom quartile of use lower priority for receiving HWR.

3. Paper reports delivered by mail appear to be more effective in terms of water savings than electronic reports delivered by email. On average, households receiving paper reports were found to save about 1% of mean household use more than households receiving email reports. An implementing utility will still need to evaluate a host of factors, including the cost of delivering mail versus email reports, the avoided cost of saved water, and the availability of customer email addresses, to determine the preferred delivery method.
4. We estimate that the unit cost of saved water is likely to range between $250 and $590 per acre-foot for email reports and between $290 and $570 per acre-foot for paper reports.[1] The mid-point unit costs for email and paper reports are $380 and $400 per acre-foot, respectively. Even at the upper-end of the cost ranges, the unit costs are less than the cost of most other water demand management and new water supply options, indicating SNB efficiency programs could provide very cost-effective water savings.
5. We find strong evidence that households in the Pilot's treatment groups were significantly more likely to participate in audit and rebate programs offered by EBMUD than households in the control groups. Looking at both audit and rebate programs together, we estimate that households receiving HWRs were 2.3 times more likely to participate in a program than households not receiving reports. The effect appears to be strongest for audit programs, where we estimate households getting HWRs were 6.2 times more likely to participate. The effect is weaker for rebate programs (1.7 times more likely), but statistically significant. The results suggest that SNB efficiency programs can provide an effective conduit for channeling customers into other utility conservation programs.
6. Our analysis indicates that households receiving a water score of 3 on their HWR, which tells them to take action, are in fact more likely to do just that. The magnitudes of the treatment effects for both average daily use and program participation are positively correlated with water score. While our results should not be interpreted to imply that there is value to adjusting the scores to place more households in the high score category, they do suggest that targeting HWRs to homes that fall within this category is likely to

[1] Unit cost estimates have been rounded to the nearest $10 throughout this report.

yield better results in terms of average water savings and boosting program participation rates.

7. We do not find evidence that HWRs improve household knowledge of water use in the conventional sense of being able to quantitatively estimate average daily use. The proportion of homes stating they did not know their water use was essentially the same between households in the control and treatment groups. Similarly, the tendency to underestimate daily water use was also generally the same between control and treatment households. It may be that over time this will change and as households receive more HWRs they will begin to incorporate this information into their general understanding of how they use water.
8. We do, however, find strong evidence that households receiving HWRs view them as providing useful and actionable information for managing their water consumption. Households in the treatment group were 52 to 80% more likely to score EBMUD as "Excellent" in terms of explaining household water use, showing ways to save money on water bills by conserving water, and giving useful tips and tools needed to use water efficiently. Thus, HWRs appear to be effective at delivering information on ways to use water efficiently that households can, and judging by the measured effects on daily water use and program participation, do act upon.

I. INTRODUCTION

This report presents the results of our evaluation of the outcomes of the East Bay Municipal Utility District's (EBMUD) year-long pilot project (Pilot) of WaterSmart Software's Home Water Reports (HWRs) service. HWRs provide households with periodic information on their current water use and compare it to their past use, use by similar households, and efficient use. This data is coupled with actionable information on ways to use water around the home more efficiently. HWRs aim to motivate households to reduce their water use through simple to implement changes in behavior or adoption of more water efficient technology. The approach is based on research on social norms marketing coming out of the field of social psychology and for this reason we refer to these type of programs as social-norms-based (SNB) efficiency programs. While SNB efficiency programs have been broadly adopted by energy utilities across the United States in recent years, they are new to water utilities.

The EBMUD Pilot is the first relatively large-scale implementations of an SNB efficiency program by a large urban water utility. The Pilot was intended to address three primary questions:

1. First, would an SNB efficiency program result in measurable reductions in household water use?
2. Second, would it increase rates of participation in other EBMUD conservation programs?
3. Third, would it increase household knowledge and awareness of water consumption?

Within the context of each of the primary questions, it was hoped the Pilot would yield information to address a number of additional questions of interest. These included:

1. Are households that are above (below) the norm more (less) likely to reduce their consumption of water?
2. Does whether the household receives a paper or electronic HWR affect the level of savings?
3. Is there a seasonal shape to water savings?
4. If HWRs increase participation in other conservation programs, which programs receive the greatest boost? Are households receiving HWRs that are above (below) the norm more (less) likely to participate in other conservation programs?
5. Are HWRs cost-effective? What is the expected cost of saved water from HWRs relative to other conservation program options or the cost of new water supply?

The analysis that follows touches on each of these questions. To our knowledge, this report provides the first published independent evaluation of the effect of an SNB efficiency program on residential water use.[2] The remaining parts of this report are organized as follows. In Section II we provide an overview of SNB efficiency programs, including a discussion of the theoretical basis for and empirical evidence of their effectiveness. In Section III we describe the WaterSmart service that was implemented for this Pilot. In Section IV we describe the Pilot, including its goals and objectives, experimental design, and implementation. In Section V we present the results of our evaluation. This section is divided into five main parts that address Pilot outcomes in terms of household water use, participation in other conservation programs, knowledge and awareness of water use, cost effectiveness, and potential for integration with or extension of existing water use efficiency programs and strategies. In Section VI we provide a summary of Pilot outcomes and implementation lessons learned. We conclude the report in Section VII with recommendations for future research.

II. OVERVIEW OF SNB EFFICIENCY PROGRAMS

A. SOCIAL NORMS MARKETING

Social norms marketing is increasingly being used to motivate behavioral change (Andreasen, 2002). The central idea behind social norms marketing is that much of people's behavior is influenced by their perceptions of what is "normal" or "typical." According to social norms theory, if people are shown that their behavior is outside of the norm or that their perception of the norm is incorrect, they will be motivated to change the way they behave so they conform more closely to the norm. Moreover, it is believed the effect can be enhanced by coupling information on social norms with actionable information that facilitates the desired behavioral change.

Social norms marketing originated with issues related to college student drinking and substance abuse (Perkins & Berkowitz, 1986), but has evolved over the last two decades into a much more broadly applied concept. The effectiveness of social norms marketing in motivating behavioral change has been studied in a wide variety of contexts, including voting (Gerber & Rogers, 2009), environmental awareness (Goldstein, Cialdini, & Griskevicius, 2008), retirement savings (Beshears,

[2] An unpublished working paper by University of Washington researchers also examined average treatment effects of HWRs using similar panel regression techniques (Brent, et al, 2013).

Choi, Laibson, Madrian, & Milkman, 2009), charitable giving (Frey & Meier, 2004), and energy conservation (Allcott, 2011).

B. STRUCTURE OF SNB EFFICIENCY PROGRAMS

Interest in the use of social norms marketing within the energy and water utility sectors has grown significantly in the last decade. Partly this has been spurred by the transition to Advanced Metering Infrastructure (AMI) in the energy utility sector, which has substantially lowered the marginal cost of delivering detailed consumption information to customers and matching this information to the usage patterns of other similar customers. All of the major energy utilities in California are transitioning to AMI and most have coupled this technology with the provision of detailed consumption information to their customers. The largest provider of social-norms-based (SNB) efficiency program services is Opower, a private sector software-as-a-service company based in Virginia. Opower currently has contracts to run SNB efficiency programs at more than 90 energy utilities -- including 8 of the U.S.'s 10 largest -- and its programs reach more than 22 million homes worldwide.

Typical elements of SNB efficiency programs designed to promote efficient usage behavior, customer engagement, and individual consumption management include:[3]

1. Normative comparison of a customer's usage against comparable customers in the same geographical area;
2. Use of what social psychologists call "injunctive norms" which convey to the customer that efficient use of natural resources is pro-social while excessive use is anti-social;
3. Targeted conservation tips based on an analysis of a customer's past usage and individual profile;
4. Information and enticements to direct customers to other utility programs based on their previous usage patterns and individual customer profiles.

This information is delivered to customers through customized reports that they receive -- via mail or electronically -- on a monthly, bi-monthly, or quarterly basis, depending on their utility's

[3] Adapted from Sergici & Farugui (2011).

billing cycle.[4] Typically, SNB efficiency programs also provide customers access to a web portal that provides even more information on their consumption and ways in which they can improve their efficiency. Customer relationship, analytical, and reporting tools are used by the utility to respond to customer inquiries, monitor and analyze changes in usage patterns, and report on outcomes.

C. THEORETICAL BASIS FOR SNB EFFICIENCY PROGRAMS

Allcott (2011) identifies three primary mechanisms through which SNB efficiency programs may induce households to increase the efficiency of their consumption. First, providing actionable information to households on how to reduce consumption lowers the cost of implementing efficiency improvements and therefore increases household demand for them.[5] Second, given that households have incomplete knowledge about how much water is needed to achieve desired levels of water-dependent household services (e.g. a lush landscape or clean clothes), the use of social comparisons and injunctive norms may result in households adjusting their privately-optimal levels of water use when confronted with new information about what constitutes "average" and "efficient" water use for similarly situated households. Third, the use of social comparisons and injunctive norms may alter the "moral cost" of water use, thereby altering household demand for water. Households using more than the norm may be made to feel they are using more than "their fair share" and try to use less because of this. Alternatively, households using much less than the norm may be made to feel they are not getting "their just desserts" and may therefore increase their consumption.

The last case raises the possibility that use of social comparisons could induce either lower or higher consumption, depending on how households perceives their own consumption after receiving information on normative consumption for similarly situated households. If the goal of the treatment is to get households to use less of something, then inducing some households to use more of it would be an unintended and undesirable consequence of the intervention. In the social psychology literature this is termed a boomerang effect and at least one study has reported its occurrence in the context of an energy efficiency program providing normative information on household energy

[4] In the absence of AMI, the billing cycle sets the maximum frequency in which reports can be offered. However, utilities may choose to provide them less frequently than every billing cycle.

[5] Information and search costs are costs associated with finding, gathering, and processing information needed to make informed investment and consumption decisions. Consumers will balance of the cost of obtaining additional information against the benefit they expect to gain from it. Lowering information costs can therefore increase demand for goods or services where these costs had heretofore been relatively high.

consumption (Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007). However, Schultz et al (2007) also found that boomerang effects could be neutralized by coupling the normative information with an injunctive message conveying social approval or disapproval. Telling households with low use relative to the norm they are doing great appears to prevent them from adjusting their consumption upward, while telling households with high use relative to the norm they could do better appears to induce them to adjust their consumption downward. In his impact evaluation of Opower home energy reports, which included both information on social norms and injunctive messaging, Allcott (2011) did not find evidence of boomerang effects.[6]

Another way of thinking about the "moral" cost of using a scarce good is in terms of the value (or utility) consumers get from using less of it if they believe doing so contributes to other public goods they value, such as contributing to healthy ecosystems, protecting at-risk species, reducing greenhouse gas emissions, or benefitting public health. As pointed out by Levitt and List (2007), social norms provide a key point of reference from which consumers may judge the morality of their consumption choices.[7] Allcott (2011) posits that most consumers believe their consumption of natural resources like water and energy is closer to the social norm than it actually is. Put another way, most of us tend to believe the social norm must be close to our own level of consumption because we all want to believe we only use what we need and do so efficiently. As shown in Section V, households in the Pilot consistently and significantly underestimated their consumption of water. Similar underestimation of usage has been reported for energy consumption (The Economist, 2010). In this case, consumers may not perceive much of a gain in moral utility from using less of the resource because they already believe they are consuming near or below the socially acceptable level. When provided information reinforced with injunctive messaging that this is not the case, consumers update their beliefs about the social norm -- downward for high use consumers and upward for low use consumers. High use consumers find the moral utility they would get from using less of the good to have gone up and adjust their demands accordingly.

[6] The SNB energy efficiency programs evaluated by Allcott involved nearly 600,000 households served by 14 different energy utilities. Six of the utilities were in California and Washington, six were in the Midwest, one was in the urban Northeast, and one was in a suburban area in a Mountain state.

[7] Musings on the role of morality in economic choices is actually much older than this. The first formal treatise by an economist on the subject was Adam Smith's seminal book *The Theory of Moral Sentiments* published in 1759.

D. EMPIRICAL EVIDENCE FOR EFFECTIVENESS OF SNB UTILITY PROGRAMS

1. Evidence from the Energy Utility Sector

While SNB efficiency programs are relatively new, there have nonetheless been a number of empirical evaluations of their effectiveness. Because of its dominance in the market, most of these evaluations have focused on programs run by Opower and address impacts of SNB efficiency programs on household energy use.

Evaluations of Opower programs have typically found an average treatment effect in the range of 1.5% to 3.5% of baseline consumption. Allcott (2011), the first evaluation of a scaled SNB efficiency program to be published in a peer-reviewed journal, reported an average treatment effect in the range of 1.4% to 3.3% across seventeen separate utility experiments, with an unweighted mean treatment effect of 2%. Within California, evaluations of SNB efficiency programs run by Opower have reported average treatment effects ranging from 0.9% to 2.9% of baseline consumption (Perry & Woehleke, 2013; Wu & Osterhus, 2012; Summit Blue Consulting, LLC, 2009).[8]

SNB efficiency programs have been shown to be effective at reducing both seasonal, peak day, and peak hour energy demands (Jessoe & Rapson, 2013). Average treatment effects have also been shown to be constant or increasing over multiple years (Provencher, 2011), indicating the effectiveness of repeated treatments does not appear to diminish with time.[9] Additionally, the magnitude of the treatment effect has been shown to scale up with baseline use, meaning high use customers reduce use proportionally more than low use customers (Allcott, 2011). For example, in the SNB efficiency program experiments evaluated by Allcott (2011), the average treatment effect for households in the 30th percentile of baseline use was under 1% whereas for households in the 80th percentile it was approximately 3.5%.

[8] A report by McKinsey & Company found the long-term potential savings from SNB efficiency programs in U.S. residential energy markets to be immense -- 1.8 to 2.2 quadrillion BTUs per year, or 16% to 20% of current U.S. non-transportation residential energy use (Heck & Tai, 2013). The largest savings potential -- accounting for more than half of the total --is associated with changing temperature set points for heating and hot water systems during cold weather. Other significant potentials are associated with changing the operating parameters for air-conditioning and refrigerators. According to the report, these savings potentials are as yet largely untapped, but could be through broader use of SNB efficiency programs over a sustained period.

[9] The span of years evaluated, however, has been relatively short -- usually two to three years. The effectiveness of SNB efficiency programs over longer stretches has yet to be tested.

SNB efficiency programs also may increase customer participation in other efficiency programs, which the evaluation literature terms "uplift" or "channeling." Opower claims its home energy reports have boosted participation in other utility programs by 17% to 59%. The evaluation literature is somewhat mixed. Several studies have shown positive uplift (Provencher, Hampton, Brown, & Hummer, 2013; Opinion Dynamics Corporation, 2012) while others have shown no uplift or even negative uplift (Perry & Woehleke, 2013; Gunn, 2012).

Assessments of SNB energy efficiency program costs have found them to be cost effective relative to other energy efficiency programs (Allcott & Mullainathan, 2010; Allcott, 2011). Cost estimates for Opower-like SNB energy programs are in the neighborhood of 2.5 to 3.5 cents per kilowatt-hour saved. This is substantially below the average cost of 6.4 cents per kilowatt-hour saved estimated for conventional energy demand-side-management (DSM) programs (Arimura, Newell, & Palmer, 2009). It also is comparable to an incremental cost of 3 cents per kilowatt-hour saved estimated for DSM programs at utilities with little or no historical investment in DSM (Arimura, Newell, & Palmer, 2009).

2. Evidence from the Water Utility Sector

To our knowledge there have not been any published independent evaluations of the effectiveness of SNB efficiency programs in the water utility sector. Our evaluation of the EBMUD pilot may constitute the first such evaluation. WaterSmart has reported savings estimates in the neighborhood of 5% for its City of Cotati and EBMUD pilots. However these estimates have not been independently verified.[10] Our estimates of the average treatment effect of the EBMUD Pilot are consistent with these previous estimates. They are also consistent with average treatment effects of three WaterSmart pilots -- including the EBMUD Pilot -- reported by University of Washington researchers in an unpublished working paper (Brent, et al, 2013). If these results are replicated in

[10] WaterSmart's internal metrics rely on difference-in-differences (DID) estimators. DID estimators, however, require strong identifying assumptions -- in particular that in the absence of treatment the average outcomes of the treatment and control groups would have followed parallel paths over time (Abadie, 2005). The preferred approach for estimating the treatment effect of SNB efficiency programs is panel data regression analysis, which can more effectively control for other factors, such as weather, impacting differences in consumption between the pre and post intervention periods for the control and treatment groups (Sergici & Farugui, 2011).Typically either a fixed-effects or random-effects estimator is recommended. For information on estimation of fixed and random effects models, more generally, the reader is referred to Wooldridge (2001).

other evaluations of SNB efficiency programs for water, it would provide compelling evidence for the viability of SNB efficiency programs in the water utility space.

III. THE WATERSMART SERVICE

SNB efficiency programs can be implemented in varying ways which may yield differing results. It is therefore important to acknowledge that our evaluation results are based on a particular implementation provided by WaterSmart Software. In this section, we describe the WaterSmart SNB efficiency program that was used in the EBMUD Pilot.

A. HOME WATER REPORT DESIGN

The design of the WaterSmart HWR is very similar to the design employed by Opower for home energy reports. It is divided into two primary modules. The Social Comparison Module appears at the top of the first page of the HWR -- it is designed to be the first thing the viewer of the report sees. As illustrated in Figure 1, the Social Comparison Module of the report presents the "descriptive norm" by comparing the household to the mean and 20th percentile of its comparison group. A household's comparison group comprises geographically proximate houses of similar irrigable area and number of occupants.

The WaterSmart HWR uses injunctive norms to convey to the household how they are doing. For the EBMUD Pilot, households were told they are doing "Great" if their use was less than the 20th percentile of their usage comparison group, they are doing "Good" if their use was within the 20th and 55th percentiles, and to "Take Action" if their use was above the 55th percentile.[11] This messaging is reinforced with a large smiley face emoticon (in the shape of a water drop) whose expression -- smiley, neutral, or worried -- corresponds to where the household's water use falls within the distribution of water use for its comparison group (Figure 2).

[11] In other implementations of WaterSmart, households were placed in the "Good" group if their consumption was between the 20th and 50th percentiles. This was broadened to the 55th percentile for the EBMUD Pilot at the request of EBMUD staff.

Figure 1. WaterSmart Home Water Report Social Comparison Module

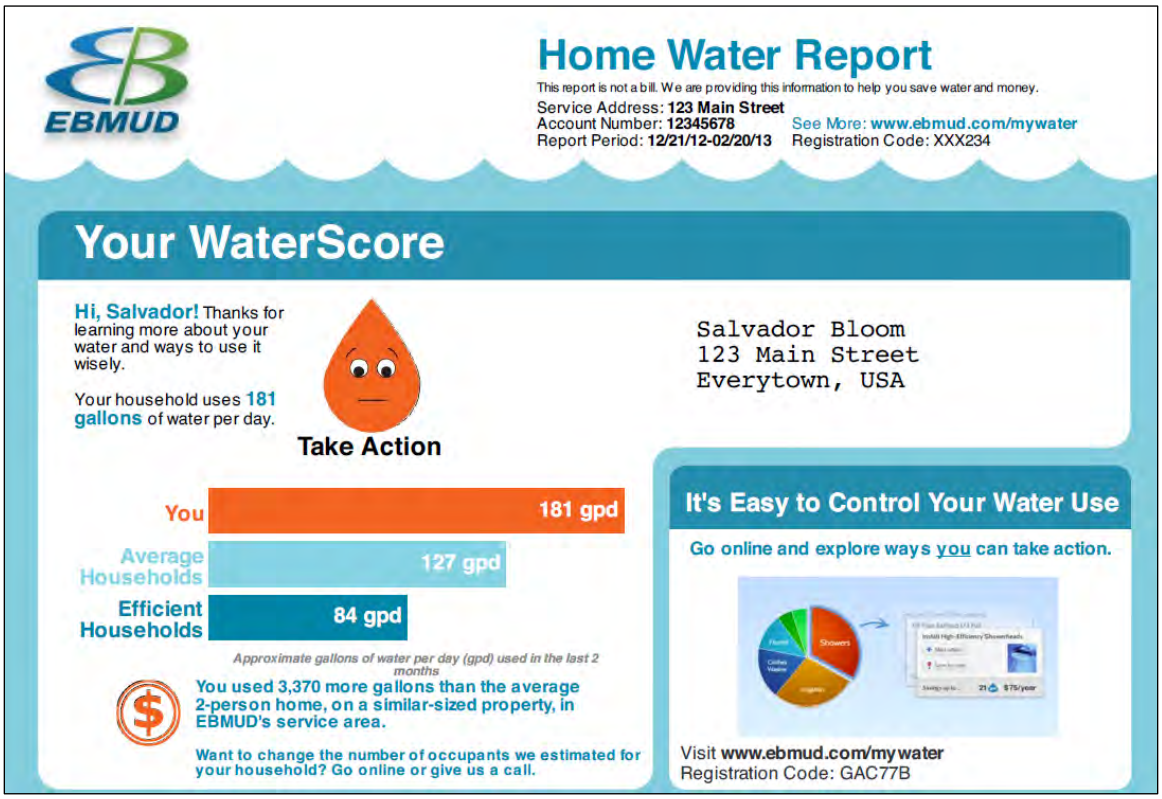


Figure 2. WaterSmart Emoticons Used With Injunctive Messages About Water Use

Great Smiling Smiley Face Indicates Household Use is Considered Efficient	 Neutral Smiley Face Indicates Household Use is Okay	Take Action Worried Smiley Face Indicates Household Use is Excessive

The second part of the report is the Suggested Actions Module. An example is shown in Figure 3. This module provides targeted recommendations of actions the household can take to use water more efficiently. The recommendations are tailored to each household based on their usage history, household characteristics, season of the year, and other factors. For example, actions related to landscape water use may be directed to households with high summer to winter use ratios or

suggestions related to leaks may be directed to households showing abnormally high use compared to their prior use history.

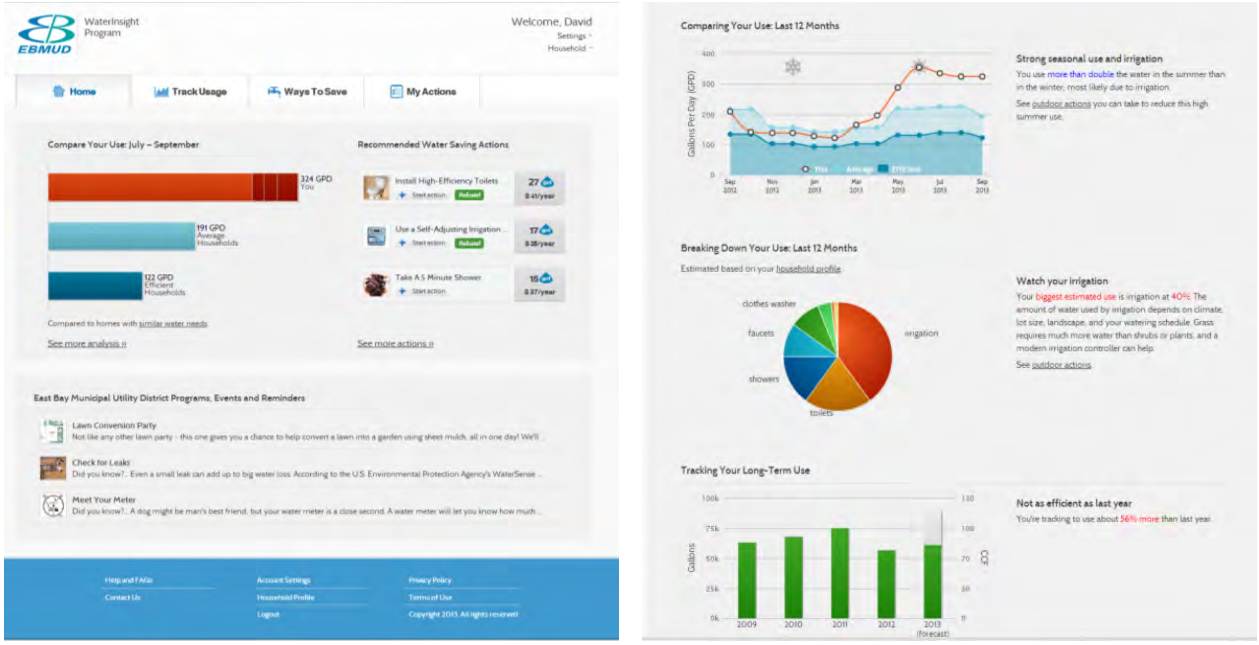
Figure 3. WaterSmart Home Water Report Suggested Actions Module

WaterSmart HWRs are delivered to households either via mail or electronically. The initial report is delivered electronically if WaterSmart has a valid email address for the household, and via mail otherwise. Households receiving paper reports can use the web portal to opt for electronic report delivery. HWR delivery is synchronized with the customer's billing cycle. In the case of the EBMUD Pilot, HWRs were delivered bi-monthly.

B. WEB PORTAL

WaterSmart HWRs direct households to a web portal where they can get more detailed information on their water consumption and tailored recommendations for reducing their consumption. The web portal for the EBMUD Pilot is called the WaterInsight Program. Users land on a home page where they get the most current summary of their consumption relative to their comparison group as well as recommended water saving actions. From the home page they can go to pages that allow them to verify or update information about their household; track their usage in greater detail; provide additional recommendations and tips for reducing consumption; and track the actions they have taken to reduce consumption. Figure 4 shows a screenshot of the home page and some of the usage charts on the Track Usage page.

Figure 4. WaterInsight Web Portal Used in EBMUD Pilot



IV. EBMUD PILOT

In this section we provide a descriptive summary of the EBMUD Pilot.

A. PILOT GOALS AND OBJECTIVES

EBMUD hoped to address three basic questions through the Pilot. First, would an SNB efficiency program like the one implemented by WaterSmart result in measurable reductions in household water use? Second, would it increase rates of participation in other EBMUD conservation programs? And third, would it increase household knowledge and awareness of their water consumption? According to interviews with EBMUD staff, the district had been interested for some time in using billing information and other household-level data to provide information to customers on their water usage relative to other households, encourage more efficiency, and direct customers to other EBMUD conservation programs. WaterSmart's implementation of HWRs provided an attractive turnkey solution that would enable the district to test the effectiveness of doing this. At the onset of the Pilot, EBMUD staff expected that it might reduce household water use by about 2%.[12]

[12] Personal communication with EBMUD Conservation Staff, October 22, 2013.

EBMUD hoped the Pilot would address a range of additional questions stemming from the three primary questions. These included:

1. To what extent do water savings vary seasonally? Are savings primarily due to changes in outside water use, inside water use, or a combination?
2. How do water savings relate to the information households receive on their HWRs about their water consumption relative to other similarly situated households? Are households that are above (below) the norm more (less) likely to reduce their consumption of water?
3. Does the level of savings depend on whether the household receives a paper or electronic HWR?
4. If HWRs increase participation in other conservation programs, which programs receive the greatest boost? Are households receiving HWRs that are above (below) the norm more (less) likely to participate in other conservation programs?
5. Are HWRs cost-effective? What is the expected cost per gallon saved for households receiving paper versus electronic HWRs?

In addition to these objectives, both EBMUD and WaterSmart were interested in exploring whether treatment effects differed when HWRs were provided to an entire community with similar characteristics rather than to randomly selected households spread across a service area, which was how WaterSmart had implemented a previous pilot for the City of Cotati.

B. PILOT EXPERIMENTAL DESIGN

The EBMUD Pilot was comprised of two experiments. The first we call the Random Group Experiment. The second we call the Castro Valley Group Experiment. In both experiments, households were selected to be in either a treatment group or a control group. Households in the treatment groups received HWRs while households in control groups did not. The treatment period, meaning the period when homes in the treatment groups received HWRs, ran from June 2012 through June 2013. Treatment in the Random Group Experiment spans this entire period. As we explain below, for the Castro Valley Group Experiment the treatment was rolled out in phases over this period, so that the duration of treatment varied among homes in this experiment. The details of each experiment are as follows.

1. Random Group Experiment

The Random Group Experiment consisted of randomly selected households that were split evenly between the treatment and control groups. EBMUD had previously developed a stratified random sample of its single family residential customers.[13] This sample was based on three geographic zones and seven parcel size classifications, resulting in 21 strata. For the Random Group Experiment, it proportionately sampled approximately 4,000 households from these strata. About 16% of the initially sampled households were ultimately excluded from the experiment, either because of data problems identified prior to the start of the experiment or because of discontinued service or significant data anomalies during the course of the experiment. The final count of households in the Random Group Experiment is 3,286, of which 1,576 were in the control group and 1,710 were in the treatment group.

The distribution of sampled residential accounts across EBMUD's pressure zone groups is shown in Table 1. Overall the sample is representative of the geographic distribution of residential accounts within EBMUD's service territory. Group G is somewhat under-sampled while Group F is somewhat over-sampled. A table with the proportion of sampled accounts from each of EBMUD's 120 pressure zones is provided in Appendix 1. It shows the sample is generally representative of the geographic distribution of residential accounts at the pressure zone level as well.

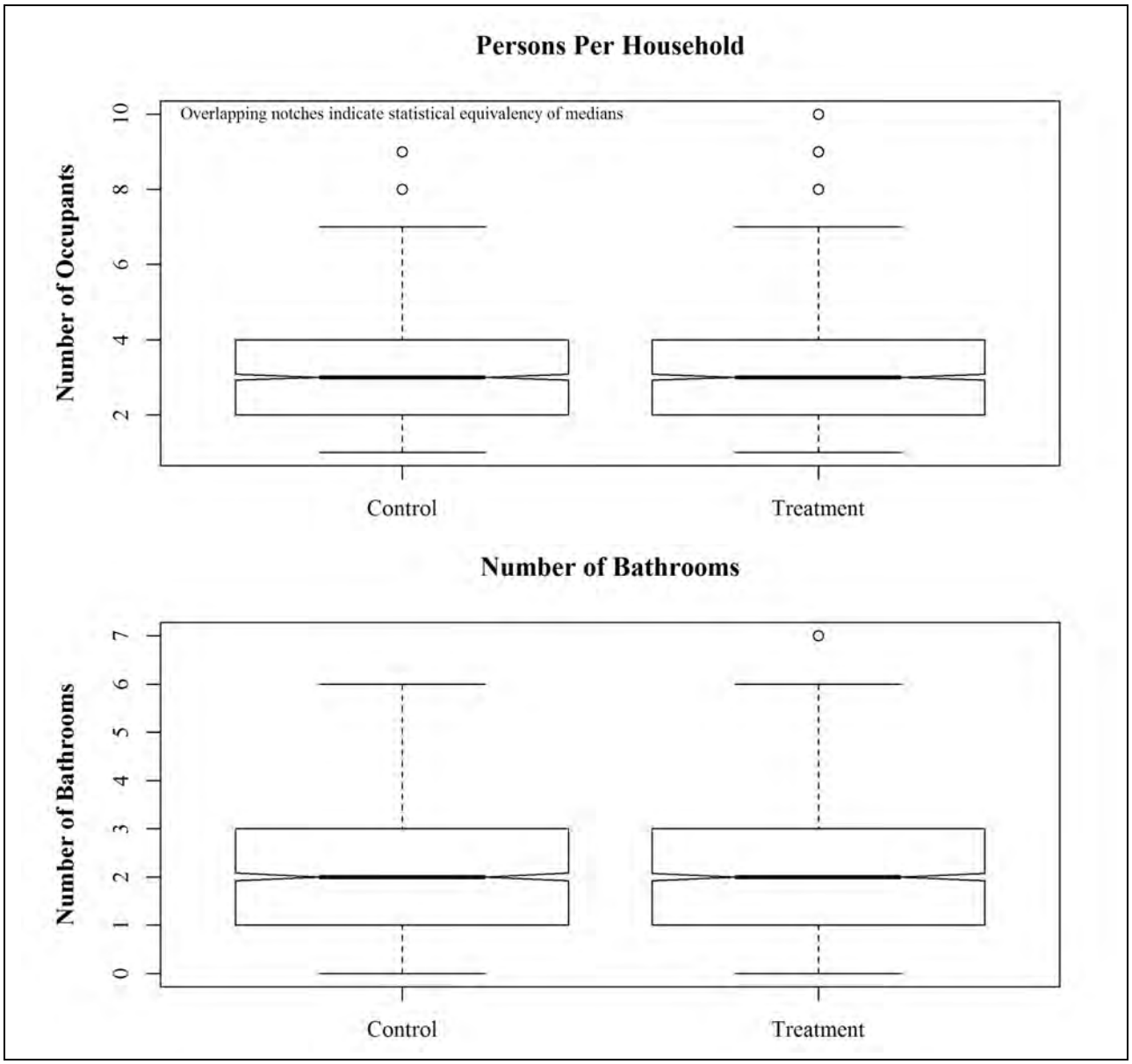
Table 1. Random Experiment Sample Distribution by Pressure Zone Group

Pressure Zone Group	No. of Zones	% Residential Accounts	% Sampled Residential Accounts		
			Total	Control	Treatment
A	32	15.6%	16.3%	8.3%	8.0%
B	23	8.7%	8.5%	4.7%	3.8%
C	15	6.6%	8.4%	1.7%	6.8%
D	20	4.4%	6.0%	2.8%	3.3%
E	8	2.2%	2.2%	1.1%	1.1%
F	17	12.5%	17.8%	9.2%	8.6%
G	4	46.9%	36.8%	18.3%	18.5%
H	1	3.1%	3.9%	1.9%	2.0%
Total	**120**	**100.0%**	**100.0%**	**47.9%**	**52.1%**

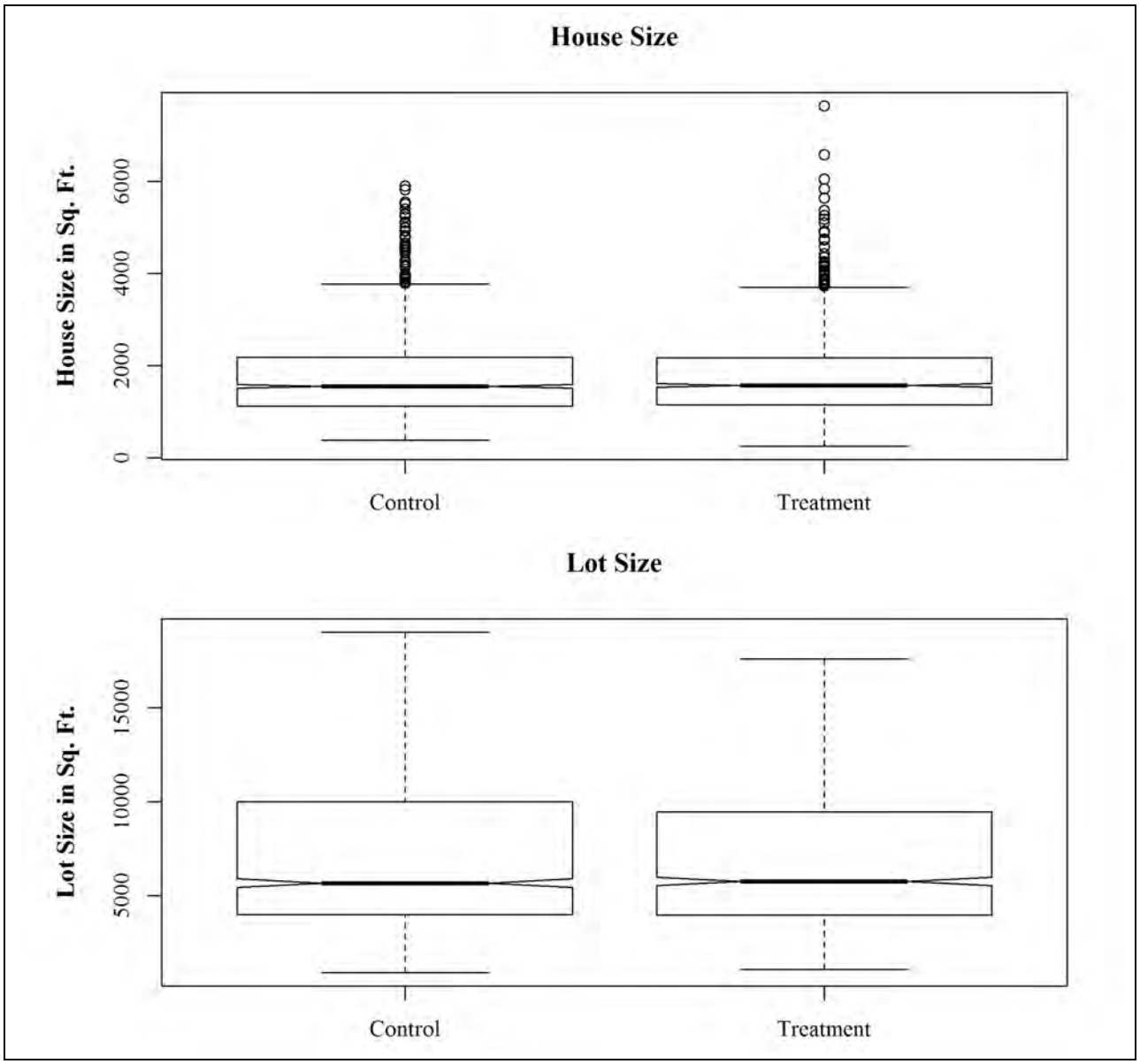
[13] EBMUD had developed the sample as part of the process it was using to calculate GPCD targets for 20x2020 (SBx7-7) compliance.

As would be expected for a random sample, the distributions of household attributes are essentially identical between the control and treatment groups, as shown in Figure 5.[14]

Figure 5. Random Experiment Sample Household Attributes

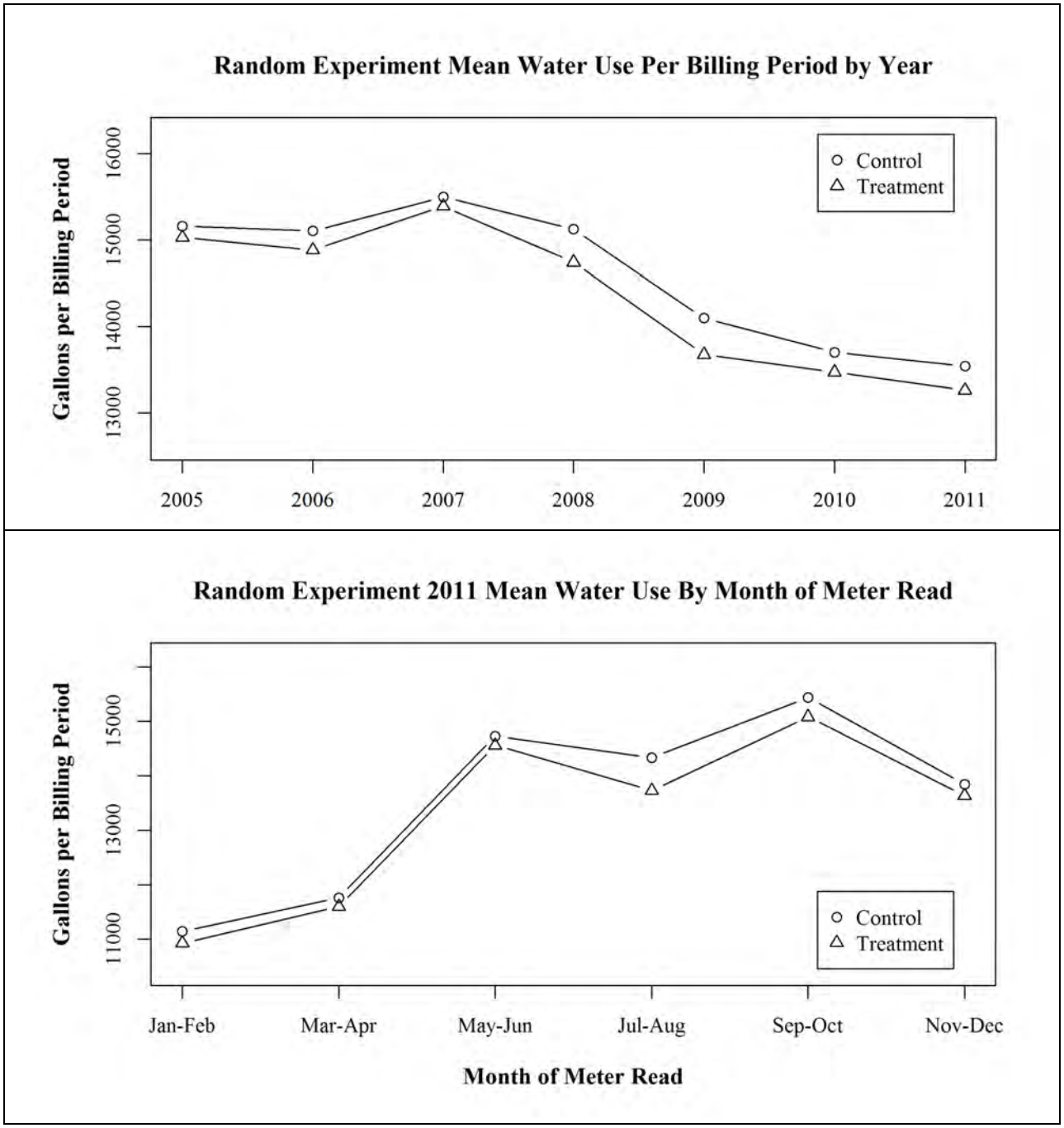


[14] The box plots in Figure 5 are interpreted as follows. The dark line segmenting the box is the median value. The top and bottom of the box are the 75th and 25th percentiles, respectively. The horizontal lines above and below the box denote the range of the distribution, excluding outliers. The circles above or below these horizontal lines represent outliers. If the notches in adjacent Control and Treatment boxes overlap, it strongly indicates the median values for the two groups are statistically the same.



The annual trend in water use prior to the start of the pilot and the seasonal pattern of water use also are similar, as shown in Figure 6. In the second panel of Figure 6, the x-axis refers to the month in which the meter was read and mean water use is for the two month period leading up to this date. For example, a meter read on 9/15 would include consumption roughly from 7/15 to 9/15. This is why Figure 6 shows a peak in mean water use for reads occurring in September and October, since reads in these months capture the bulk of summer use.

Figure 6. Random Group Temporal Patterns of Mean Water Use Per Billing Period



The first panel of Figure 6 shows a parallel trend in mean annual water use between the control and treatment groups. This is useful information for assessing the reliability of water savings estimates based on DID estimators. As previously noted, a key identifying assumption for a DID estimator is the pattern of use between the control and treatment groups would have remained the

same but for the treatment.[15] The first panel of Figure 6 strongly suggests this assumption holds for the Random Group Experiment. [16]

2. Castro Valley Group Experiment

The Castro Valley Group Experiment selected more than 8,000 single-family residences in the City of Castro Valley to receive Home Water Reports. These homes comprised the treatment group. Just over 1,300 homes in the Dingee Pressure Zone, which is adjacent to Castro Valley, thought to have similar single-family residential characteristics and climate comprised the control group for this experiment.[17] The distribution of sampled accounts by pressure zone is shown in Table 2.

Table 2. Castro Valley Experiment Sample Distribution by Pressure Zone

Pressure Zone	Control	Treatment
B5A	100%	
C2A		43.5%
C4A		34.7%
C4D		0.6%
C5C		7.0%
C5D		7.9%
C5E		1.0%
C6B		3.5%
C7A		1.8%
Total	**100%**	**100.0%**

Castro Valley was selected by EBMUD for the Pilot because the community is comprised of homes thought to approximate characteristics and climate of homes that would be targeted in a future expanded program implemented throughout the EBMUD service area. On average, compared to

[15] The idea being there are no exogenous factors other than the treatment causing changes in use of the treatment group but not the control group.

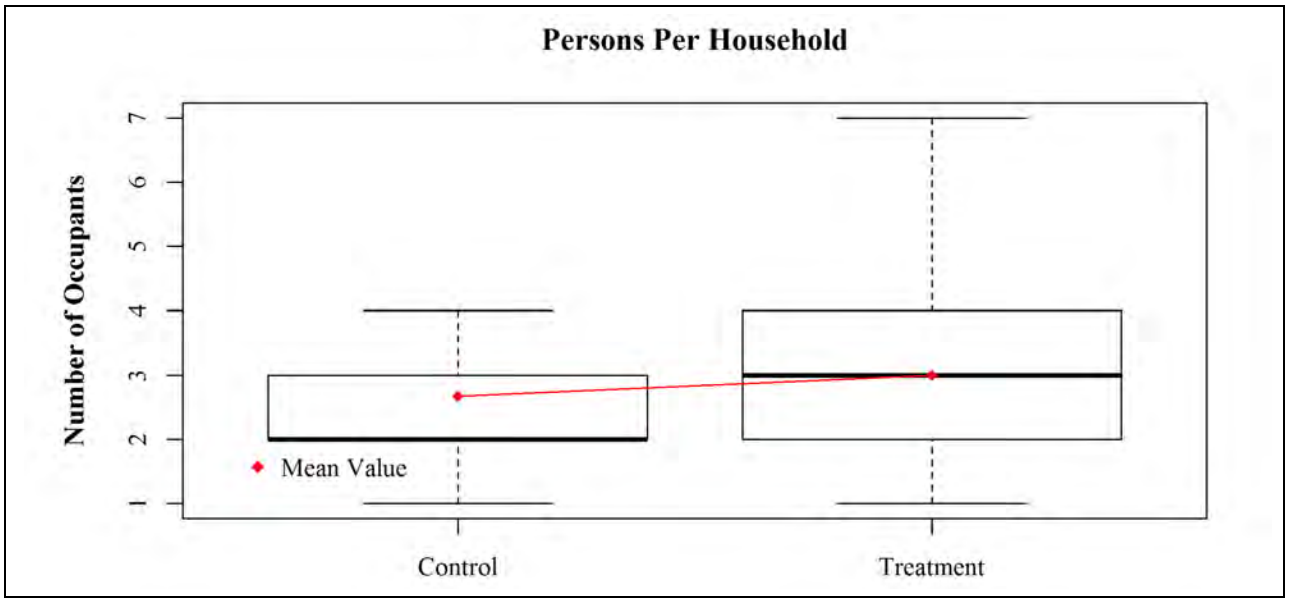
[16] For the reasons laid out in Sergici and Farugui (2011) and Chesnutt and McSpadden (1995), we employ panel data regression techniques to estimate the mean treatment effect on water use rather than a DID estimator.

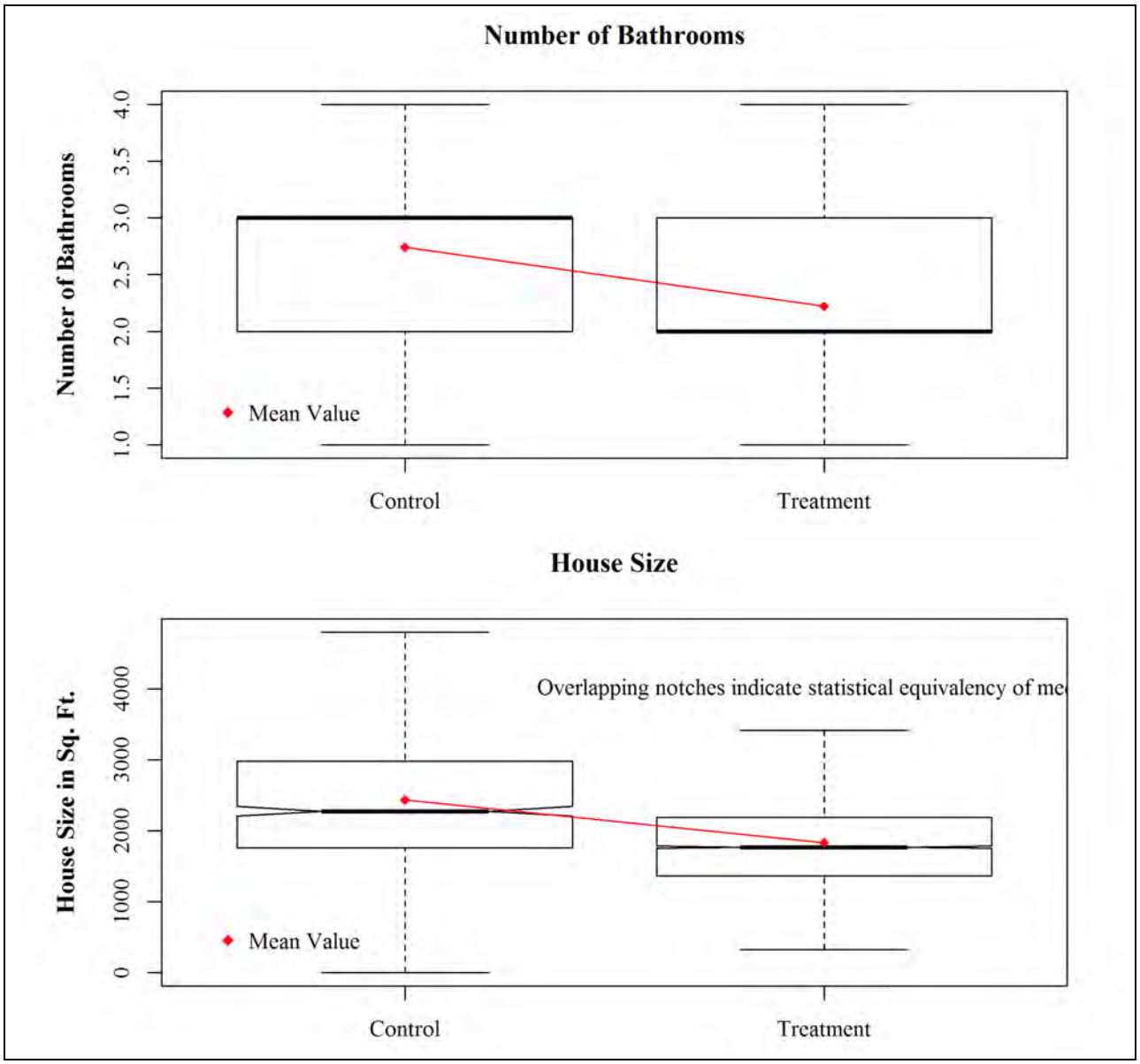
[17] These are the sample sizes developed by EBMUD and WaterSmart for the Castro Valley Group Experiment. For the analysis of treatment effect on residential water use we extended the number of households in the control group to provide better resolution on household water use. Thus, we use consumption records from 13,765 households to serve as controls in our statistical model of water use.

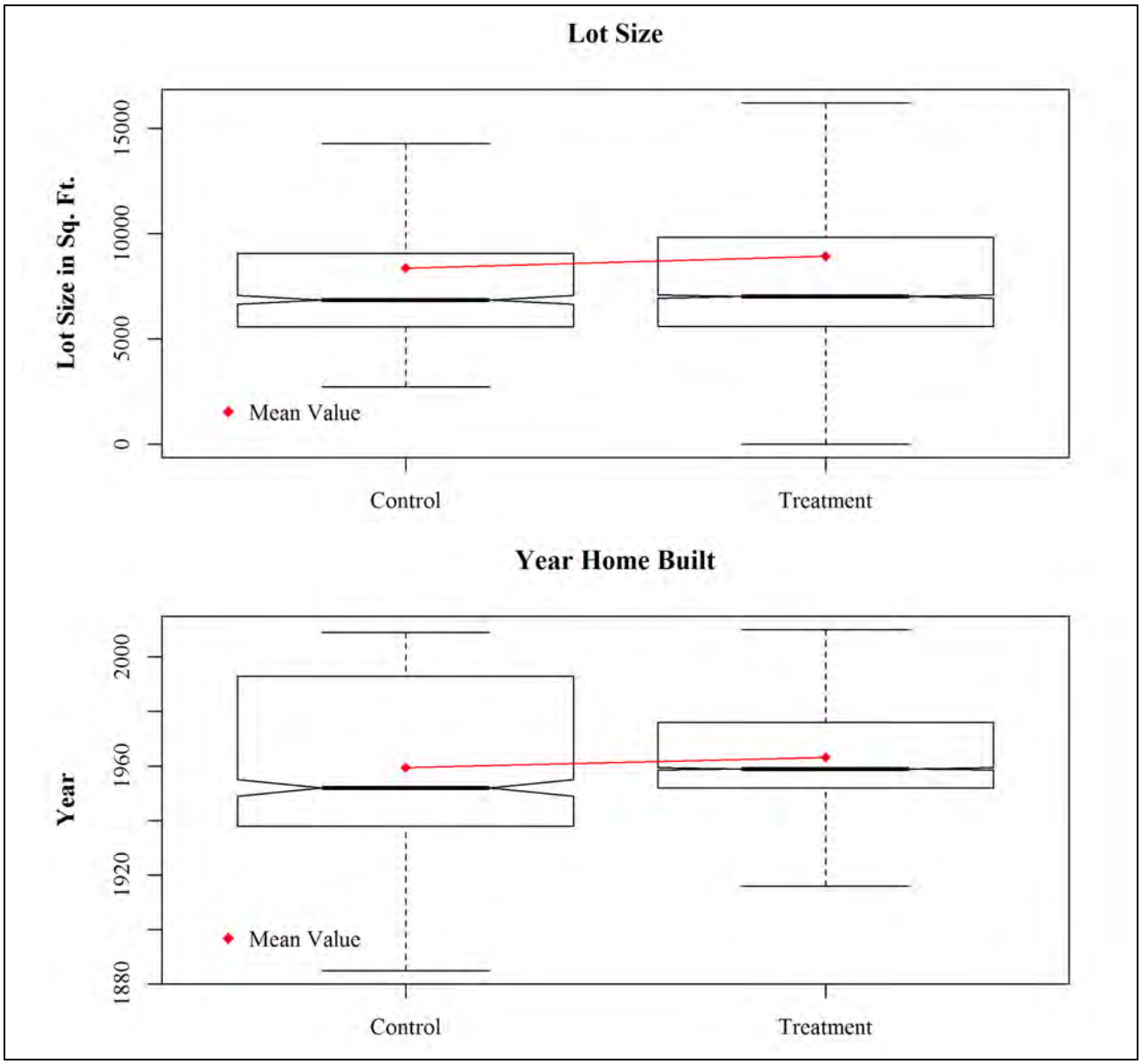
homes in the Random Group Experiment, homes in the Castro Valley Group Experiment are larger, have more bathrooms, and have larger irrigable area. They are also more homogenous, showing smaller coefficients of variation for key household characteristics. Most single family homes in Castro Valley are in the middle to upper-middle income brackets. The income distribution within the Random Group Experiment is more varied. Given the differential in home attributes between the two experiments, it was hoped the Castro Valley Group Experiment would provide insight into the effectiveness of HWRs directed at homes thought to be good targets, while the Random Group Experiment would provide insight into what the average effectiveness of HWRs might be if the program were expanded across EBMUD's whole service area.

The distributions of household characteristics for the control and treatment groups in the Castro Valley Group Experiment are summarized in Figure 7. Unlike the Random Group Experiment, the data show significant differences in household characteristics between control and treatment households. According to the data we obtained from WaterSmart, control group households tend to be larger and have more bathrooms, though fewer persons per household, on average. The age of control group homes is more varied and has a higher proportion of newer homes. Lot sizes are similar for the two groups, but water use per billing period is higher for the control group than for the treatment group.

Figure 7. Castro Valley Experiment Sample Household Attributes




Number of Bathrooms
Number of Bathrooms
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Mean Value
Control
Treatment
House Size
House Size in Sq. Ft.
0
1000
2000
3000
4000
Overlapping notches indicate statistical equivalency of me
Mean Value
Control
Treatment



As we describe in the next section, the Castrol Valley Group Experiment was rolled out in three phases. Originally the intention was to roll out the experiment in four phases, but the first two phases were ultimately combined. The rollout phases are therefore referred to as Phase 1/2, Phase 3, and Phase 4. The differences in household characteristics between the control and treatment groups by rollout phase are shown in Figure 8 and Figure 9. From these figures it is seen that Phase 1/2 and Phase 3 homes have similar attributes. Phase 4 homes are generally smaller, have fewer bathrooms, and smaller lots. These differences are only important if they have the potential to differentially affect home water use in the pre- and post-treatment periods, which could then confound estimates of

the treatment effect if not controlled for in the statistical model. This is not expected to be the case for attributes like number of bathrooms or house size.[18] It could be the case for lot size since this correlates positively with irrigable area and seasonal water use. Larger lot homes may be expected to respond differently than smaller lot homes to differences in weather between the pre- and post-treatment periods. Since Phase 4 and control group homes have significantly smaller lot sizes than Phase 1/2 and Phase 3 homes, it is necessary to put appropriate weather controls into the statistical model of mean treatment effect.

The distributions of water use per billing period by rollout phase are summarized in the top panel of Figure 10. Relative to homes in the control group, median and mean water use for homes in Phase 1/2 is higher; it is about the same in Phase 3 homes; and it is lower in Phase 4 homes.

The second panel of Figure 10 shows the time trend for mean water use per billing period for each treatment phase and the control group. This panel shows that the treatment and control groups followed generally parallel trends in annual use leading up to the start of the Pilot.

The seasonal pattern of water use for 2009-2011 is shown in Figure 11. Seasonal use in 2009 and 2010 follow nearly identical patterns, suggesting a fairly stationary relationship between the different treatment phases. However, seasonal use in 2011 deviates from this pattern with a dip in water use during the summer billing period (which corresponds to the spring to early summer consumption period). The relative position of the control group shifted somewhat in 2011, perhaps in response to weather anomalies during the spring months, which again points to the need to put appropriate statistical controls on weather effects when estimating the mean treatment effect of the Pilot on water use.

[18] We employ fixed-effects regression techniques to control for the stationary differences in home attributes.

Figure 8. Castro Valley Experiment Sample Household Attributes by Rollout Phase

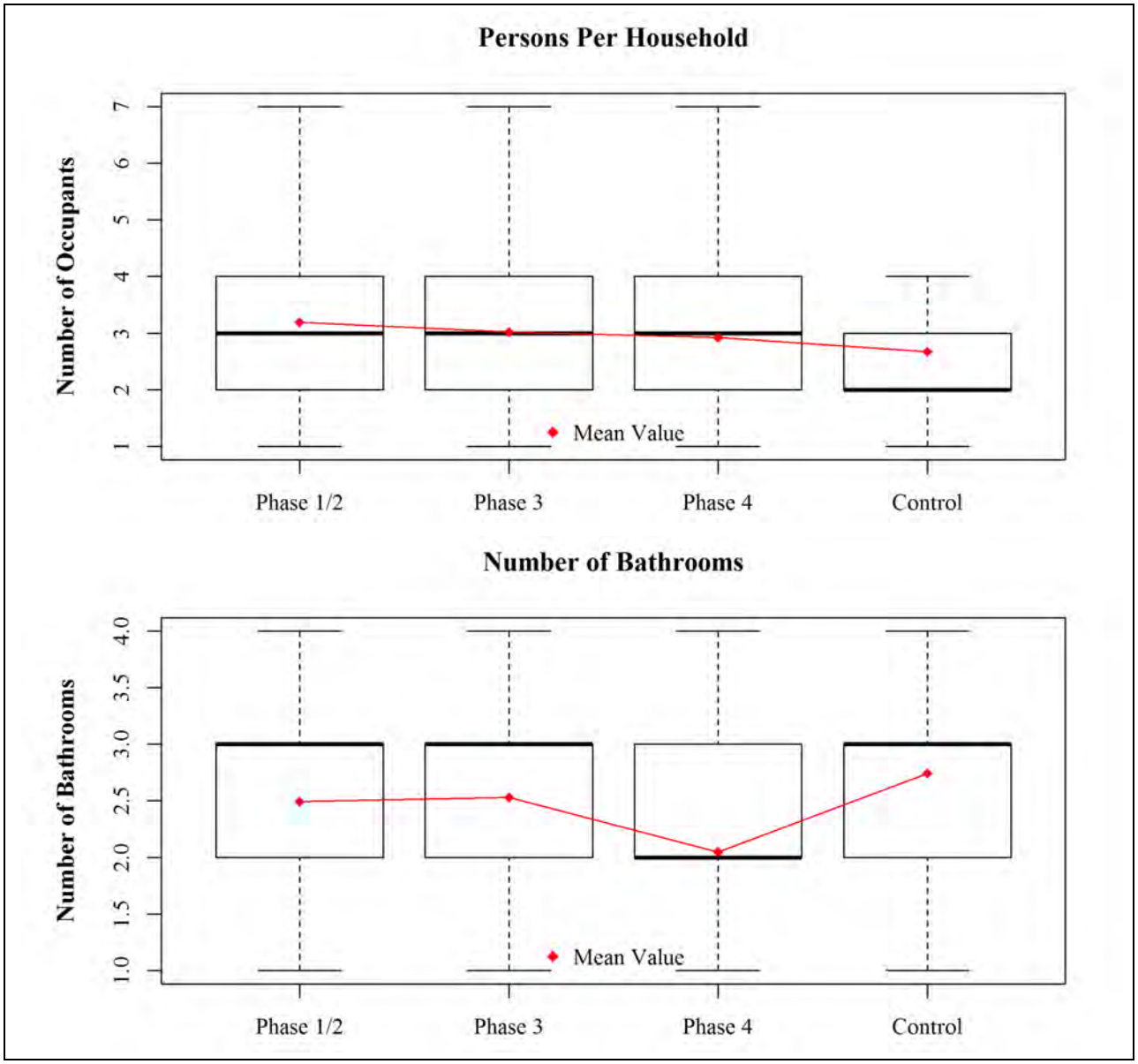


Figure 9. Castro Valley Experiment Sample Household Attributes by Rollout Phase

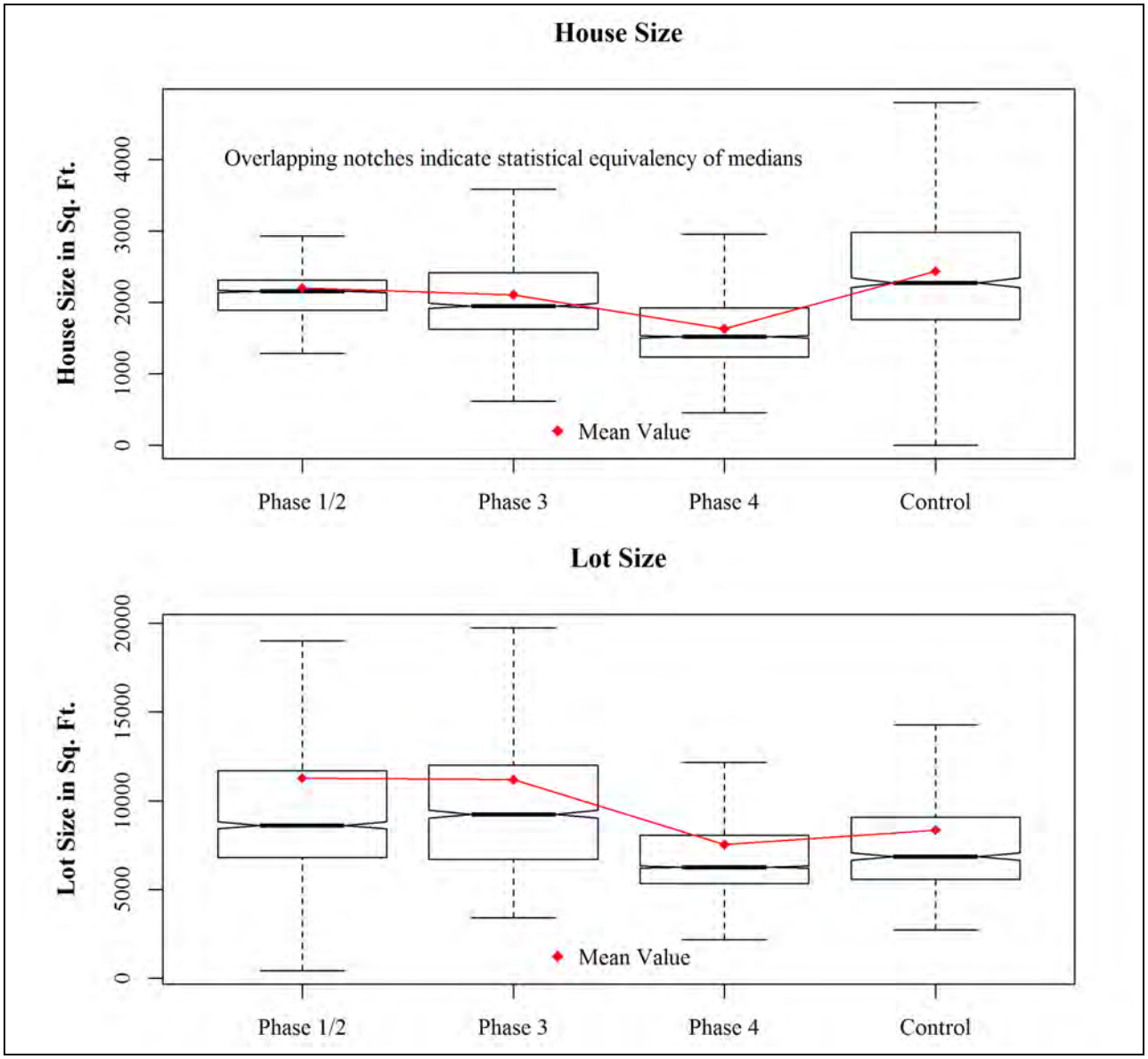


Figure 10. Castro Valley Experiment Water Use by Rollout Phase

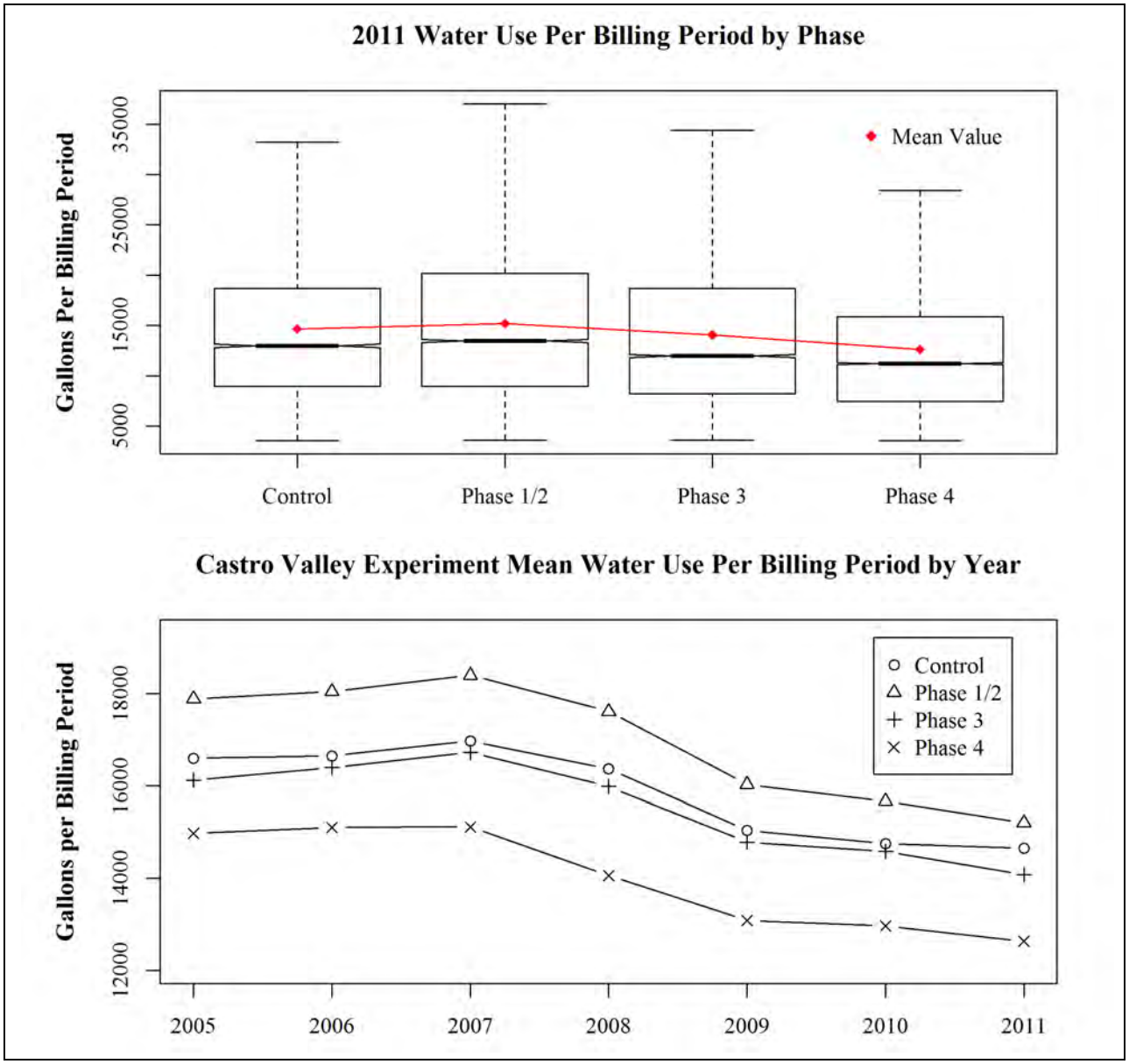
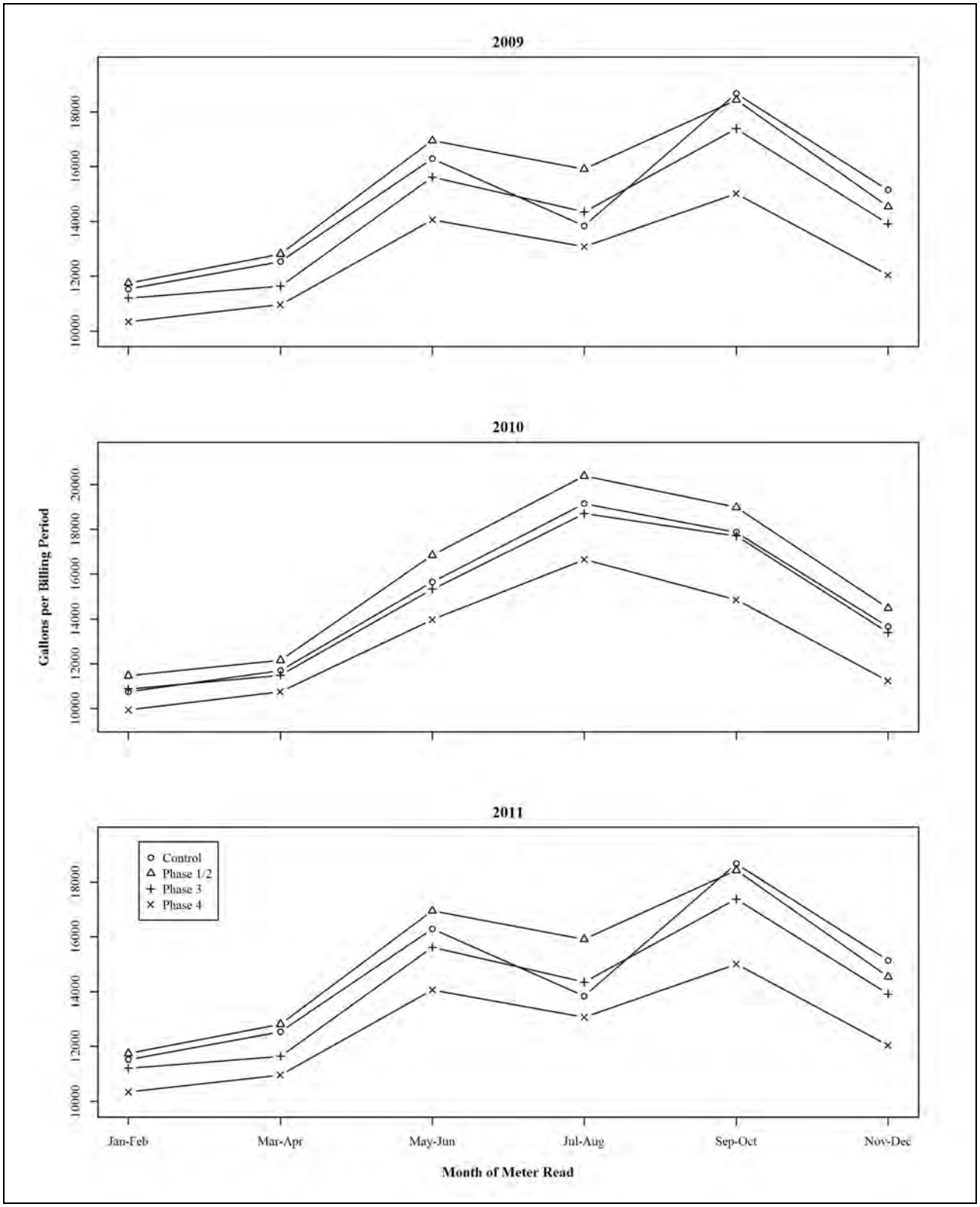


Figure 11. Castro Valley Group Seasonal Patterns of Mean Water Use Per Billing Period



C. CASTRO VALLEY HWR ROLLOUT PHASES

Primarily for administrative reasons, EBMUD chose to implement the Castro Valley Group Experiment in phases. Originally there were to be four phases. However, the first two phases were combined so ultimately the experiment was rolled out in three phases. As noted above, we refer to these phases as Phase 1/2, Phase 3, and Phase 4. Table 3 shows the number of homes in each phase along with the date they started to receive HWRs. Note there are two start dates for each phase. Which of the two dates applies for a particular home in a phase depends on its billing cycle. Homes in Phase 1/2 started receiving HWRs after June 15 or July 6 of 2012; homes in Phase 3 started receiving them after August 9 or September 7, 2012; and homes in Phase 4 started receiving them after October 7 or November 14, 2012.[19] The Pilot ran through June of 2013. Homes in Phase 1/2 received six or seven HWRs over the course of the Pilot. Homes in Phase 3 received five or six and homes in Phase 4 received four or five. Homes had continuous access to the web portal following the receipt of their first report.

Table 3. Castro Valley Group Experiment HWR Rollout

Phase	No. of Homes	HWR Start Date	No. Reports Received During Pilot
1/2	1,964	6/15/12 or 7/6/12	6 or 7
3	1,598	8/9/12 or 9/7/12	5 or 6
4	5,435	10/7/12 or 11/14/12	4 or 5

D. PRE-PILOT HOUSEHOLD SURVEY

Prior to the start of the Pilot, a household survey was administered to homes in the treatment group for the Castro Valley Group Experiment and to homes in both the control and treatment groups of the Random Group Experiment. The purpose of the survey was to collect information on household knowledge and attitudes about water use and conservation as well as information on household attributes, such as number of people in the home, number of toilets, presence and type of water using appliances, type of landscaping and irrigation, presence of pool or spa, etc. The information was used in creating the customer profiles, which were then used to tailor water saving

[19] Since the majority of the Castro Valley homes have meter read dates in the second half of the two-month billing cycle, the majority of the homes received reports in the latter months of July, September and November.

tips and other information provided on the HWRs and through the web portal. The pre-pilot survey had an approximately 20% response rate.

E. POST-PILOT HOUSEHOLD SURVEY

Following the end of the Pilot period, a second household survey was administered to homes in the treatment of control groups of both experiments. This survey was sent to an equal number of homes that did and did not respond to the pre-pilot survey. In total, surveys were sent to 4,766 households. The post-pilot survey had an approximately 31% response rate. Results from the two surveys are used in this evaluation to assess the mean treatment effect of HWRs on household knowledge and attitudes about water use and conservation.

V. EVALUATION OF PILOT OUTCOMES

In this section we present results of our evaluation of Pilot outcomes. Broadly, we address the three primary questions presented in Section IV.A:

1. Did the Pilot result in measurable reductions in household water use?
2. Did it increase rates of participation in other EBMUD conservation programs?
3. Did it increase household knowledge and awareness of their water consumption?

Within the context of each of these primary questions, we also present evaluation results for a range of secondary questions of interest. Additionally, we examine the cost-effectiveness of HWRs and their potential for integration with existing conservation programs.

A. WATER USAGE

Arguably the most important question to be addressed by the Pilot is did providing households with HWRs result in measurable reductions in household water use compared to the control group? While SNB efficiency programs are multi-dimensional in what they offer to utilities in terms of customer services and demand management, they are primarily marketed as a way to reduce customer water use.[20] As previously discussed, WaterSmart has reported savings estimates in the neighborhood of 5% for its City of Cotati and EBMUD pilots. WaterSmart's internal metrics, however, rely on less statistically robust DID methodology (Sergici & Farugui, 2011). To our

[20] Indeed, the banner across WaterSmart's homepage currently reads "Reduce Water Demand by 5% in 6 months."

knowledge, this report provides the first published independent evaluation of the effect of an SNB efficiency program on residential water use based on more robust panel data regression methodology.

1. Methodology

We use panel data regression techniques to estimate the mean effect of HWRs on household water consumption for the two experiments. Specifically, we estimated a fixed-effects model of water consumption that controls for time-variant seasonal and weather effects on consumption over the pre- and post-treatment periods as well as effects of unobserved time-invariant differences in household characteristics.

The general form of the model is given in equation (1):

(1) $$Use_{it} = \mu_i + S_t + W_t + E_{it} + \varepsilon_{it}$$

where Use_{it} is household i's average daily water use in period t, μ_i is household i's mean daily water use, S_t is the seasonal effect on average daily water use in period t, W_t is the weather effect on average daily water use in period t, E_{it} is the effect of HWRs on household i's average daily water use in period t, and ε_{it} is model error.

We model the seasonal and weather effects as continuous (as opposed to discrete bi-monthly) functions of time following the approach in Chesnutt and McSpadden (1995). We also include interactions between the seasonal and weather components to isolate season-specific weather responses.

The seasonal term, S_t, is formed by the Fourier series shown in equation (2), where d = 1, 2, 3, ... 365 is an index of the days of the year, and $\underline{d}_t$ and $\overline{d}_t$ are the first and last indexed days in period t, respectively.[21] For this analysis, we assume the number of days between billing periods, $\left(\overline{d}_t - \underline{d}_t + 1\right)$, is a constant 61 days.

[21] A Fourier series is an expansion of a periodic function f(x) in terms of a sum of sines and cosines. The use of Fourier series to represent periodic functions is called harmonic analysis, which was first employed to estimate a seasonal component in a regression context by Hannan(1960). Jorgenson (1964) extended the use of harmonics in least squares estimation to include both trend and seasonal components. Note that if t has the length of 1 day (e.g., daily observations of water use), then equation (2) simplifies to $S_t \equiv \sum_{j=1}^{6} \left\{\beta_{1j} \cdot sin\left(\frac{2\pi \cdot j \cdot t}{365}\right) + \beta_{2j} \cdot$

(2) $$S_t \equiv \sum_{j=1}^{6}\left\{\beta_{1j}\cdot\frac{1}{(\overline{d}_t-\underline{d}_t+1)}\sum_{d=\underline{d}_t}^{\overline{d}_t} sin\left(\frac{2\pi\cdot j\cdot d}{365}\right)+\beta_{2j}\cdot\frac{1}{(\overline{d}_t-\underline{d}_t+1)}\sum_{d=\underline{d}_t}^{\overline{d}_t} cos\left(\frac{2\pi\cdot j\cdot d}{365}\right)\right\}$$

The model incorporates two types of weather measures into the weather component -- rainfall and average daily evapotranspiration -- both of which are logarithmically transformed. These measures are defined in equation (3).[22]

(3) $$R_t \equiv ln\left[1+\sum_{d=\underline{d}_t}^{\overline{d}_t} Rain_d\right], ET_t \equiv ln\left[\frac{1}{(\overline{d}_t-\underline{d}_t+1)}\sum_{d=\underline{d}_t}^{\overline{d}_t} ET_d\right]$$

Because weather has a strong seasonal pattern, the weather measures are correlated with the seasonal component. To address this collinearity, the weather component is constructed as a departure from the "normal" or expected weather given the season, as shown in equation (4).

(4) $$W_t \equiv \left(R_t-\hat{R}_t\right)\cdot\beta_R+\left(ET_t-\widehat{ET}_t\right)\cdot\beta_{ET}$$

The expected values for rainfall, $\hat{R}_t$, and evapotranspiration, $\widehat{ET}_t$, are derived from regression against the seasonal harmonics. The weather measures expressed in this way are thereby separated from the seasonal effects. The seasonal component, therefore, captures all constant seasonal effects, including those caused by normal weather conditions, while the weather component captures the effect of weather departing from its normal pattern (e.g. unusually wet or dry for the given time of year).

The effect of HWRs on average daily water use is specified in equation (5), where the indicator variable, I_{it}, takes the value 1 if household i is receiving HWRs in period t and 0 otherwise.

(5) $$E_{it} \equiv I_{it}\cdot\beta_{HWR}$$

The coefficient β_{HWR} measures the mean treatment effect of HWRs on average daily water use and is expected to have a negative sign if HWRs induce lower average daily water use.[23] Note

$cos\left(\frac{2\pi\cdot j\cdot t}{365}\right)\Big\}$. The index j represents the frequency of each harmonic. Because the lower frequencies tend to explain most of the seasonal variation in average daily water use, the higher frequencies can often be omitted with little predictive loss.

[22] Total rainfall in period t is scaled by adding one in equation (3) to accommodate periods in which total rainfall is zero, in which case the logarithm of total unscaled rainfall would be undefined.

that β_{HWR} captures the effect on average daily water use of both changes to behavior and any induced participation in other conservation programs. We interact I_{it} with treatment group affiliation to separately estimate the mean treatment effect for each experiment. We also interact it with other indicators of household characteristics -- e.g., Water Score, paper vs. email report, consumption level -- to measure how the treatment effect varies with these factors.

We use Hausman's specification test to select between a fixed effects or a random effects estimator. While a random effects estimator can be more efficient, it depends on a more restricted set of assumptions about the structure of the model error, ε_{it}. Hausman's specification test indicated these assumptions were unlikely to hold and we therefore adopted a fixed effects estimation approach. The model was estimated in STATA (version 13.1) using the panel data estimator for fixed effects models with consistent standard errors for clustered data.

2. Data and Estimation

We compiled household metered consumption records from January 2006 to September 2013. We converted metered consumption to average daily use by dividing by the length of the billing period.[24] These data were then matched to the corresponding weather data for each billing period.

We collected daily weather measurements -- precipitation, maximum air temperature, and evapotranspiration -- from the CIMIS weather stations located in EBMUD's service area: Union City/Oakland Foothills (CIMIS station #149), Concord (CIMIS station #170), and Moraga (CIMIS station #178). Customer accounts were assigned to one of the three stations on the basis of zip code.

[23] Because average daily water use is logarithmically transformed prior to estimation, the coefficient β_{HWR} approximates the percentage difference in average daily water use between households that receive HWRs (i.e. receive the treatment) and households that do not.

[24] As previously noted, we treat the length of the billing period as a fixed 61 days. While this is not strictly true in all cases, doing so greatly simplifies the conversion of the billing data to average daily use with little predictive loss.

We then generated rolling bimonthly averages of rainfall, temperature, and evapotranspiration to exactly match the weather variables to the meter read dates for household water use.[25]

Data from meter reads can contain a lot of noise in the form of missing reads, duplicative reads, erroneous reads, and interpolated reads. This resulted in the elimination of some accounts from the sample for data quality reasons—too short a pre-intervention consumption history, change of residence, unconfirmed high consumption reading. Robust regression techniques were used on the remaining data to detect and address any residual data quality errors. This methodology determines the relative level of inconsistency of each observation with a given model form. A measure is constructed to depict the level of inconsistency between zero and one; this measure is then used as a weight in subsequent regressions. Less consistent observations are thereby down-weighted during model estimation.

Table 4 presents the counts on the final sample used to estimate the water use model given in equation (1).[26]

Table 4. Model Estimation Sample Sizes by Experiment

	Treatment	Control	Total
Castro Valley Group			
No. Households	10,529	13,765	24,294
No. Meter Reads	362,198	473,204	835,402
Random Group			
No. Households	1,710	1,576	3,286
No. Meter Reads	58,824	54,214	113,038

[25] A meter read represents the end of a consumption period. For example, a meter read on June 30 would represent consumption roughly from May 1 to June 30. However, meters are read on a schedule that often does not coincide with the start or end of calendar months. Thus, the need to work with daily weather data so that the weather variables can be correctly aligned with the corresponding consumption data.

[26] The sample sizes in Table 4 for the Castro Valley Group Experiment differ from the sample as originally developed by EBMUD and WaterSmart because we expanded the control group in order to get better statistical resolution on the treatment effect on water use.

3. Estimation Results

Model estimation results are presented in Table 5. The results are based on water consumption for 27,580 single family households between January 2006 and September 2013. This sample contains 1,710 households in the treatment group of the Random Group experiment, 10,529 households in the treatment group of the Castro Valley Group experiment, and over 15,000 single family control households.

The first variable in Table 5 is the overall intercept term. The estimated model also includes fixed effects intercepts for each household represented in the model, which are excluded from the table for obvious reasons of parsimony. Variables 2 thru 9 comprise the seasonal component, S_t, of the model. These correspond to the sines and cosines of the Fourier series in equation (2). These variables and their coefficients describe the shape of demand over the year given normal weather. Variables 10 thru 16 measure changes in average daily use that result from departures in weather from normal conditions. Thus, variables 10 and 11 indicate that above average rainfall pushes demand down (as one would expect), while variable 14 shows that higher than average evapotranspiration pushes demand up (again as one would expect). Interactions between season and weather are captured by variables 12 and 13 for rainfall and by variables 15 and 16 for evapotranspiration. The coefficients for these variables indicate that departures of evapotranspiration from normal produce the largest percentage effect in the spring growing season. Similarly, an inch of rainfall produces a larger effect on water use in the summer than in the winter.

The treatment effects of HWRs are captured by variables 17 thru 23. These variables represent an expanded version of equation (5) to include interactions with other household characteristics. The main effect for the Random and Castro Valley experiments are given by the coefficients for variables 17 and 18, respectively. Both are negative and statistically different from zero at better than 99% confidence, meaning the model definitively rejects the null hypothesis of no treatment effect on average daily water use.

Table 5. Household Average Daily Water Use Fixed Effects Model Estimation Results

Model Variable	Coeff.	St. Err.	t-statistic
1. Constant (Mean intercept)	5.2406	0.0003	17468.67***
2. First Sine harmonic, 12 month (annual) frequency	0.0485	0.0007	69.29***
3. First Cosine harmonic, 12 month (annual) frequency	-0.337	0.0017	-198.24***
4. Second Sine harmonic, 6 month (semi-annual) frequency	0.0000	0.0006	0.00
5. Second Cosine harmonic, 6 month (semi-annual) frequency	0.0003	0.0007	0.43
6. Third Sine harmonic, 4 month frequency	-0.0128	0.0008	-16.00***
7. Third Cosine harmonic, 4 month frequency	0.0235	0.0008	29.38***
8. Fourth Sine harmonic, 3 month (quarterly) frequency	-0.0076	0.0014	-5.43***
9. Fourth Cosine harmonic, 3 month (quarterly) frequency	-0.0092	0.0013	-7.08***
10. Deviation from logarithm of 61 day moving sum of rainfall	-0.0525	0.001	-52.50***
11. Bimonthly lag from rain deviation	-0.0051	0.0008	-6.38***
12. Interaction of contemporaneous rain with annual sine harmonic	-0.0475	0.0013	-36.54***
13. Interaction of contemporaneous rain with annual cosine harmonic	0.0126	0.0012	10.50***
14. Deviation from logarithm of 61 day moving average of CIMIS Evapotranspiration	0.2537	0.0047	53.98***
15. Interaction of CIMIS Evapotranspiration with ann. sine harmonic	0.261	0.0053	49.25***
16. Interaction of CIMIS Evapotranspiration with ann. cosine harmonic	0.1306	0.005	26.12***
17. Main Effect of HWR Intervention Random Group	-0.0564	0.0162	-3.48***
18. Main Effect of HWR Intervention in Castro Valley Group	-0.0742	0.0045	-16.49***
19. Interaction of HWR Intervention with bottom usage quartile (0-25%)	0.0292	0.0121	2.41**
20. Interaction of HWR Intervention with top usage quartile (76-100%)	-0.0116	0.0063	-1.84*
21. Interaction of HWR Intervention with Email Delivery	0.0111	0.0074	1.50
22. Interaction of HWR Intervention with Max Water Score of 2	0.0192	0.0123	1.56
23. Interaction of HWR Intervention with Max Water Score of 1	0.0546	0.0272	2.01**
Number of observations	948,440		
Number of households	27,570		
Standard Error of Individual Constant Terms (sigma_u)		0.59	
Standard Error of White Noise Error (sigma_e)		0.4172	
Time period of Consumption	Jan. 2006 - Sep. 2013		
* significant at 90% confidence level, ** significant at 95% confidence level, *** significant at 99% confidence level			

4. Mean Treatment Effect

The coefficients on variables 17 and 18 represent the treatment effect for households receiving paper reports with pre-treatment consumption that fell between the 25th and 75th percentiles. For the Random Group Experiment (variable 17), households in this category reduced

consumption by approximately 5.5% (95% CI 2.4% to 8.4%).[27] Similarly situated households in the Castro Valley Group Experiment (variable 18) reduced consumption by approximately 7.1% (95% CI 6.3% to 8.0%).

To get the mean treatment effect for the full sample in each experiment we take a weighted average of the product of the intervention variables (17-23) and their estimated coefficients.[28] For the Random Group Experiment we estimate an overall mean treatment effect of 4.6%. For the Castro Valley Experiment we estimate an overall mean treatment effect of 6.6%. While the mean treatment effect for the Castro Valley Experiment is greater than for the Random Group Experiment, we cannot reject the possibility that this is due to chance, since the confidence intervals surrounding the two estimates overlap. However, a larger effect in the Castro Valley experiment is not implausible given the greater homogeneity of the homes in terms of household characteristics and water use (see Section IV.B). Indeed, a primary reason that EBMUD selected Castro Valley for the experiment was the belief that its homes would be good candidates for HWRs.

5. Impact of Household Water Use Percentile on Treatment Effect

A question relevant to the targeting of HWRs if they are not going to be provided on a universal basis is whether savings scale with level of water use. That is, is the treatment effect larger for households in the upper percentiles of consumption than for households in the lower percentiles? The model results suggest the answer is yes. We find that the treatment effect for households in the bottom quartile of use is reduced by about 2.9% while it is increased by about 1.1% for households in the upper quartile of use, relative to households with use in the inter-quartile range. The difference in treatment effect between households in the middle two quartiles and households in the upper quartile is not statistically significant. This is not the case for households in the bottom quartile, where the difference is significant. The results suggest utilities should consider giving households in the bottom quartile of use lower priority for receiving HWRs if they are not to be universally provided.

[27] While the coefficient is -0.0564, we are employing the estimator proposed by Kennedy (1981) for the expected percentage change for an indicator variable in a model with a logarithmically transformed right hand side variable, which is $exp(\hat{\beta}_{HWR} - 0.5\hat{\sigma}^2) - 1$, where $\hat{\beta}_{HWR}$ is the estimated coefficient and $\hat{\sigma}^2$ is its estimated variance. Thus, $exp(-0.0564 - 0.5(0.0162)^2) - 1 \approx -0.055$.

[28] We again employ the second order correction described in the previous footnote.

6. Impact of Water Score on Treatment Effect

We also find that treatment effect scales with HWR score. Thus, we calculate a treatment effect of 7.1% if a household in the Castro Valley treatment group received a HWR score of 3 (Take Action!); a treatment effect of 5.2% if it received a HWR score of 2; and a treatment effect of just 1.6% if it had a HWR score of 1 (Doing Great!). We view the results as indicating correlation of treatment effect with the HWR score but not necessarily causation. While it is certainly plausible that the injunctive norms implicit in the HWR scores and corresponding emoticons may motivate participation -- after all households getting a score of 3 are the only households explicitly told to take action -- it also could be the case that other underlying factors that correlate with the score are causing the response. For example, since score correlates with where households fall within the distribution of water use within their cohort, it could also be the case that households in the upper percentiles of their comparison group find more ways to reduce water use -- perhaps because they have more older water using fixtures or larger landscapes where they can make adjustments -- while households in the lower percentiles may already have efficient fixtures and perhaps minimal or already water efficient landscapes. In this case, while the injunctive norm to take action may provide some of the motivation to reduce use, other factors could also be at play. Allcott (2011) addressed this question with respect to the mean treatment effect of Opower home energy reports on energy consumption and concluded that the injunctive norms could explain no more than 15% to 30% of the differential effect in response across scores. As we discuss later in the report, we find similar effects between the HWR score and the odds of a household participating in an EBMUD audit or rebate program.

7. Impact of Paper vs Electronic Reports on Treatment Effect

Because electronic reports delivered by email offer a definite cost advantage over paper reports, there is interest in whether they generate equivalent savings. The model results suggest they do not. The coefficient on variable (21) indicates that email reports reduced the treatment effect by about 1%. We also note, however, that we cannot reject the null hypothesis of no difference at the 95% confidence level. Thus our evaluation does not provide a definitive answer to the question, other than to suggest that paper reports appear to have greater impact, on average. Even if savings are lessened by use of email reports, the cost savings may nonetheless justify their use. We take up this question later in the report.

8. Seasonal Shape of Treatment Effect

Preliminary models provide some evidence of stronger treatment effects associated with reports received in the fall and winter than in the spring and summer.[29] This finding suggests a lagged response to high water use since households using large amounts of water in the summer do not receive feedback on this until they receive reports in the late summer and fall. More research is needed to better parse the seasonality of treatment effect. In particular, a longer period of treatment spanning more than 12 months would provide better information with which to examine this question.[30]

B. CONSERVATION PROGRAM PARTICIPATION

As discussed in the previous section, embedded in the mean treatment effect on average daily water use are any changes in use resulting from increased participation in EBMUD audit and rebate programs. In this section we examine the question of whether and to what extent homes in the treatment groups of the two Pilot experiments were more likely to participate in EBMUD audit and rebate programs. Home energy reports have been reported to increase customer participation in other energy efficiency programs. This effect is sometimes referred to as "uplift" or "channeling" in the literature. Opower, the largest provider of home energy reports, claims its home energy reports have increased participation in other energy conservation programs by 17 to 59%. On its website, WaterSmart claims up to a three-fold increase in program participation for homes receiving HWRs.[31]

1. Pre-Pilot Program Participation

During the four years prior to the start of the Pilot, program participation rates were similar for the treatment and control groups of both experiments, as shown in Figure 12 and Figure 13. In particular, both groups exhibit similar trends in participation over time, with participation declining steadily from 2008 to 2011. The sample participation rates in each year are statistically equivalent between the control and treatment groups of each experiment with one exception. The one exception is 2008 rebate participation rates for the Castro Valley Experiment. In subsequent years, however,

[29] This seasonal effect was also detected by Brent, et al (2013).

[30] Recall that households in Phase 4 did not start receiving HWRs until October or November and these homes comprised the bulk of the Castro Valley treatment group.

[31] http://www.watersmartsoftware.com/our-solution.html#our-solution

the differences in the sample participation rates are not statistically significant at the 95% confidence level.[32]

From this data we conclude that rates of participation for the treatment and control groups in both experiments were very similar both in magnitude and trend leading up to the Pilot. This suggests the key identifying assumption of parallel trend needed for the difference-in-differences modeling approach is likely to hold for the two experiments with regard to program participation.

[32] If the paired confidence intervals in Figure 12 overlap, it indicates the difference between the control and treatment group participation rates are not statistically significant. Conversely, if they do not overlap, it indicates the difference is statistically significant. Note the wider confidence interval for the control group compared to the treatment group in the Castro Valley Group Experiment is due to the smaller sample size for the control group.

Figure 12. Pre-Pilot Audit Program Participation Rates

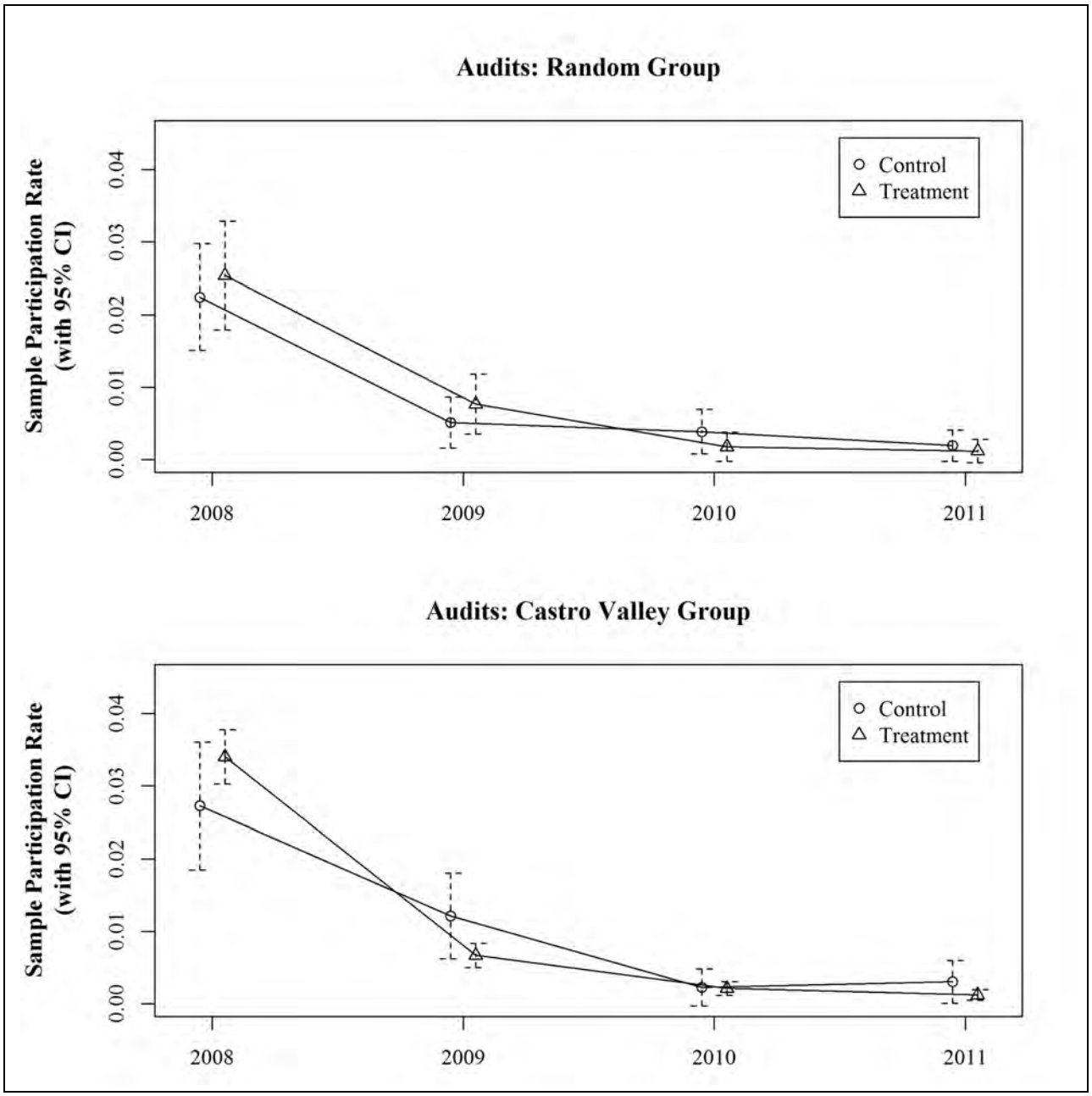
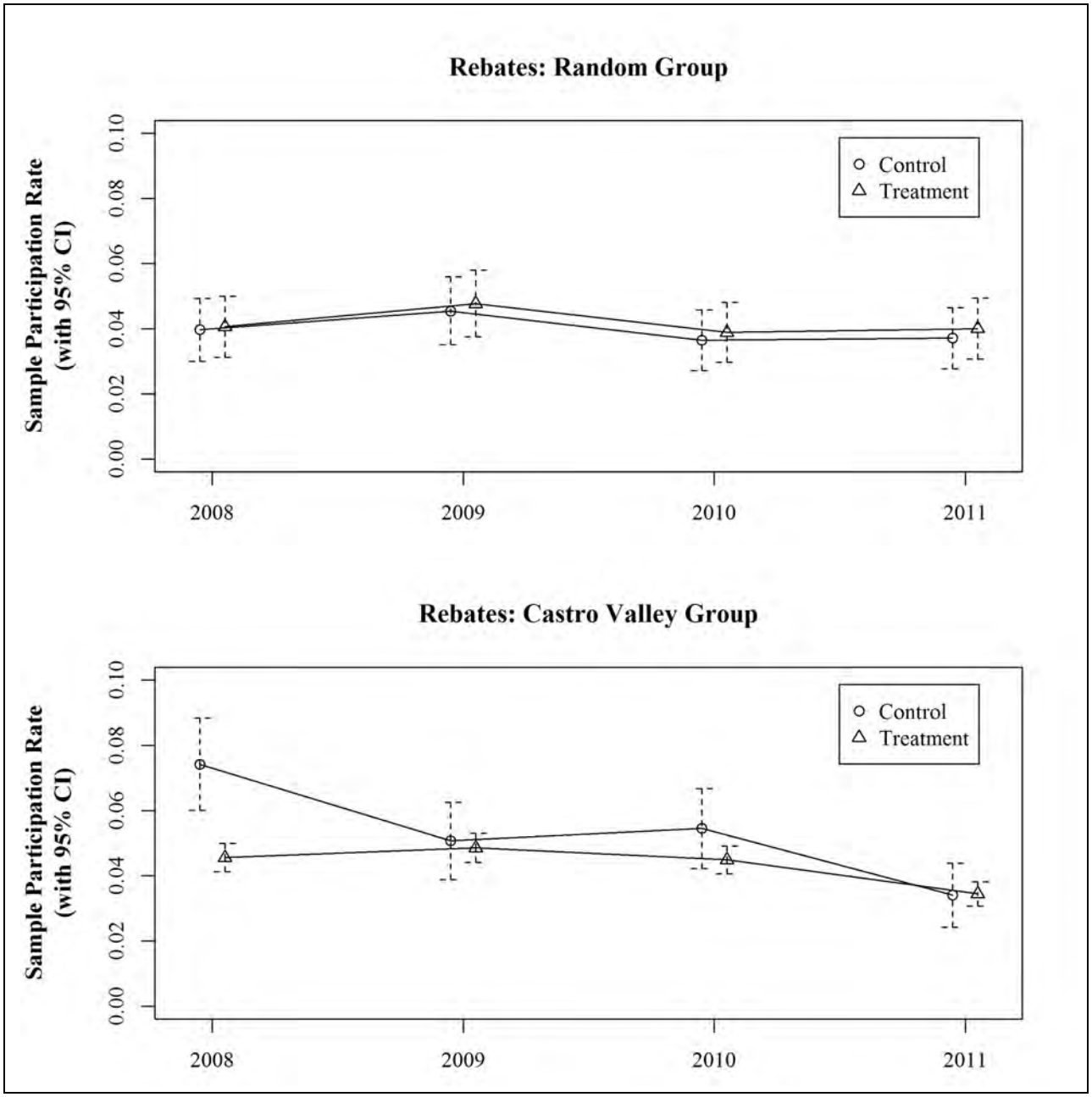


Figure 13. Pre-Pilot Rebate Program Participation Rates



2. Post-Pilot Program Participation

Participation rates in audit and rebate programs pre- and post-treatment are summarized in Figure 14 and Figure 15. These rates are for the Phase 1/2 treatment groups, which received a full year of HWRs. We define the pre-treatment period as the year prior to the start of Phase 1/2, roughly

6/15/2011 to 6/14/2012, and the post-treatment period as the year of the Pilot, roughly 6/15/2012 to 6/14/2013.

Differences in participation between the control and treatment groups in the pre-treatment period are statistically insignificant at the 95% level of statistical confidence. However, while audit participation rates for the control groups remain essentially unchanged in the post-treatment period, rates for the treatment groups increase sharply in both experiments. Given the parallel pattern in audit participation rates leading up to the Pilot (Figure 12 and Figure 13), this suggests that HWRs had a definite effect on a home's decision to request an audit. For rebates, the parallel pattern in participation between control and treatment homes is also broken -- participation rates decrease between the pre and post periods for the control groups, while they increase for the treatment groups. The effect is clearly not as large as for audits, but the trend reversal suggests there is some effect.

Figure 14. Pre- vs. Post-Treatment Audit Participation Rates

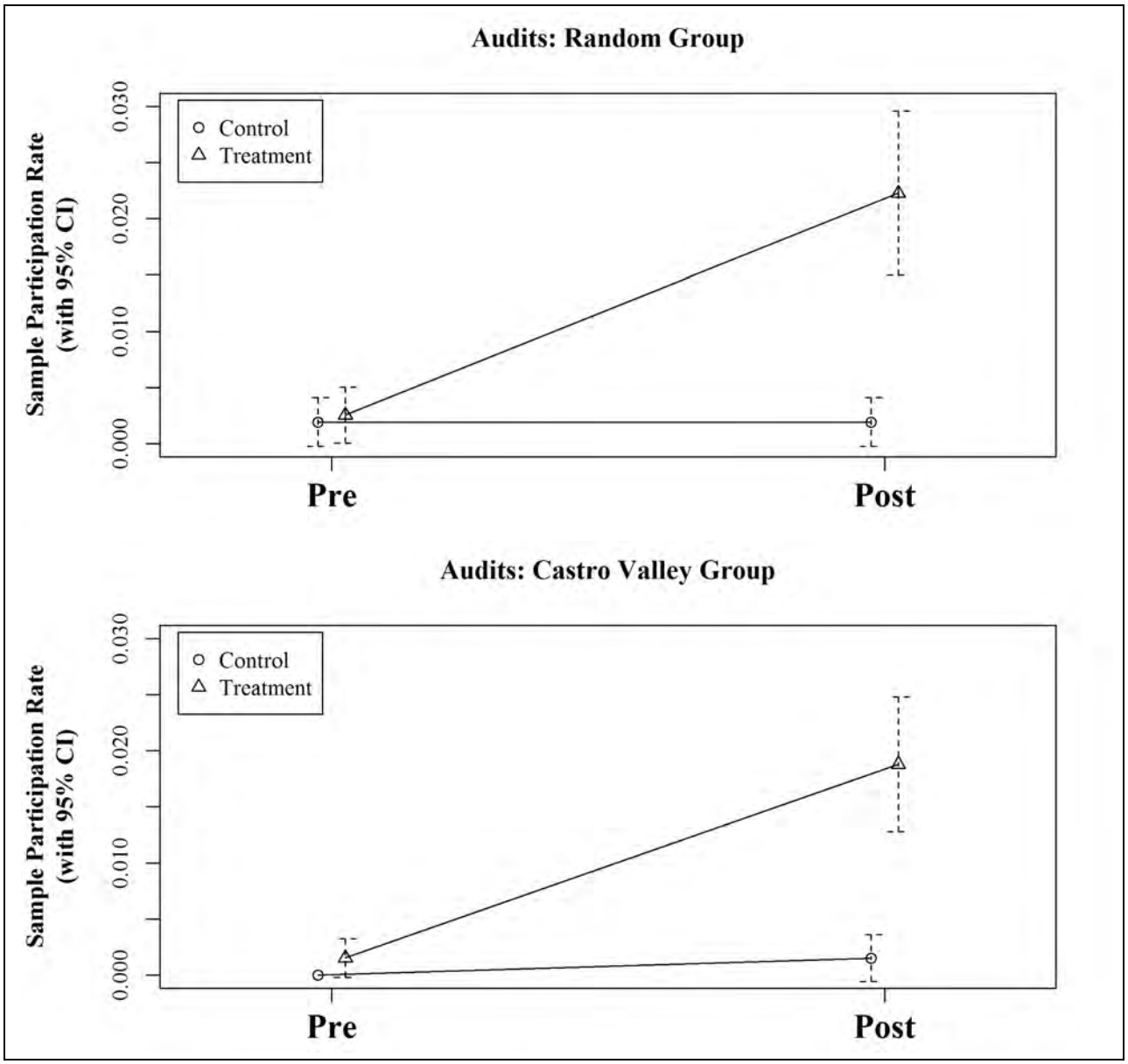
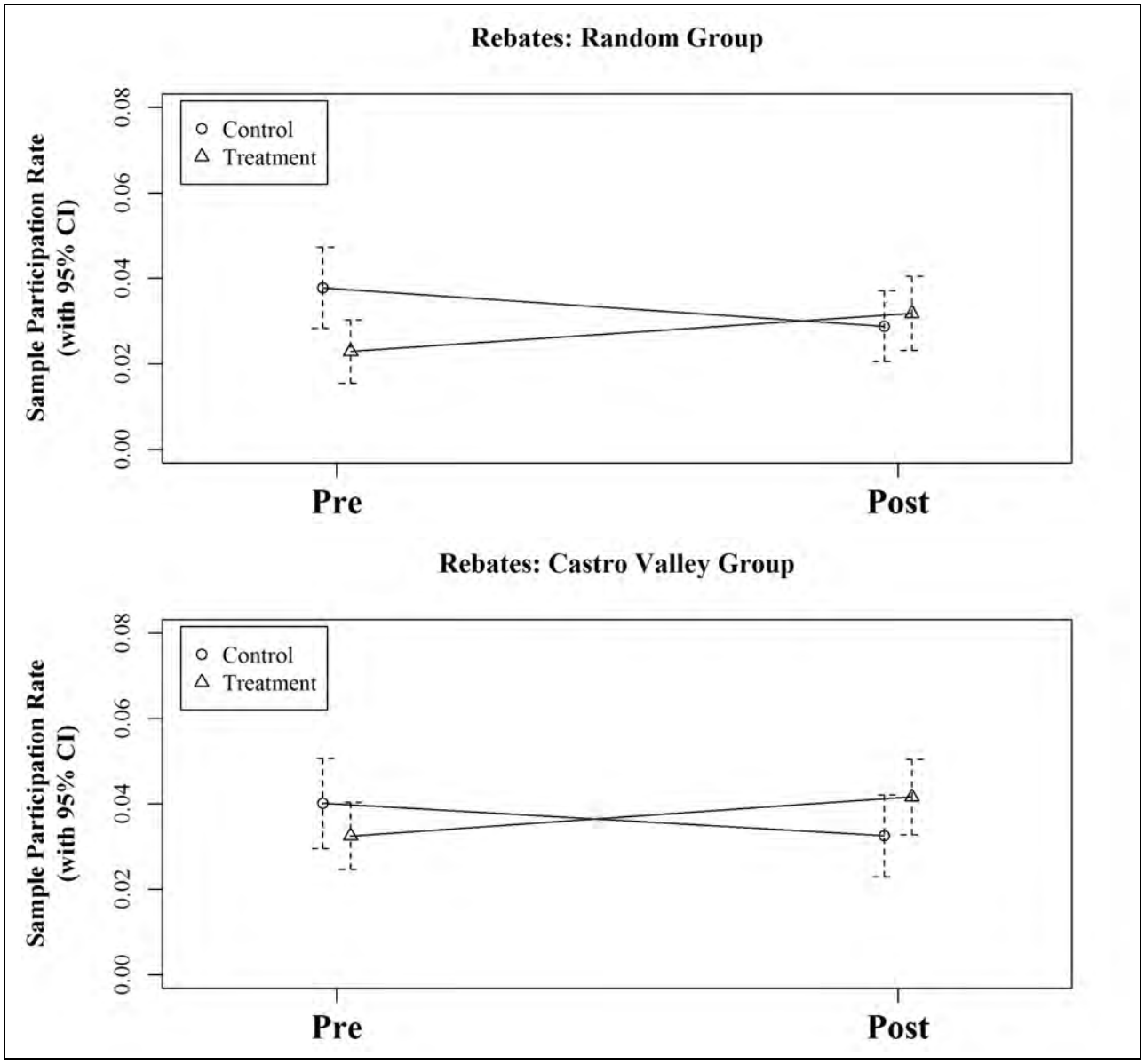


Figure 15. Pre- vs. Post-Treatment Rebate Participation Rates



3. Estimation of Mean Treatment Effect

We use logit regression techniques to estimate the strength of the effect of HWRs on the choice to participate in EBMUD rebate and water audit programs. Logit regression can be used to predict the outcome of a categorical dependent variable (in our case, the choice to participate in an

EBMUD conservation program) based on one or more predictor variables.[33] For this analysis, the key predictor variables are whether a household is in the control group or treatment group and whether the time period is pre-treatment or post-treatment. Other predictor variables are whether the household had previously participated in a rebate program, size of the household, and landscape characteristics.[34] The general specification of the model follows the DID specification in Puhani (2008) for estimating the treatment effect on a dichotomous choice variable in the context of a nonlinear regression model. The basic model is given in equation (6)

(6) $p_i = F(\beta_1 T_i + \beta_2 G_i + \beta_3 T_i \times G_i + \boldsymbol{x}_i \boldsymbol{\Theta})$, where

p_i is the probability of participation, T = 1 in the post treatment period and 0 otherwise, G = 1 if the household is in the treatment group and 0 otherwise, the $\boldsymbol{x}_i$ are additional predictor variables, and $F(\cdot)$ is the cumulative distribution function for a logistic random variable. The coefficient β_3 on the interaction term $T_i \times G_i$ measures the mean treatment effect of HWRs on participation in other EBMUD programs. The increase in the odds that a household chooses to participate in an EBMUD program given that it was in the treatment group is given by e^{β_3}.

We estimated the model given by equation (6) separately for each experiment and also for the pooled experiments. Results were similar across the individual and pooled experiments. We therefore present the results for just the pooled estimation.

Table 6 presents the results for combined participation in rebate and audit programs. That is, it shows the mean treatment effect on overall program participation, without regard to type of

[33] In the logit regression model, the probability, p, that the observed value y takes the value 1 (e.g., the household participates in a program) given the predictor variable x is $p = P[L \leq \alpha + \beta x] = F(\alpha + \beta x) = \frac{1}{1+e^{-(\alpha+\beta x)}}$, where L is a random variable that follows the logistic distribution. Given a set of observed values for y and x, maximum likelihood estimation techniques are used to estimate values for α and β. It can be shown that the log of the odds that y takes the value 1 is equal to $\alpha + \beta x$, or equivalently, the odds that y takes the value 1 is equal to $e^{\alpha+\beta x}$. If x is a binary predictor variable, such as x=1 if treatment is received and x=0 otherwise, then the change in the odds that y takes the value 1 given x=1 is equal to e^{β}. This provides a particularly convenient way to assess the strength of the effect of x on the odds that y takes the value of 1 (e.g., the odds the household participates in a program).

[34] Past participation in audit programs was not found to have a statistically significant effect and was dropped from the model.

program. The coefficient on the treatment effect variable, TG, is positive and is statistically significant at the 99% level of confidence, indicating treatment increased the likelihood of participation in other EBMUD programs.

Model results indicate that households receiving HWRs were 2.34 times more likely to participate in other EBMUD conservation programs than households not receiving HWRs.[35]

Table 6. Mean Treatment Effect on EBMUD Program Participation

Predictor Variable	Logit Model Coefficient	t-statistic
TG (treatment effect)	0.84943	4.4920 ***
T (time effect)	-0.23407	-1.6349
G (group effect)	-0.30235	-2.1869 **
PPH (persons per household)	-0.074468	-0.19239
PREV_REB (received a rebate in prior 3 years)	-0.71114	-4.1360 ***
IR_SMALL (irrigable area 4000 sqft or less)	-0.17816	-1.9393 *
CONSTANT	-2.9795	-19.494 ***
* significant at 90% confidence level, ** significant at 95% confidence level, *** significant at 99% confidence level no. obs. = 12,672		

Table 7 presents the results for participation in audit programs only. The coefficient on the treatment effect variable, TG, is positive and is statistically significant at the 95% level of confidence, indicating treatment increased the likelihood of participation in other EBMUD programs. Model results indicate that households receiving HWRs are 6.2 times more likely to participate in EBMUD audit programs than households not receiving HWRs.[36]

[35] The increase in the odds of participation is calculated by exponentiation of the coefficient for TG ($e^{0.84943} \approx 2.34$). If the probability of participation without treatment is p0 and the probability of participation with treatment is p1, then the odds ratio is defined as $\frac{p1/(1-p1)}{p0/(1-p0)}$. Given the odds ratio and knowledge of the probability of participation without treatment, one can easily calculate the probability of participation given treatment. Suppose the probability of participation without treatment is 1% and the odds ratio is 2.34. Then the probability of participation given treatment is $p1 = \frac{2.34(0.01/0.99)}{1+2.34(0.01/0.99)} \approx 0.023, or\ 2.3\%$.

[36] Again, the increase in the odds of participation is calculated by exponentiation of the treatment effect coefficient TG ($e^{1.8263} \approx 6.2$).

Table 7. Mean Treatment Effect on EBMUD Audit Program Participation

Predictor Variable	Logit Model Coefficient	t-statistic
TG (treatment effect)	1.8263	2.1975 **
T (time effect)	0.51160	0.70065
G (group effect)	0.75408	-1.0921
PPH (persons per household)	-0.20386	2.1686 **
IR_SMALL (irrigable area 4000 sqft or less)	0.57681	-2.5435 **
CONSTANT	-6.6846	-10.316 ***
* significant at 90% confidence level, ** significant at 95% confidence level, *** significant at 99% confidence level no. obs. = 12,672		

Table 8 presents the results for participation in rebate programs only. The coefficient on the treatment effect variable, TG, is positive and is statistically significant at the 95% level of confidence, indicating treatment increased the likelihood of participation in other EBMUD programs. Model results indicate that households receiving HWRs are 1.66 times more likely to participate in EBMUD rebate programs than households not receiving HWRs.

Table 8. Mean Treatment Effect on EBMUD Rebate Program Participation

Predictor Variable	Logit Model Coefficient	t-statistic
TG (treatment effect)	0.50382	2.5224 **
T (time effect)	-0.26467	-1.8107 *
G (group effect)	-0.32403	-2.3019 **
PPH (persons per household)	-0.027124	0.65012
PREV_REB (received a rebate in prior 3 years)	-0.81709	-4.1760 ***
CONSTANT	-3.2026	-20.870 ***
* significant at 90% confidence level, ** significant at 95% confidence level, *** significant at 99% confidence level no. obs. = 12,672		

Table 9 summarizes the mean increase in the odds of program participation given a household received HWRs and its corresponding 95% confidence interval. In each case, we reject the null hypothesis of no treatment effect at the 95% level of confidence.[37]

[37] The confidence intervals are calculated as $e^{\hat{\beta}_3 \pm 1.96SE}$, where SE is the standard error on the coefficient estimate. The broad span of the confidence interval for Audits Only is driven by the very low audit counts overall for the sample of pre- and post-treatment observations. Only 86 audits were completed out of 12,672 pre- and post-treatment observations. The great majority of these audits were completed in the post-treatment period on homes in

Table 9. Mean Treatment Effect on Odds of Conservation Program Participation

EBMUD Conservation Program	Odds Ratio*	95% CI	
		Lower	Upper
Pooled Audit and Rebate Participation	2.34	1.61	3.39
Audits Only	6.21	1.22	31.66
Rebates Only	1.66	1.12	2.45

* The odds ratio shows the increase in the odds of program participation given the household received HWRs. The null hypothesis that HWRs do not affect the odds of participation is rejected when the lower bound of the 95% CI is greater than 1.

4. Effect of HWR Score on Likelihood of Program Participation

Recall that if household consumption is in the 20th percentile of their cohort (HWR score = 1) the report tells them they are efficient, has a large smiling emoticon, and a reinforcing message telling them they are great. If consumption is between the 20th and 55th percentiles (HWR score = 2) the report tells them they are average and gives a smiley emoticon without a reinforcing message. If consumption is above the 55th percentile (HWR score = 3) the report tells them they need to take action and reinforces the message with a worried face emoticon.

As we did for the treatment effect on average daily water use, we consider whether participation in other conservation programs is influenced by the initial score received. It seems reasonable to expect that households told they are efficient and doing great would see less reason to participate in an audit or rebate program -- why fix what's not broken -- than households told they are using too much water and need to take action. We test for this effect by extending the model in equation (6) by interacting the treatment effect term with HWR score indicator variables.

The extension of the model is given in equation (7)

$$(7) \quad p_i = F(\beta_1 T_i + \beta_2 G_i + \beta_3 T_i \times G_i + \beta_4 T_i \times G_i \times SCR1_i + \beta_5 T_i \times G_i \times SCR2_i + \boldsymbol{x}_i \boldsymbol{\Theta}),$$

where SCR1 and SCR2 are binary indicator variables that take the value 1 if the household received the indicated score and 0 otherwise. The coefficient β_4 measures the effect of an initial HWR score of 1 on participation (relative to a score of 3) while the coefficient β_5 measures the effect of an initial HWR score of 2. The change in the odds of participation given treatment is therefore given as

the treatment group. However, with so few observations on completed audits, the variance on the odds ratio for audits only is large.

$$Odds\ Ratio = \begin{cases} e^{\beta_3+\beta_4}\ given\ HWR\ score = 1 \\ e^{\beta_3+\beta_5} given\ HWR\ score = 2 \\ e^{\beta_3} given\ HWR\ score = 3 \end{cases}$$

If initial scores of 1 and 2 decrease the incentive to participate in programs we would expect the estimated values for β_4 and β_5 to be negative and statistically significant. Moreover we would expect the magnitude of β_4 in absolute value to exceed that of β_5. This is in general what we find, as reported in Table 10, which shows the estimated treatment effect coefficients and their t-statistics for rebates and audits combined, audits only, and rebates only. The score effects are all significant at the 99% level of confidence for the audit and/or rebate and audit only participation models. The score effects are of the expected sign and rank order for the rebate only participation model, but they do not have statistical significance at the 95% confidence level.

Table 10. Effect of Initial WaterSmart Score on Mean Treatment Effect on EBMUD Program Participation

Predictor Variable	Logit Model Coefficient	t-statistic
Model 1: Participation in audit and/or rebate programs		
TG (β_3)	1.1770	5.9543 ***
TG_SCR1 (β_4)	-0.89304	-3.9858 ***
TG_SCR2 (β_5)	-0.63286	-3.4769 ***
Model 2: Participation in audit programs only		
TG (β_3)	2.3912	2.8671 ***
TG_SCR1 (β_4)	-2.3165	-3.8936 ***
TG_SCR2 (β_5)	-1.2261	-3.6866 ***
Model 3: Participation in rebate programs only		
TG (β_3)	0.68080	3.1614 ***
TG_SCR1 (β_4)	-0.44076	-1.7778 *
TG_SCR2 (β_5)	-0.31475	-1.4671
* significant at 90% confidence level, ** significant at 95% confidence level, *** significant at 99% confidence level no. obs. = 12,672		

The increase in the odds of participation given the initial HWR score for the three participation models are shown in Table 11.[38] As with the effect of score on average daily water use,

[38] The 95% confidence intervals for the score=1 category is calculated as $e^{(\hat{\beta}_3+\hat{\beta}_4)\pm 1.96SE}$, where $SE = \sqrt{\left(SE_{\hat{\beta}_3}\right)^2 + \left(SE_{\hat{\beta}_4}\right)^2 + 2\rho SE_{\hat{\beta}_3} SE_{\hat{\beta}_4}}$ and ρ is the correlation between $\hat{\beta}_3$ and $\hat{\beta}_4$. The confidence interval for the score = 2 category is done in the same way.

we view the results as indicating correlation of treatment effect but not necessarily causation. Again, while it is plausible that the injunctive norms implicit in the HWR scores and corresponding emoticons are motivating participation it also could be the case that other underlying factors that correlate with the score are causing the response.[39] What we can say is there is clearly a differential response in participation across score categories and that some of the differentiation may result from the injunctive norm (e.g., take action) and some may be due to other underlying factors.

Table 11. Effect of Initial HWR Score on Odds of Program Participation

Initial WaterSmart Score	Odds Ratio*	95% CI	
		Lower	Lower
Model 1: Participation in audit and/or rebate programs			
Score = 3 (e^{β_3})	3.24	2.20	4.78
Score = 2 ($e^{\beta_3+\beta_5}$)	1.72	1.09	2.72
Score = 1 ($e^{\beta_3+\beta_4}$)	1.33	0.79	2.24
Model 2: Participation in audit programs only			
Score = 3 (e^{β_3})	10.93	2.13	56.03
Score = 2 ($e^{\beta_3+\beta_5}$)	3.21	0.57	17.89
Score = 1 ($e^{\beta_3+\beta_4}$)	1.08	0.15	7.74
Model 3: Participation in rebate programs only			
Score = 3 (e^{β_3})	1.98	1.30	3.01
Score = 2 ($e^{\beta_3+\beta_5}$)	1.44	0.88	2.36
Score = 1 ($e^{\beta_3+\beta_4}$)	1.27	0.73	2.20

* The odds ratio shows the increase in the odds of program participation given the household received HWRs. The null hypothesis that HWRs do not affect the odds of participation is rejected when the lower bound of the 95% CI is greater than 1.

The broader and arguably more important point is that households with scores of 3 are more likely to participate (for whatever reason) in other conservation programs and this is useful information for where to target HWRs if it is not possible to provide universal coverage within a service area. While our results should not be interpreted to imply that there is value to adjusting the scores to place more households in the score = 3 category, they do suggest that targeting HWRs to homes that fall within this category is likely to yield better results in terms of channeling customers to other programs than not targeting.

C. WATER USE AWARENESS

A third objective of the Pilot was to see if HWRs increase household knowledge and awareness of its water consumption. Knowledge about water use can take many forms, and thus this

[39] See Section V.A.6 for additional discussion on this topic.

is really a multi-dimensional question. For example, in the most straightforward sense, households may be considered knowledgeable about their water use if they know approximately how much they use overall or for particular purposes. However, they may also be considered knowledgeable if they have a general understanding of how to efficiently perform various water-related things (e.g. taking a shower, washing clothes, irrigating landscape) even if they are unsure of the exact quantities of water involved. In this section we consider the more straightforward sense of water use awareness as well as less tangible measures.

1. Household Estimates of Water Use

The pre- and post-Pilot customer surveys asked respondents to estimate how much water they use on average on a daily basis. Presumably, if HWRs are effective at increasing household awareness of water use, estimates from homes in the treatment group would become more accurate and less biased (i.e., not show a marked tendency to over or underestimate consumption) relative both to their pre-pilot estimates and to estimates by control group households. Ideally, we would want to compare how responses to the same question about water use differed between the pre- and post-pilot surveys. However, this is not possible because the question about water use is different in the two surveys. In the pre-pilot survey, households were asked to estimate how much water they use on average on a daily basis across the entire year. In the post-pilot survey, households were asked the same question but for the summer and for the winter. Thus the responses in the two surveys are not directly comparable. However, it is still possible to look at accuracy and bias of responses between the treatment and control groups in the post-Pilot survey to get a measure of whether HWRs improved households' quantitative estimates of their water consumption.

It is a truism among those working in the water industry that most households generally have no idea how much water they use on a daily basis. Both the pre- and post-Pilot survey responses seem to bear this out. In the pre-Pilot survey more than 40% of households either indicated they did not know their water use or left the question blank. In the post-Pilot survey, this proportion increased to over 55%. Notably, there is little difference in the response rates between the control and treatment groups, suggesting that households receiving HWRs are no more likely to think they know their water use than households not receiving HWRs.

Households that did provide an estimate of average daily water use showed a significant downward bias in both the pre- and post-Pilot surveys. This is illustrated in Figure 16, which

compares actual to estimated water use for those respondents providing use estimates. The tendency for households to underestimate their water consumption by a fairly wide margin is present in both periods, regardless of treatment.

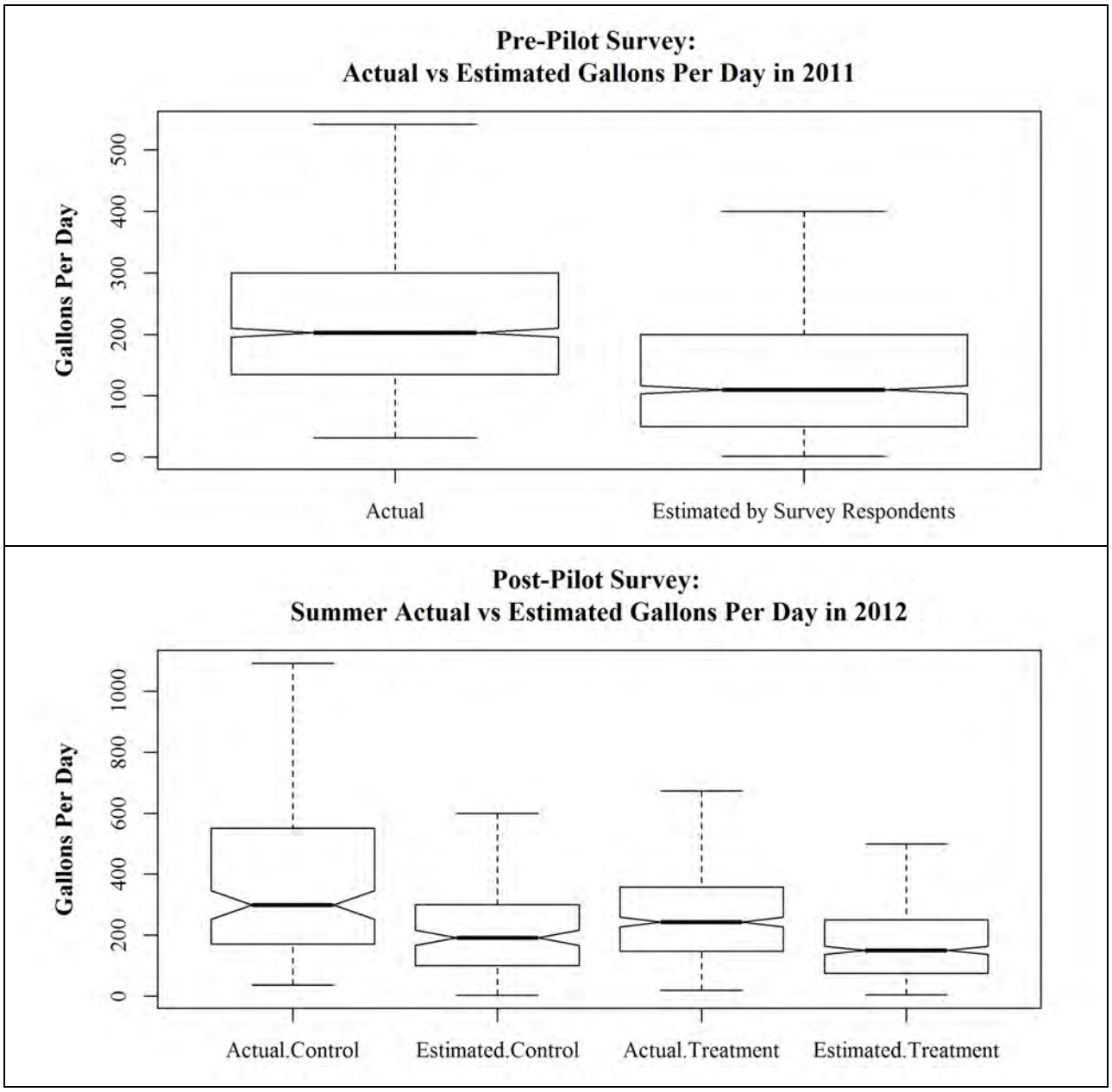
In the post-Pilot survey the distribution of estimation errors is similar between the control and treatment groups, as shown in Figure 17. Both groups consistently underestimate their average use. Note that the mean error (the curved lines in Figure 17) is nearly identical for both groups and shows a tendency to increase with usage, indicating that high water use homes are more likely to underestimate their water use by a wider margin than low water use homes, which is not especially surprising.

In summary, we do not find evidence that HWRs increased the ability of households to provide an accurate quantitative estimate of their average daily water use. The proportion of homes stating they did not know or not answering the question was essentially the same between households in the control and treatment groups responding to the post-Pilot survey. Similarly, the tendency to underestimate daily water use was also generally the same between control and treatment households responding to the survey. It may be that over time this will change and as households receive more HWRs they will begin to incorporate this information into their general understanding of how they use water. Importantly, WaterSmart reported gallons per billing period rather than gallons per day on HWRs prior to April 2013, so it may be that households will be better at estimating daily water use going forward. However, it should also be noted that EBMUD has for a long while now provided average daily water use on its bills. Judging from the results of the pre-Pilot survey, however, this practice has not had much of an impact on the ability of households to estimate their water use.

It is also not obvious to us that a quantitative knowledge of daily water use is particularly relevant to most decisions about household water use. Households can make informed decisions on water use regardless of knowing precisely how much water they use. For example, to irrigate efficiently it is perhaps more important to know when and how long sprinklers should run and which parts of the yard can be effectively served with drip, than it is to know how much water the irrigation system uses. Similarly, the choice of a new washer may be made more effectively based on its potential to save on water and energy bills than on how many gallons per load it uses. Besides, our results on the effect of HWRs on household water use and decisions to participate in other conservation programs clearly show that households are responsive to the combination of social norms, injunctive messaging, and actionable information presented in HWRs regardless of their

ability to accurately estimate water use. In this respect, the proof is in the pudding when it comes to whether HWRs work.

Figure 16. Pre- and Post-Pilot Estimates of Household Water Use Compared to Actual Water Use



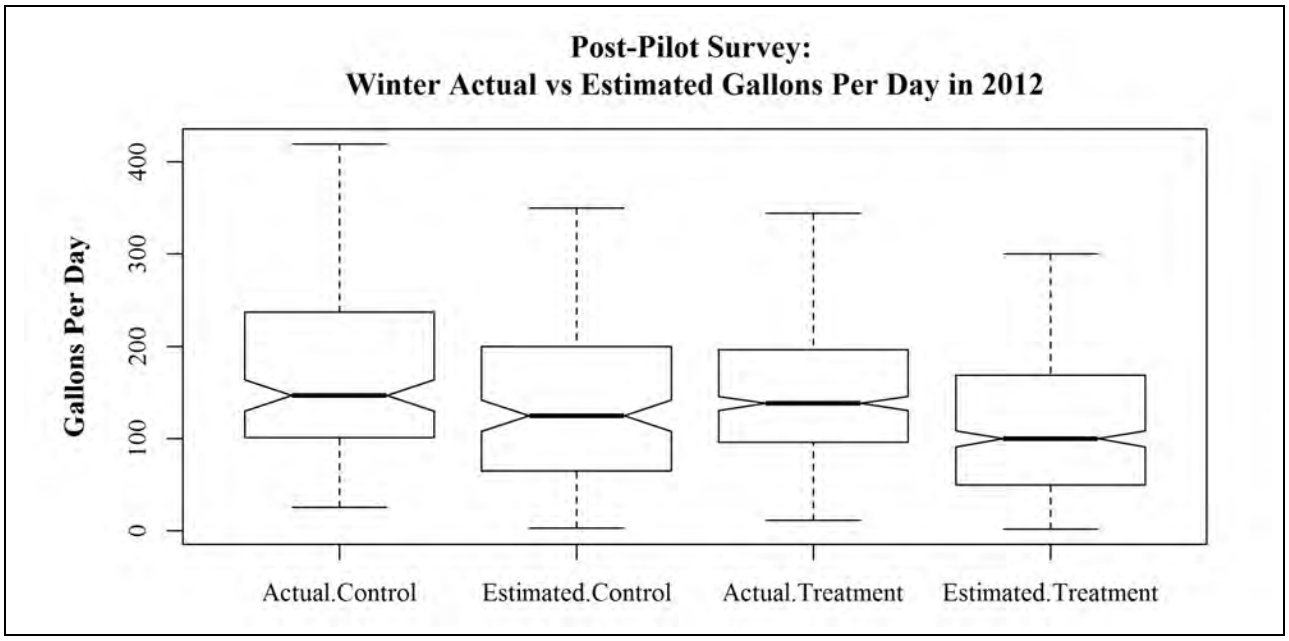
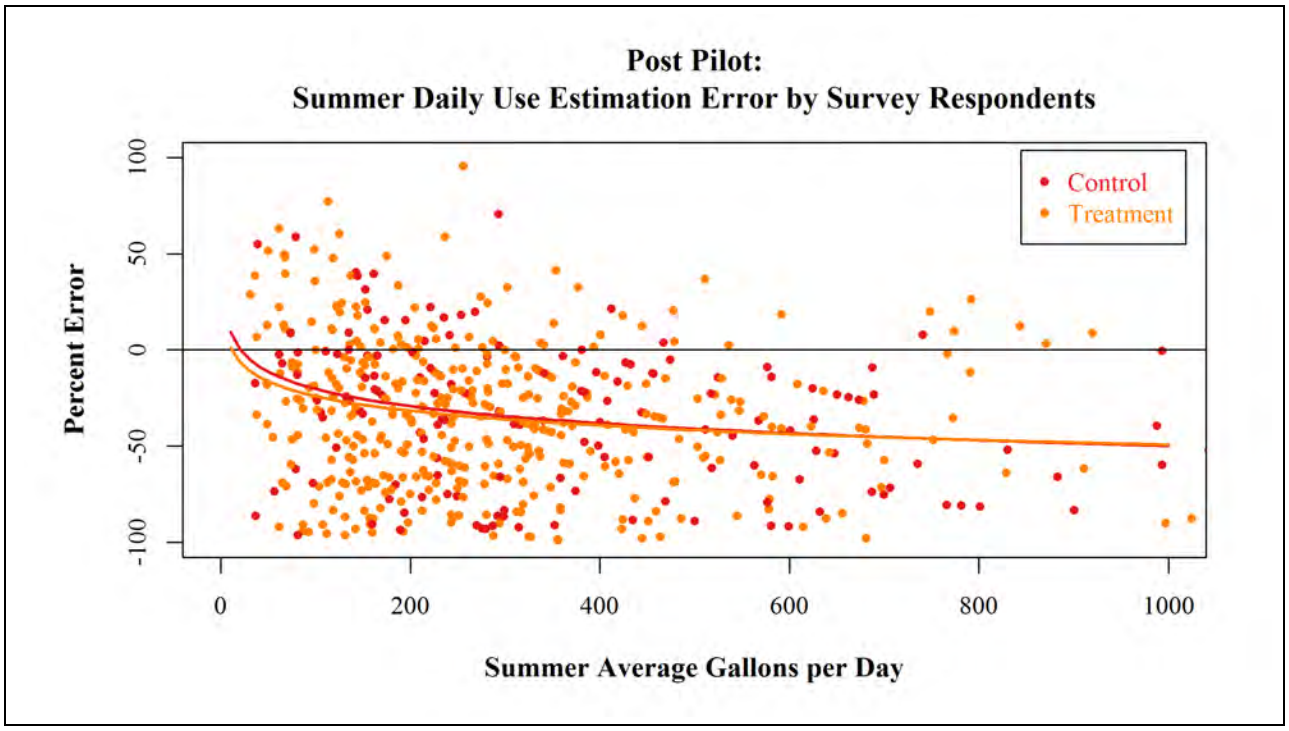
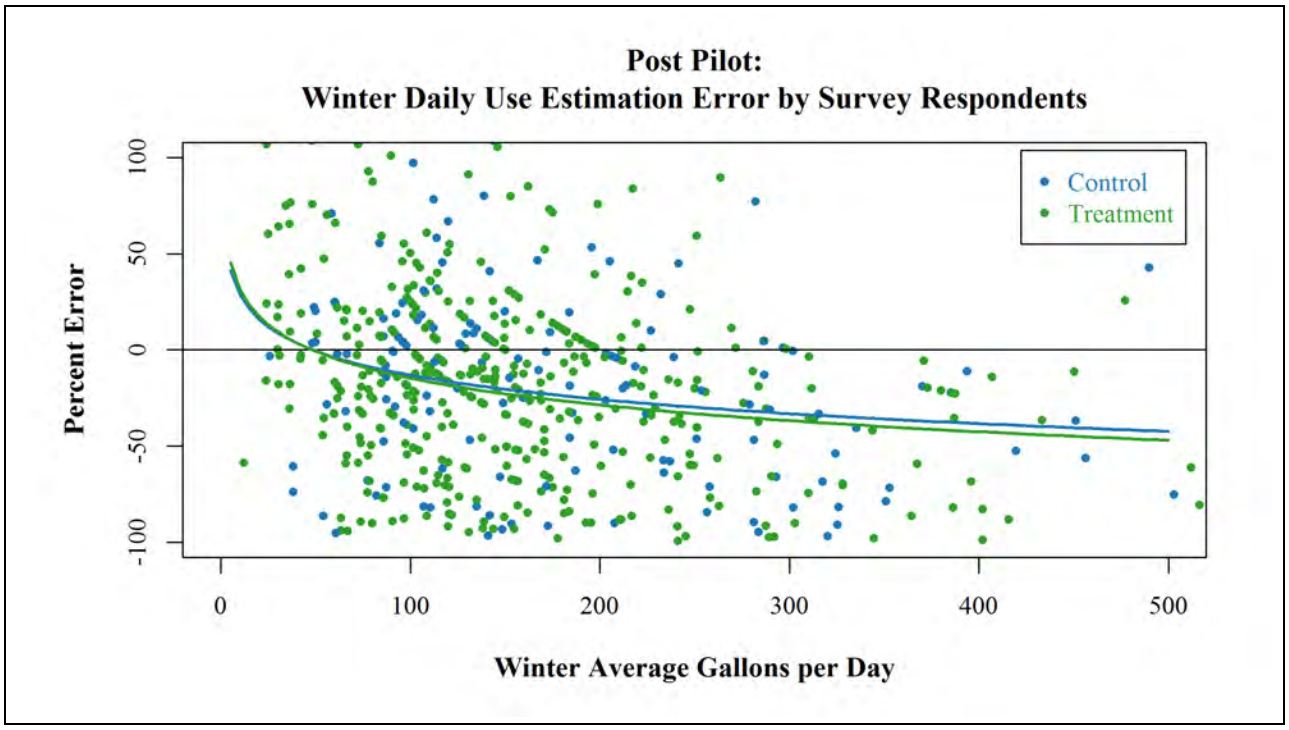


Figure 17. Post-Pilot Distribution of Water Use Estimation Error for Treatment and Control Households





2. Household Commitment Towards Water Conservation

Another dimension of a household's awareness and knowledge of its water use might be viewed in terms of its expressed beliefs in the importance of using water efficiently. The pre- and post-Pilot surveys asked respondents whether they agreed strongly with the following four statements:

1. I make an active commitment to use water efficiently.
2. It is important to me to reduce my water bills.
3. I talk with others in my household about reducing our water use.
4. I talk with friends and neighbors about ways to conserve water.

If HWRs are effective in shaping attitudes along these lines, we might expect to see more households in the treatment group indicating they agree strongly with the above statements than households in the control group. We used a difference-in-differences logit model to test for this effect. Our analysis generally does not support the hypothesis that survey respondents that were in the treatment group are more likely to agree strongly with the above statements than respondents that were in the control group.

The estimated odds ratio from the logit model and its 95% confidence interval for agreeing strongly with each of the four statements is shown in Table 12. The null hypothesis of no treatment effect is only rejected in the case of the second statement -- *It is important to me to reduce my water bills* -- and then only barely. In the other three cases, the null hypothesis of no treatment effect is not rejected, meaning that HWRs do not appear to change the odds that a household will agree strongly with the statements.

These results should be interpreted with some caution. Self-selection bias in opinion polls of this type is a common problem (Groves & Peytcheva, 2008). Typically individuals that are interested in a topic or have strongly held views on the topic are more likely to respond to voluntary polls. This can result in a biased sample that disproportionately represents individuals with particularly strong opinions or beliefs -- such as strongly supporting the need for water conservation. This type of self-selection could be present in both treatment and control group respondents.[40]

Table 12. Treatment Effect on Odds Survey Respondent Strongly Agrees with Statement

Statement	Odds Ratio*	95% CI	
		Lower	Upper
I make an active commitment to use water efficiently	0.98	0.73	1.30
It is important to me to reduce my water bills	1.37	1.03	1.83
I talk with others in my household about reducing our water use	1.19	0.90	1.59
I talk with friends and neighbors about ways to conserve water	1.17	0.79	1.70

* The odds ratio shows the increase in the odds of strongly agreeing with the statement given the respondent received HWRs. The null hypothesis that HWRs do not affect the odds of strong agreement is rejected when the lower bound of the 95% CI is greater than 1.

3. Getting Help on How to Save Water

The pre- and post-Pilot surveys also asked households to score EBMUD in terms of the following:

1. Explaining your water use on your bill
2. Showing you ways to save money on your water bill by conserving water
3. Giving you the tips and tools you need to use water efficiently

[40] The fact that the question about water bills is the only one showing a statistically significant treatment effect lends some support to this possibility. Self-selection is more likely to be caused by strong moral beliefs in the importance of and need for water conservation than by a strong pecuniary interest in lowering water bills.

If households view HWRs as providing useful and actionable information we would expect respondents that received HWRs to be more likely to give EBMUD a high score in these areas then other respondents. Again, we used a differences-in-differences logit model to test for this effect. In this case, we reject the null hypothesis of no treatment effect in each case, meaning we find evidence that respondents who received HWRs are more likely to score EBMUD high in terms of providing useful information for managing household water use and bills then other respondents. The estimated odds ratio from the logit model and its 95% confidence interval for scoring EBMUD as "Excellent" in each of the three above categories is shown in Table 13. The estimated mean increase in the odds of scoring EBMUD as "Excellent" ranges from 52 to 80%.

Table 13. Treatment Effect on Odds Survey Respondent Scores EBMUD as "Excellent" by Area of Assistance

Area of Assistance	Odds Ratio*	95% CI	
		Lower	Upper
Explaining your water use on your bill	1.52	1.07	2.17
Showing you ways to save money on your water bill by conserving water	1.64	1.12	2.41
Giving you the tips and tools you need to use water efficiently	1.80	1.23	2.65

* The odds ratio shows the increase in the odds of respondent score EBMUD as "Excellent" given the respondent received HWRs. The null hypothesis that HWRs do not affect the odds of an "Excellent" score is rejected when the lower bound of the 95% CI is greater than 1.

D. COST EFFECTIVENESS

Many considerations go into a utility's decision to implement a specific demand management program. A key one is the cost of the program relative to other alternatives or doing nothing at all. A common metric for assessing the relative cost of a demand management program is to calculate the unit cost of water savings, which can then be compared to the unit cost of water savings for other demand management options as well as to the unit cost of water supply. In California, unit costs are typically expressed in dollars per acre-foot.[41]

In its most general form, the equation for calculating unit cost is given by equation (8)

(8) $$UC_i = \frac{\sum_{t=0}^{t=T_i-1} C_{it} / (1+d)^t}{\sum_{t=0}^{t=T_i-1} W_{it} / (1+d)^t}$$, where

[41] An acre-foot of water is the volume of water that would cover an acre one foot deep in water, approximately 325,851 gallons.

C_{it} is the cost incurred by the utility in year t from implementing program i, W_{it} is the water savings expected from program i in year t, T_i is the number of years savings from program i are expected to last, and d is the discount rate. When program costs and savings last just one year, the general equation for unit cost simplifies to the ratio of annual cost to annual savings, as shown in equation (9).

(9) $$UC_i = {}^{C_i}/_{W_i} \; when \; T_i = 1$$

Equation (9) is applicable for HWRs if we make the conservative assumption that savings occur in the year in which the HWRs are received and do not persist beyond this time.[42]

1. Average Water Savings Per Household

Results from the Pilot indicate a mean treatment effect for the Random Group Experiment in the range of 4.5 to 6.5% for households receiving paper reports by mail and in the range of 3.5 to 5.5% for households receiving electronic reports by email. Because the Random Group Experiment is representative of the distribution of households for the entire EBMUD service area, these ranges provide appropriate estimates of expected water savings if the program were extended to the entire service area.

Pre-treatment mean water use for households in the Random Group Experiment was about 261 gallons per day, or about 95,265 gallons per year. Average annual household water savings would therefore be expected to range between 4,287 and 6,192 gallons for households receiving paper reports and between 3,334 and 5,240 gallons for households receiving electronic reports. Converting to acre-feet, the expected savings would be 0.0132 to 0.0190 acre-feet for paper reports and 0.0102 to 0.0161 acre-feet for email reports.

[42] While this is a common assumption made for SNB efficiency programs (Allcott, 2011), there are of course plausible scenarios where savings might persist after a household stopped receiving HWRs, such as if the household had made significant changes to its landscape or had replaced toilets or other water using appliances as a result of getting HWRs. Thus the assumption is conservative in the sense that it is likely to impart an upward bias to the unit cost estimate.

2. Average HWR Cost Per Household

EBMUD is in the process of evaluating the expansion of HWRs to more parts of its service area. As part of this evaluation it has estimated average costs per household for providing one year of HWRs based on information from potential vendors as well as its own internal costs of program implementation. For electronic HWRs delivered by email it estimates an annual cost of $4.50 to $5.00 per household. For paper HWRs delivered by mail it estimates an annual cost of $6.40 to $6.60 per household. These are average costs over three years assuming the program is scaled up from its present level of less than 15,000 households to 100,000 households by the end of the third year.

Because some costs are fixed and others are variable, the average cost depends on the number of households in the program. Thus unit costs for other service areas may be more or less than what EBMUD has estimated depending on the scale of the program. For assessing program cost-effectiveness, we assume a cost range for paper and email reports of $4.00 to $6.00 and $5.50 to $7.50 per household, respectively.

3. Unit Costs of Water Savings

Expected program unit costs, in dollars per acre-foot, are summarized in Table 14.[43] The unit cost range for conserved water from email reports is $250 to $590 per acre-foot; for paper reports, it is $290 to $570 per acre-foot. The mid-point unit costs for email and paper reports are $380 and $400 per acre-foot, respectively.[44]

[43] Unit cost estimates have been rounded to the nearest $10.

[44] While email reports have slightly lower unit costs, paper reports offer somewhat more water savings. The economic advantage of one over the other depends on the avoided cost of saved water. For example, if 10,000 reports can be provided by email at a cost of $5/report and by mail at a cost of $6.50/report, and the expected savings for email and mail reports are 0.0161 and 0.01315 acre-feet, respectively, which is the midpoint of the expected savings range, then the paper reports would cost $15,000 more than the email reports but also save 29.5 acre-feet more. An avoided cost of saved water of $508 or more would give the economic advantage to paper over email reports, since the value of the incremental water savings would exceed their incremental cost. If the avoided cost of saved water was less than $508 (but still above the unit cost for email reports), the economic advantage would be with the email reports. In reality, most utilities are likely to start with either all paper or a mix of paper and email reports, since delivery of email reports requires a utility to have working email addresses for its targeted

Even at the upper-end of the cost range, the unit costs are competitive with most other options for water demand management. A review of unit costs from conservation master plans conducted for the California Water Foundation in 2012 found unit costs to typically range from $450 to $950 per acre-foot, with a central tendency in the neighborhood of $700 per acre-foot (M.Cubed, 2012). The unit costs for HWRs are mostly below this range, especially in the case of email HWRs.

Table 14. Unit Cost of Saved Water from HWRs Program in $/AF

Email Reports		Average Annual Water Savings				
		3.5%	4.0%	4.5%	5.0%	5.5%
Annual Cost/ Household	$4.00	$390	$340	$300	$270	$250
	$4.50	$440	$390	$340	$310	$280
	$5.00	$490	$430	$380	$340	$310
	$5.50	$540	$470	$420	$380	$340
	$6.00	$590	$510	$460	$410	$370

Paper Reports		Average Annual Water Savings				
		4.5%	5.0%	5.5%	6.0%	6.5%
Annual Cost/ Household	$5.50	$420	$380	$340	$310	$290
	$6.00	$460	$410	$370	$340	$320
	$6.50	$490	$450	$400	$370	$340
	$7.00	$530	$480	$440	$400	$370
	$7.50	$570	$510	$470	$430	$400

The unit costs in Table 14 are also competitive with most other options for new water supply. Costs vary significantly by type of supply. For recycled water, costs can range from the low hundreds to over $2,000 per acre-foot. A review of 26 Bay Area recycled water projects found an average cost of about $1,100 per acre-foot (M.Cubed, 2007). Costs for desalination range even higher. Recent cost estimates for five proposed desalination projects in Southern California range from $1,191 to $2,340 per acre-foot (California Natural Resources Agency, 2013). The California Department of Water Resources (DWR) estimates the implicit cost of water supply from proposed new conveyance for the Delta at between $302 to $408 per acre-foot at the Delta. Additional costs would accrue for transmission, treatment (for urban users), and distribution, which could add up to several hundred dollars to the price paid by urban water users, putting the cost of the water at the

residential customers, which is often not the case. As the program is implemented, customers can be directed to the web portal to select the type of delivery -- email or paper -- according to preference.

point of use (which is the appropriate cost when comparing to demand management costs) in the $500 to $700 range.[45] The unit cost of HWRs, even at the upper end of the range, are competitive or more than competitive with each of these supply options.

Targeting reports to households in the upper percentiles of consumption would lower the unit costs even further. Recall that we estimate households in the upper quartile of water use save, on average, about 1% more than households in the inter-quartile range. For households in this category, the mid-point unit cost of HWRs would be $310 and $340 per acre-foot for paper and email reports, respectively.

E. PROGRAM INTEGRATION

Another important consideration that goes into a utility's decision to implement a specific demand management program is how well it integrates with or enhances the existing programs it offers. From the perspective of EBMUD conservation staff, the Pilot highlighted several key advantages of an SNB efficiency program in terms of overall customer service and extension of its existing programs.

In terms of customer service, EBMUD staff reported finding the customer analytics accessed through what WaterSmart calls the Utility Dashboard to be extremely useful. This gave them detailed information on home water use and household attributes which they could access when interacting with customers over the phone to address questions about water use, bills, or other issues. With this information at their fingertips they could better determine how to help the customer and better direct customers to other programs that could help them reduce their water use. In this regard, EBMUD staff believe an SNB efficiency program like the one tested in the Pilot will help them achieve a long-term goal of having more specific and relevant dialog about water use with their customers.

The Utility Dashboard also gave EBMUD staff the ability to update or extend the customer profile data in real time. This proved to be important during the Pilot when customers called with questions about the water score they received on the HWR. With the Utility Dashboard, staff could

[45] These estimates are based on the assumption of no cost overruns for the conveyance facilities relative to current cost estimates, which would be unusual for a large public infrastructure project of this sort. For less sanguine estimates of implicit supply cost of new Delta conveyance, see http://hydrowonk.com/blog/2013/09/16/what-would-be-californias-water-supply-situation-without-the-bdcp-and-what-it-means-for-tunnels/.

quickly determine whether the score that was generated was based on accurate information on household attributes. If the information was inaccurate, EBMUD staff could update the information while on the phone with the customer.

EBMUD staff also reported the ability to customize the HWRs gave them options for crafting content and messaging that could evolve with their overall program direction and objectives. In particular, as EBMUD shifts the focus of its conservation programs to landscape water savings, staff anticipate using HWRs to emphasize outdoor water use efficiency and to channel more customers into landscape audit and rebate programs.

The potential scalability of an SNB efficiency program is also viewed as important to EBMUD staff. The ability to ramp up or down the program at little cost gives them options for either targeting specific customer groups with HWRs or rolling them out on a much broader scale, potentially as part of a drought response. With respect to drought management, EBMUD staff expect HWRs will play an increasingly important role by giving them the ability to customize drought response messages, more effectively communicate the importance of curbing water use, and even possibly developing customer-specific water shortage allocations.

Overall, EBMUD staff reported that an SNB efficiency program like the one tested in the Pilot will give them new and better ways to provide customer service related to water use efficiency and to more effectively market and channel customers into complementary conservation programs.

VI. SUMMARY OF OUTCOMES AND IMPLEMENTATION LESSONS

A. PILOT OUTCOMES

To summarize the results of the evaluation, our principal findings on Pilot outcomes are as follows:

1. We find strong evidence that households in the Pilot's treatment groups reduced their water use in response to the HWRs. We estimate mean treatment effects of 4.6% and 6.6% for the Random Group and Castro Valley Group experiments, respectively. Our estimates of mean treatment effect bracket the 5% mean effect estimated by WaterSmart using a less robust DID methodology. The consistency of results between the DID estimates and our results is useful corroborating information.

2. We also find evidence that the magnitude of the effect scales with level of household water use. Households in the top quartile of water use save, on average, 1% more, while households in the bottom quartile of water use save, on average, 3% less, than households in between these two categories. This suggest utilities should consider giving households in the bottom quartile of use lower priority for receiving HWRs if they are not going to be universally provided.
3. Paper reports delivered by mail appear to be more effective in terms of water savings than electronic reports delivered by email. On average, households receiving paper reports were found to save about 1% of mean household use more than households receiving email reports. Whether this translates into an economic advantage for an implementing utility, however, will depend on the cost of delivering mail versus email reports as well as the avoided cost of water saved.
4. We estimate that the unit cost of saved water is likely to range between $250 and $590 per acre-foot for email reports and between $290 and $570 per acre-foot for paper reports.[46] The mid-point unit costs for email and paper reports are $380 and $400 per acre-foot, respectively. Even at the upper-end of the cost ranges, the unit costs are less than the cost of most other options for water demand management and new water supply, indicating SNB efficiency programs could provide very cost-effective water savings.
5. We find strong evidence that households in the Pilot's treatment groups were significantly more likely to participate in audit and rebate programs offered by EBMUD than households in the control groups. Looking at both audit and rebate programs together, we estimate that households receiving HWRs were 2.3 times more likely to participate in a program than households not receiving reports. The effect appears to be strongest for audit programs, where we estimate households getting HWRs were 6.2 times more likely to participate. The effect is less strong for rebate programs (1.7 times more likely), but statistically significant. The results suggest that SNB efficiency programs can provide an effective conduit for channeling customers into other conservation programs the utility is promoting.
6. Our analysis indicates that households receiving a water score of 3 (Take Action!) are in fact more likely to do just that. The magnitudes of the treatment effects for both average daily use and program participation are positively correlated with water score. While our

[46] Unit cost estimates have been rounded to the nearest $10 throughout this report.

results should not be interpreted to imply that there is value to adjusting the scores to place more households in the score = 3 category, they do suggest that targeting HWRs to homes that fall within this category is likely to yield better results in terms of average water savings and boosting program participation rates.

7. We do not find evidence that HWRs improve household knowledge of water use in the conventional sense of being able to quantitatively estimate average daily use. The proportion of homes stating they did not know their water use was essentially the same between households in the control and treatment groups. Similarly, the tendency to underestimate daily water use was also generally the same between control and treatment households. It may be that over time this will change and as households receive more HWRs they will begin to incorporate this information into their general understanding of how they use water.
8. We do find evidence that households receiving HWRs view them as providing useful and actionable information for managing their water consumption. Households in the treatment group were 52 to 80% more likely to score EBMUD as "Excellent" in terms of explaining household water use, showing ways to save money on water bills by conserving water, and giving useful tips and tools needed to use water efficiently. Thus, HWRs appear to be effective at delivering information on ways to use water efficiently that households can, and judging by the measured effects on daily water use and program participation, do act upon.

B. IMPLEMENTATION LESSONS

Implementation lessons from the Pilot are still emerging and we expect them to evolve as more experience is gained with SNB efficiency programs. Some preliminary lessons from the Pilot include:

1. Good data management provides one of the most important keys to successful implementation of SNB efficiency programs. If the program is outsourced to a third-party company, this requires the establishment of robust protocols for data handling, quality control, and security. Privacy issues are of paramount concern since HWRs rely on customer-specific information that needs to be safeguarded from improper use.
2. Regular communication between utility staff and the SNB efficiency program service provider is essential. Throughout the Pilot, staffs of EBMUD and WaterSmart met on a

routine basis to review progress and interim results, discuss challenges, and plan next steps. These meetings allowed them to bring to the table emerging issues and to address them before they became significant problems.

3. Surveying households prior to implementation to gather additional information on household characteristics and water use attitudes provides essential information for binning customers into cohorts and tailoring the messaging of the initial HWRs. It is important to make sure sufficient resources have been set aside for this task. EBMUD staff reported being caught somewhat off guard by the high rate of responses and resources required to to process the survey data, but also noted its importance to successfully launching the Pilot.
4. Prior to implementation it is also important to educate customer service representatives about the new program and train them on how to respond to or direct customers with inquiries or complaints about the information in their HWR. In the Pilot, the most common complaint was from customers receiving a water score of 3 who felt they had been scored incorrectly. EBMUD worked with its customer service representatives to turn these calls from complaints to opportunities for customer outreach by first verifying with the customer the information upon which the score was based and second by providing them information on ways to more effectively use water around the home and to alert them to audit and rebate programs that may directly benefit them.
5. It is important to experiment with how information is presented in the HWR. In the Pilot, EBMUD quickly discovered that customers responded negatively when told their use was being compared to their neighbor's but seemed to be okay if told their use was being compared to similarly situated homes.
6. Phasing implementation afforded EBMUD and WaterSmart the opportunity to fine-tune the process as they gained feedback and experience with producing and delivering the reports and responding to customer inquiries. Phasing enabled them to implement an adaptive management approach to implementing the program.

VII. RECOMMENDATIONS FOR FUTURE RESEARCH

These are early days for the application of SNB efficiency programs to residential water use and there is still much to be learned in terms of efficacy, cost, and implementation. Some questions that future research can help address include:

1. Are treatment effects persistent or do they fade with time? Literally, only time will tell. As noted in Section II.D, empirical evaluations of home energy reports have found the treatment effect to persist and even strengthen over three years. These studies, however, have only considered a relatively short amount of time. Whether something similar will be the case for HWRs is an important topic of inquiry. There are several related questions: (1) Do effects persist even if HWRs are discontinued, perhaps because of induced changes in water using appliances and fixtures? (2) Do HWR savings grow, stay constant, or decline with time? (3) Does so-called demand hardening impose a limit on the changes in household water use that can reasonably be expected from HWRs?
2. To what extent are water savings driven by changes in outdoor water use? Our preliminary models provided some evidence of stronger treatment effects associated with reports received in the fall and winter than in the spring and summer. This may indicate a lagged response to receiving information about high summer water use, but the phasing of the Pilot, which resulted in the largest block of Castro Valley homes not getting their first HWR until October or November, could also be involved.
3. Does the frequency in which HWRs are provided matter? Our results found that providing HWRs on a bi-monthly basis yielded significant reductions in water use. Would providing reports more (less) frequently result in a larger (smaller) effect on water use? In the case of home energy reports, Allcott (2011) concluded more frequent reports did yield larger savings, but not by enough to justify the added expense. But he did not consider the potential cost advantage of providing reports less frequently just to households in the lower percentiles of use.
4. Are differences in water savings and program participation associated with the HWR water score due primarily to the injunctive messaging or other underlying factors?
5. What is a reliable range of water savings to expect from SNB efficiency programs if implemented broadly across the state? At present we have very few data points from which to gauge this. Only a handful of pilot implementations have been completed and while they seem to suggest initial water savings in the range of 4 to 6% more evaluations of outcomes under varied conditions are needed to know if this range is stable.

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"Data! Data! Data! ... I can't make bricks without clay." Sherlock Holmes exclaimed in *The Adventure of the Copper Beeches*. This cry is familiar to every statistician the world over. Fortunately in our case we had the staffs from EBMUD and WaterSmart to ensure we had the data we needed for this evaluation. We owe particular thanks to Ora Chaiken and Chad Haynes of WaterSmart and Mike Hazinski, Dave Wallenstein, and Richard Harris of EBMUD. Whenever we cried "Data! Data! Data!" they responded and got us what we needed. We would also like to thank Bill Jacoby and Mike Myatt of the California Water Foundation who shepherded this project in its beginning phases, and Ronnie Cohen, also with California Water Foundation, who kept it on track once we were underway. We also owe thanks to our funders, California Water Foundation and EBMUD, who gave us the necessary resources to do this work. All of these individuals and organizations have contributed to this project in essential ways, but only the authors are responsible for the content of this report.

APPENDIX 1: Random Group Experiment Sample Distribution by Pressure Zone

Group	Pressure Zone	% Residential Accts	% of Randomly Sampled Accts		
			Total	Control	Treatment
A	A0A	4.29%	5.59%	2.76%	2.82%
A	A11A	0.04%	0.00%	0.00%	0.00%
A	A11C	0.18%	0.03%	0.00%	0.03%
A	A1A	1.56%	1.29%	0.74%	0.55%
A	A1B	0.07%	0.09%	0.06%	0.03%
A	A2A	2.69%	1.96%	1.07%	0.89%
A	A2AA	0.11%	0.03%	0.03%	0.00%
A	A2B	1.08%	2.06%	1.01%	1.04%
A	A2C	0.16%	0.25%	0.09%	0.15%
A	A2D	0.14%	0.21%	0.09%	0.12%
A	A2E	1.93%	2.12%	1.07%	1.04%
A	A3B	0.03%	0.03%	0.03%	0.00%
A	A4A	0.02%	0.00%	0.00%	0.00%
A	A4AA	0.03%	0.09%	0.03%	0.06%
A	A4B	0.33%	0.25%	0.12%	0.12%
A	A4BA	0.09%	0.15%	0.09%	0.06%
A	A4BB	0.08%	0.06%	0.03%	0.03%
A	A4C	0.24%	0.12%	0.06%	0.06%
A	A4D	0.05%	0.12%	0.09%	0.03%
A	A4G	0.04%	0.09%	0.06%	0.03%
A	A4K	0.01%	0.00%	0.00%	0.00%
A	A4L	0.00%	0.00%	0.00%	0.00%
A	A4M	0.20%	0.31%	0.09%	0.21%
A	A4N	0.03%	0.03%	0.03%	0.00%
A	A5A	0.76%	0.52%	0.28%	0.25%
A	A5B	0.06%	0.06%	0.03%	0.03%
A	A5C	0.02%	0.00%	0.00%	0.00%
A	A7B	0.11%	0.00%	0.00%	0.00%
A	A7C	0.03%	0.03%	0.00%	0.03%
A	A7D	0.67%	0.49%	0.21%	0.28%
A	A9B	0.16%	0.12%	0.09%	0.03%
A	A9D	0.38%	0.21%	0.12%	0.09%
B	B11A	0.06%	0.12%	0.03%	0.09%
B	B11B	0.49%	0.31%	0.09%	0.21%
B	B11C	0.18%	0.15%	0.12%	0.03%
B	B11D	0.00%	0.00%	0.00%	0.00%
B	B13A	0.27%	0.21%	0.12%	0.09%
B	B2A	2.38%	1.81%	1.01%	0.80%
B	B2AA	0.19%	0.34%	0.18%	0.15%
B	B3A	2.01%	2.27%	1.20%	1.07%
B	B4AA	0.17%	0.37%	0.15%	0.21%
B	B4B	0.08%	0.15%	0.15%	0.00%
B	B4C	0.04%	0.06%	0.06%	0.00%
B	B5A	1.00%	0.46%	0.46%	0.00%
B	B5B	0.05%	0.09%	0.06%	0.03%
B	B5C	0.01%	0.03%	0.00%	0.03%
B	B5D	0.25%	0.37%	0.25%	0.12%

Group	Pressure Zone	% Residential Accts	% of Randomly Sampled Accts		
			Total	Control	Treatment
B	B7A	0.85%	0.77%	0.25%	0.52%
B	B7B	0.14%	0.37%	0.18%	0.18%
B	B7C	0.01%	0.00%	0.00%	0.00%
B	B9A	0.17%	0.09%	0.09%	0.00%
B	B9AA	0.01%	0.00%	0.00%	0.00%
B	B9B	0.17%	0.34%	0.18%	0.15%
B	B9CA	0.03%	0.06%	0.00%	0.06%
B	B9D	0.18%	0.09%	0.06%	0.03%
C	C1A	0.98%	1.04%	0.34%	0.71%
C	C2A	1.81%	2.33%	0.00%	2.33%
C	C2B	0.46%	0.68%	0.34%	0.34%
C	C2C	0.02%	0.00%	0.00%	0.00%
C	C4A	1.47%	1.57%	0.00%	1.57%
C	C4B	0.28%	0.49%	0.31%	0.18%
C	C4C	0.52%	0.83%	0.43%	0.40%
C	C4D	0.02%	0.03%	0.00%	0.03%
C	C5C	0.20%	0.43%	0.00%	0.43%
C	C5D	0.22%	0.21%	0.00%	0.21%
C	C5E	0.03%	0.03%	0.00%	0.03%
C	C6A	0.15%	0.28%	0.12%	0.15%
C	C6B	0.10%	0.15%	0.00%	0.15%
C	C7A	0.05%	0.06%	0.00%	0.06%
C	C8A	0.27%	0.31%	0.12%	0.18%
D	D11B	0.03%	0.03%	0.00%	0.03%
D	D5A	2.26%	3.62%	1.78%	1.84%
D	D5AA	0.01%	0.00%	0.00%	0.00%
D	D5AB	0.06%	0.03%	0.00%	0.03%
D	D5AC	0.04%	0.12%	0.03%	0.09%
D	D5AD	0.01%	0.03%	0.00%	0.03%
D	D5AE	0.01%	0.00%	0.00%	0.00%
D	D7A	0.89%	1.14%	0.49%	0.64%
D	D7AB	0.02%	0.00%	0.00%	0.00%
D	D7B	0.42%	0.46%	0.21%	0.25%
D	D7BA	0.00%	0.00%	0.00%	0.00%
D	D7C	0.05%	0.03%	0.03%	0.00%
D	D7F	0.18%	0.12%	0.00%	0.12%
D	D7J	0.10%	0.15%	0.12%	0.03%
D	D7K	0.03%	0.03%	0.00%	0.03%
D	D7KA	0.01%	0.00%	0.00%	0.00%
D	D9A	0.05%	0.03%	0.00%	0.03%
D	D9C	0.16%	0.25%	0.09%	0.15%
D	D9E	0.02%	0.00%	0.00%	0.00%
D	D9J	0.03%	0.00%	0.00%	0.00%
E	E3A	1.81%	1.87%	1.01%	0.86%
E	E3AA	0.00%	0.00%	0.00%	0.00%
E	E3AE	0.01%	0.03%	0.00%	0.03%
E	E5B	0.27%	0.34%	0.12%	0.21%
E	E5C	0.02%	0.00%	0.00%	0.00%
E	E7AA	0.01%	0.00%	0.00%	0.00%

Group	Pressure Zone	% Residential Accts	% of Randomly Sampled Accts		
			Total	Control	Treatment
E	E7B	0.02%	0.00%	0.00%	0.00%
E	E9A	0.02%	0.00%	0.00%	0.00%
F	F10A	0.04%	0.03%	0.03%	0.00%
F	F11A	0.03%	0.00%	0.00%	0.00%
F	F13A	0.00%	0.00%	0.00%	0.00%
F	F3A	3.46%	5.03%	2.76%	2.27%
F	F4A	2.24%	3.41%	1.75%	1.66%
F	F5B	1.04%	1.32%	0.71%	0.61%
F	F5BA	0.10%	0.09%	0.03%	0.06%
F	F5BF	3.59%	5.28%	2.61%	2.67%
F	F5BG	0.00%	0.00%	0.00%	0.00%
F	F7B	0.03%	0.00%	0.00%	0.00%
F	F7D	0.05%	0.12%	0.06%	0.06%
F	F7E	1.31%	1.50%	0.74%	0.77%
F	F7G	0.00%	0.00%	0.00%	0.00%
F	F8A	0.51%	0.74%	0.28%	0.46%
F	F9A	0.01%	0.03%	0.03%	0.00%
G	G0A	33.54%	24.59%	11.91%	12.68%
G	G1AA	10.60%	9.91%	5.34%	4.57%
G	G1AB	1.61%	1.10%	0.40%	0.71%
G	G1BA	1.16%	1.17%	0.61%	0.55%
H	H1A	3.09%	3.87%	1.87%	2.00%
F	F7F	0.09%	0.18%	0.12%	0.06%
F	F9B	0.03%	0.09%	0.09%	0.00%
	Grand Total	100.00%	100.00%	47.88%	52.12%

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Journal of Consumer Policy

The Persistent Impacts of Norm-based Messaging and their Implications for Water Conservation

--Manuscript Draft--

Manuscript Number:	COPO-D-13-00062R1
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Abstract:	Although an increasing number of studies have demonstrated the short-term impacts of behavioral nudges to achieve public policy objectives, less is known about their longer-term impacts. In a randomized experimental design with over 100,000 households, we study the longer-term impacts of a one-time behavioral nudge that aimed to induce voluntary reductions in water use during a drought. Combining technical information, moral suasion and social comparisons, the nudge has a surprisingly persistent effect. Although its effect size declines by almost 50% after one year, it remains detectable and policy-relevant six years later. In fact, the total reduction in water use achieved after the four-month period targeted by the intervention is larger than what was observed during the target period. Further analysis suggests that the intervention works through both short-lived behavioral adjustments and longer-lived adjustments to habits or physical capital. Treatment effects are not detectable in homes from which the treated consumers have moved, which provides suggestive evidence that these longer-lived adjustments are mobile rather than incorporated into the housing stock. The persistence of the effect makes the intervention more cost-effective than previously assumed (cost drops by almost 60%). Nevertheless, water utilities may find this persistence undesirable if the nudges are intended to have only a short-run effect on demand during environmental emergencies.
Response to Reviewers:	We have updated the analysis in our original submission with three more years of data, as requested by the editors.

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The Persistent Impacts of Norm-based Messaging and their Implications for Water Conservation

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Although an increasing number of studies have demonstrated the short-term impacts of behavioral nudges to achieve public policy objectives, less is known about their longer-term impacts. In a randomized experimental design with over 100,000 households, we study the longer-term impacts of a one-time behavioral nudge that aimed to induce voluntary reductions in water use during a drought. Combining technical information, moral suasion and social comparisons, the nudge has a surprisingly persistent effect. Although its effect size declines by almost 50% after one year, it remains detectable and policy-relevant six years later. In fact, the total reduction in water use achieved after the four-month period targeted by the intervention is larger than what was observed during the target period. Further analysis suggests that the intervention works through both short-lived behavioral adjustments and longer-lived adjustments to habits or physical capital. Treatment effects are not detectable in homes from which the treated consumers have moved, which provides suggestive evidence that these longer-lived adjustments are mobile rather than incorporated into the housing stock. The persistence of the effect makes the intervention more cost-effective than previously assumed (cost drops by almost 60%). Nevertheless, water utilities may find this persistence undesirable if the nudges are intended to have only a short-run effect on demand during environmental emergencies.

1. Introduction

Applications of behavioral economics are an increasingly popular means to influence a range of behaviors, such as alcohol and drug use, gambling, and investments in preventative health care (Thaler and Sunstein, 2008; Shafir, 2013). For example, both the United States and United Kingdom governments have established Behavioral Insights Teams (a.k.a. the "Nudge Squads"). These teams work with policymakers to apply insights from the behavioral sciences in order to encourage and enable individuals to make decisions that improve private and social welfare. In the private sector, there has been a rapid growth of firms providing strategies grounded in the decision sciences for both private and public clients. For example, Opower, C3 Energy, and WaterSmart Software help utilities meet their efficiency goals through the use of targeted messages designed to promote reductions in residential energy or water use.

In the environmental domain, the use of normative messaging – particular those including a social comparison – has become a popular way for practitioners to put basic behavioral principles to work. Such messages build upon Festinger's (1954) social comparison theory, which posits that individuals validate the appropriateness of an action through comparisons to others. Studies in both social psychology and economics provide empirical evidence that interventions based on this theory provide an effective means to promote environmental conservation (see, e.g., Kurz et al., 2005; Schultz et al., 2007; Goldstein et al., 2008; Nolan et al., 2008; Allcott, 2011; Ferraro and Price, 2013). For example, Allcott (2011) evaluates data from seventeen natural field experiments targeting more than 600,000 residential energy users and finds an approximate 1.4 to 3.3 percent reduction in average monthly energy consumption among households receiving a Home Energy Report that compares their energy use over the past twelve months to that for a group of like neighbors.[1]

Despite the apparent success of such interventions, the existing literature has focused largely on contemporaneous behavioral change and outcomes over the short-run.[2] The paucity of evidence on longer-run effects is symptomatic of the wider literature on behavioral nudges. In the health domain, for example, Bonell et al. (2011) claim that "…to date, few nudging interventions have been evaluated for their effectiveness in changing behavior in general populations and none…has been evaluated for its ability to achieve sustained change."[3]

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[1] Similar findings are reported in Ayres et al. (2013) and Ferraro and Price (2013) who find that normative messages are an effective way to promote conservation efforts among residential households.

[2] To the best of our knowledge, only Ferraro et al. (2011) and Allcott and Rogers (2012) examine the persistence of treatment effects and the ability of targeted messages to promote sustained behavioral change.

[3] In a November 2013 interview with The Observer, the director of the UK's Behavioral Insight Team acknowledged that the long-term effects of the impacts induced by the team's programs are unknown (http://www.psychologicalscience.org/index.php/publications/observer/2013/september-13/small-nudge-big-impact.html; accessed 5 November, 2013)

Moreover, the literature on normative messaging in the environmental domain has provided little evidence on the channels through which targeted messages impact behavior.

From a policy perspective, uncovering the channels through which "nudges" impact behavior and identifying the persistence of their impacts are important. Before one can advance such strategies as viable options to fight climate change or promote healthier living, it is critical to understand whether and how they influence choice over the long-run. The goal of this study is to extend the analysis presented in Ferraro et al. (2011) to examine how social comparisons influence longer-run patterns of residential water use and to shed more light on the channels through which the observed treatments effects are achieved.

Our study uses data generated from a randomized control trial implemented in May 2007 by a water utility in metropolitan Atlanta. Residential households were assigned into one of four treatments: a control group, a group that received a message containing technical advice on reducing water use, a group that received both technical advice and an appeal to prosocial preferences, and a group that received the advice, the appeal, and a social comparison contrasting the household's water use in the prior summer to that of the utility's median residential consumer. The messaging campaign was designed to promote conservation efforts during a period of extreme drought. As reported in Ferraro and Price (2013), the technical advice message had little impact, but the appeal to pro-social preferences and the appeal augmented with a social comparison reduced water use by 2.7 percent and 4.8 percent, respectively, relative to the control group.

Following Ferraro et al. (2011), we use data on initial treatment assignment and subsequent water use to examine the longer-run impacts of this one-time nudge. We extend their earlier analysis by including four additional years of data and transforming the estimated treatment effects to control for temporal changes in the variance of use among households in the control group. Doing so allows us to explore how the longer-run effects of treatment compare to the utility's minimum desired impact. Moreover, we follow Ferraro and Miranda (2013) and use information on movers to uncover whether the observed treatment effects arise through the adoption of new technologies in the home or the creation of new habits among residents living in the home at the time of intervention. Finally, we update Ferraro and Price's cost-effectiveness analysis to account for the observed persistence of our nudge.

The empirical results are striking; we find that our nudge has a surprisingly persistent effect. While the estimated effect size declines by nearly 50 percent after one year, we find that it remains detectable and policy relevant four years later. Moreover, if we restrict the sample to the subset of households that did not move during the entirety of the panel, the effect of treatment remains detectable in the seventh year. Calculating the long-run impact of our intervention, we find that the overall reduction in water use after the four-month period targeted for the intervention is greater than what was observed during the target period.

Such persistence is notable and makes our intervention significantly more cost-effective than previously assumed. Specifically we find that the cost per 1000 gallons saved is almost 60% lower than the figure derived by Ferraro and Price (2013) using only contemporaneous treatment effects. For policy makers, this result confirms the potential for behavioral nudges as part of comprehensive environmental policy – such strategies provide a cost-effective way to reduce water use among residential households and help promote broader environmental objectives.

Exploring the channels through which our nudge impacts water use, we find mixed evidence. Given that we observe an approximate 50 percent reduction in the estimated effect size after one year, our data suggest an important role for short-lived behavioral adjustments that wane rapidly.[4] However, the observed persistence of our intervention suggests a role for longer-lived adjustments to habits or physical capital. To disentangle these channels, we explore whether water use during summer 2010 for homes from which treated consumers have moved out is different from counterparts in the control group. Conceptually, if treatment results in changes to the capital stock of the home, we would expect such households to use less water than those in the control. Although we find no difference in the contemporaneous effect of treatment across movers and non-movers immediately following our initial intervention in summer 2007, the two household types respond in a statistically different manner in 2010. Moreover, we cannot reject the null hypothesis of zero treatment effect in summer 2010 among the subset of households for which the treated customers have moved. In other words, the treatment effect disappears when the treated customers disappear. This empirical pattern suggests that the treatment effects arise through the creation of new habits or the adoption of mobile technologies rather than changes to the capital stock of the home.

2. Study Design

Located in metropolitan Atlanta, the Cobb County Water System (CCWS) is an agency of the county government and distributes water to about 170,000 residential customers. The county is second largest user of Georgia's public water supply (Fanning, 2003). During a drought in 2007, CCWS implemented a targeted, residential information campaign within a randomized evaluation design. Its goal was to test the effectiveness of messages aimed at inducing voluntary reductions in water consumption during the summer months (June-September). Ferraro and Price (2013) describe the experimental design and treatments in detail. We outline the key elements here.

[4] Such a pattern of decay is consonant with prior evidence suggesting that normative appeals have greatest impact on use in the first few days after information on the norm is received and then tend to decrease over time (e.g., Ferraro and Price, 2013; Allcott and Rogers, 2012; Ayres et al. 2013; Dolan and Metcalfe, 2013).

In late May 2007, three messages were randomly assigned to single-family, detached dwellings whose customers had lived in the home since May 2006 and who were above the 22nd percentile of use June-October 2006 (see appendix for message examples):

(i) A *technical information message*, which presented customers with a double-sided "tip sheet" that explained ways in which the household could reduce its water consumption;

(ii) A *weak social norm message*, which augmented the tip sheet with a personalized letter signed by a CCWS employee on official stationary that explained the drought conditions, reiterated historical use information on the customer's bill, and, using norm-laden language, encouraged the customer to act on the enclosed tips;

(iii) A *strong social norm message*, which augmented the weak social norm message with a social comparison, in which the customer's own consumption during the previous year's summer was compared to median county consumption during the same period and the customer's percentile was reported. County residents are referred to as the customer's "neighbors." An example of a social comparison is the following:

Your own total consumption June to October 2006:	**52,000 gallons**
Your neighbors' average (median) consumption June to October 2006:	*35,000 gallons*
You consumed more water than 73% of your Cobb County neighbors.	

Prior to randomizing the messages, the CCWS staff determined that if a message could induce a reduction in water use of 2% during the 2007 summer watering season (Jun-Sept), the message would be deemed cost-effective. Accounting for the variance in baseline water use, this reduction corresponds to an effect size of 0.025. The small effect size reflects a common feature of behavioral nudges: they are so inexpensive that even small effect sizes are policy-relevant. In our application, the estimated cost of treatment was approximately $0.997 per household.

Each treatment group comprises approximately 11,700 households and the control group comprises approximately 71,600 households – numbers determined via power calculations using the targeted 2% reduction in use and 90% power. The messages were mailed (first class) on the same day in late May 2007 and randomized within almost 400 meter route units (small neighborhoods). Ferraro and Price (2013) show that randomization was effective at balancing pre-treatment water use across treatment arms (despite the large sample, differences were statistically insignificant), and there was unlikely to have been any interference among units (i.e., violations of the Stable Unit Treatment Value Assumption, SUTVA) or treatment noncompliance.

Based on the analysis in Ferraro and Price (2013), the effect of the technical information message was statistically indistinguishable from zero and well below the policy-relevant threshold identified by the Water System (trimming 780 observations from the top and bottom 0.25 percentile increases the precision of this estimate but it remains small and policy irrelevant). The weak social norm message reduced water use by, on average, 990 gallons (2.7% reduction; $p<0.01$) and the strong social norm message reduced water use by, on average, 1740 gallons (4.8% reduction). They find the treatment effects for the two norm-based messages are immediately detectable in the month after treatment assignment and still detectable four months later.

Subsequent analysis by Ferraro et al. (2011) and Ferraro and Miranda (2013) highlight substantial differences in the long-run impacts of treatment. Whereas Ferraro et al. (2011) find that the effect of the strong social norm remains detectable in summer 2009, Ferraro and Miranda (2013) find that the effect of the weak social norm is no longer detectable by December 2007. Given that previous studies failed to detect persistent impacts in the technical information and weak social norm messages, we focus our study on the persistence of the strong social norm message. In doing so, we restrict the analysis to households initially assigned to either the strong social norm treatment or the control.

We extend previous analyses in several ways. First, we elaborate on the nature of the persistence observed in Ferraro et al. (2011) who report treatment effects in gallons only. Reporting results in gallons only ignores changes in the mean and variance of water use over time in the control group (representing counterfactual water use). We believe that reporting percentage reductions and effect sizes, and how these measures compare to the CCWS's policy relevant threshold, is more informative. Second, we extend their analysis for four more summer watering seasons (2010-2013), which is important because of the time-varying institutional changes that were occurring between 2007 and 2010. At the end of September 2007 (the end of the period of analysis in Ferraro and Price), a complete outdoor watering ban was instituted in metropolitan Atlanta. The ban was in force until mid-June 2009, with only two small exceptions: in March 2008, the state government allowed hand watering for 25 minutes a day between midnight and 10 am (defined as one person with one hose with a shut off nozzle) and, in April 2008, 30 days of watering between midnight and 10 am for new professional landscape installations. Summer 2010 was the first full summer without an outdoor water ban.

Moreover, we extend previous analyses to think more deeply about the potential channels through which households changed their behaviors in response to the strong social norm message. In the context of water consumption, as in other environmental contexts like energy use or toxic waste generation, consumers can adjust their behaviors in cheap-to-reverse ways (e.g., shorter showers; re-use water) or costly-to-reverse ways (e.g., let the outdoor vegetation die during drought). Some behavioral adjustments require constant vigilance to maintain (e.g., only run full loads of laundry), while others can be done and forgotten about (e.g., put programmable

irrigation system or dishwasher on eco-friendly setting). Consumers can also invest in technology capital that requires higher up-front fixed costs but lower variable costs (e.g., fix leaks; buy low-flow toilets or high-efficiency irrigation systems).

Such physical capital-based adjustments, like a persistent shock to water demand, would be expected to induce more persistent treatment effects. Yet some of these adjustments may be mobile and follow the treated household members (e.g., an efficient above-ground sprinkler system or washing machine). Others may be immobile and stay with the home (e.g., the purchase of a more efficient below-ground sprinkler, repaired leaks, or the installation of low-flow toilets). Thus the analysis is equivalent to asking whether treatment affects the home or the homeowner. A treatment response based on investments in immobile, physical capital might be expected to be more persistent than a response based on behavioral adjustments or investments in mobile capital.

Without observations of behavior inside the households over time, we cannot identify specific mechanisms like "purchased low-flow toilets," but we can probe the nature of the potential channels. To do so, we look both at the pattern of treatment effects over time and contrast the heterogeneous responses over time of homes from which the customers moved during the post-treatment assignment period and homes from which the customers did not move. For example, if the treatment effect observed in 2007 wanes over time, such a pattern would not be consistent with all of the effect coming from costly-to-reverse behavioral adjustments, or cheap-to-reverse behavioral adjustments that require no vigilance to maintain over time by the customer, or technology investments that lead to persistent demand shocks. Furthermore, if the treatment effects are persistent for non-movers but disappear in homes in which the originally treated customers have moved, the pattern would be inconsistent with treatment effects being achieved through investment in immobile forms of physical capital. If investments in immobile forms of physical capital were an important driver of changes in water use, the treatment effect should depend on the home, not who lives in the home.

3. Results

3.1 Persistence of Impacts

The average treatment effects of the strong social norm message for each summer are presented in Table 1 (we restrict attention here to the treatment effect estimates and suppress the coefficients on pre-treatment water use variables and the 400 meter route dummies). As measured by gallons of water, the observed treatment effect in 2007 declines by 63% ($p<0.05$) in 2008. However, in 2008 outdoor watering was banned and thus the counterfactual water use was much smaller than in 2007. Thus, in terms of percent reduction or effect size, the treatment effect declined by less than 50% in 2008. After 2008, the treatment effect in both absolute and

relative terms remains roughly similar and can still be detected in summer 2011. We cannot, however, reject the null of zero treatment effect in the 2012 and 2013 summer seasons. We return to this issue in section 3.3.

Table 1. Average Treatment Effect for Summer (June-September) 2007-2013

	Utility's Minimum Desired Impact in First Year	(1) Summer 2007	(2) Summer 2008	(3) Summer 2009	(4) Summer 2010	(5) Summer 2011	(6) Summer 2012	(7) Summer 2013
Strong Social Norm Treatment (thousands of gallons)	0.729	-1.741**	-0.637***	-0.344**	-0.509**	-0.397**	-0.0453	-0.205
Standard Error		(0.166)	(0.161)	(0.162)	(0.245)	(0.200)	(0.191)	(0.207)
Percent Reduction (compared to controls)	2.00%	4.77%	2.50%	1.25%	1.71%	1.33%	0.16%	0.89%
Effect Size /1	0.025	0.060	0.032	0.016	0.021	0.015	0.002	0.012
Meter Route Dummy Variables		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre-treatment Water Use Variables		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Robust Standard Errors		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations		106,669	106,669	106,669	106,153	106,353	106,353	106,353

*** p<0.01, ** p<0.05, * p<0.10
/1/ Effect Size = (treatment effect)/(standard deviation of control group)
(i.e., mean reduction in use divided by SD of the counterfactual water use)

Before proceeding, it is worthwhile to note that the effect size of the impact in 2010 and 2011 (0.021 and 0.015 respectively) differs only slightly from the desired effect size of 0.025 for the original 2007 target period. Thus, although the water utility believed that the behavioral nudge would be cost-effective if it had an effect size of 0.025 in 2007, the nudge persisted in having a similar effect size four summers later. In fact, the estimated total reduction in water use achieved after the four-month period targeted by the intervention is larger than the reduction during the target period.

3.2 Implication for our Understanding of Behavioral Channels

The large decline in the estimated treatment effects after 2007 implies an important role for short-lived behavioral adjustments. However, the observed persistence of our intervention also suggests the presence of longer-lived adjustments to either habits or capital stock in the home. To evaluate the relative importance of investments in capital stock and the development of new habits, we consider three sources of evidence. Although neither source by itself identifies a unique channel, when combined they offer a consistent picture.

First, we note that Ferraro and Price (2013) find the treatment effects for the two norm-based messages are immediately detectable at full strength in the month immediately after treatment

assignment (June). Although it is possible that households quickly adopted new capital stock into their homes in such a rapid time frame, it seems less plausible than purely behavioral adjustments.

Second, Ferraro and Miranda (2013) find effects only in summers, when outdoor watering forms a large part of the water budget, but not in winter, when most of the water use is indoors. This pattern suggests that the treatment effects are largely being realized through changes in outdoor watering. In Cobb County, in-ground, immobile irrigation systems are much less prevalent than in other regions such as the arid western states in the US (Kathy Nguyen, pers. comm.). CCWS believed that an important water saving channel was reducing improper, over-watering of lawns and this reduction would require a change in habits. Thus changes in outdoor watering in Cobb County seem more likely to happen through changes in watering habits (e.g., watering one day a week in the early morning, rather than three days per week during the middle of the day). Nevertheless, investments in more efficient, but mobile, irrigation systems (e.g., above-ground sprinklers) are also a potential channel.

Third, Ferraro and Miranda (2013) show that owner-occupied homes are much more responsive than renter-occupied homes.[5] In fact, they cannot reject the null hypothesis that renters do not respond to treatment. This result is relevant because owners are more likely to invest in physical capital stock for two reasons. First, Davis (2012) has shown that renters are significantly less likely to have energy efficient appliances, like clothes washers and dishwashers. This pattern is consistent with the hypothesis that when tenants pay the utility bills, landlords may buy cheap inefficient appliances. In our sample, almost all renters are directly billed (apartment buildings are not in the sample). Second, owner-occupants have a greater incentive to invest in high fixed-cost, water conservation technologies that are capitalized into the value of the home, like low-flow toilets or high-efficiency in-ground sprinkler systems. Thus if some of the persistence of the treatment effect comes from investment in physical capital stock that is incorporated into the home, the most likely subgroup to see such investment is the owner-occupied homes.

We hypothesize that if owner-occupied homes have invested in immobile physical capital – capital that becomes part of the home – rather than through changes in habits or investments in mobile physical capital, we should see the treatment effect persist even after the customer has moved from the home. From the water utility data, we can observe whether the customer name on the bill changes at some point between treatment assignment and May 2010, the month before the summer 2010 period. We call these homes "movers." Non-movers have the same customer name on the bill at treatment assignment and in May 2010.

[5] Ferraro and Miranda (2013) identify ownership by merging the water data with the 2007 tax assessor database.

Table 2. Average Treatment Effects for Movers and Non-Movers

	Summer 2007	Summer 2010
Strong Social Norm Treatment	-2.077***	-0.720**
	(0.191)	(0.296)
Treatment*Movers	0.481	1.375*
	(0.521)	(0.717)
Movers	-2.286***	-4.658***
	(0.225)	(0.332)
Meter Route Dummy Variables	Yes	Yes
Pre-treatment Water Use Variables	Yes	Yes
Robust Standard Errors	Yes	Yes
Observations	68,107	
Number of Movers	8,904	
Percent of Treated Group that Moves	13.1%	
Percent of Control Group that Moves	13.1%	
H0: Treatment + Treatment*Movers=0		
(p-value)	0.001	0.301

Note: All water consumption variables are in thousands of gallons.
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In the first column of Table 2, we first show that, in 2007, both movers and non-movers are responsive to the treatment message and there is no statistical difference between their responses. In 2010, however, the results are very different. We can reject the null hypothesis of zero treatment effect for the non-movers, but not for the movers, and we can reject the null that movers and non-movers respond equally. In other words, before people move out, we detect a treatment effect that looks like similar to what we observe in all households. But after people move out, the treatment effect among movers is undetectable and very different from those of non-movers.[6]

The combined weight of the three sources of evidence suggest that changes in water use as a result of receiving the strong social norm message appear to arise through the creation of new habits among treated customers (or mobile capital stock) rather than changes in the capital stock of the treated homes. This analysis provides some evidence for the conjecture advanced in

[66] A rival explanation for this pattern in the data is that although movers and non-movers are observationally similar in 2007 in terms of their treatment response, the channels through which they achieve the response are completely different in unobservable ways. As noted in the text, in the absence of direct observations inside the households, our evidence is suggestive rather than definitive.

Allcott and Rogers (2012), that persistence in the treatment effects from normative messaging that includes social comparisons reflects habit formation.

3.3 Revisiting the Longer-run Effects

Using our definition, almost one in four households in the treatment and control groups (23%) had moved by summer 2013. The analysis in section 3.2 suggests that one reason why we may be unable to detect a treatment effect in 2013 in Table 1 is because treated homeowners have left the treated homes. Therefore we replicate Table 1, but restrict the sample to the subset of 51,846 owner-occupied homes for which the customer name on the bill did not change between initial treatment assignment and May 2013. We acknowledge that we did not randomize treatment within this subgroup, but randomization was done within small neighborhood units and the sample remains large. To mitigate concerns about hidden biases in this subgroup analysis, we also conduct a placebo test using pre-treatment summer 2006 water use.

Table 3 reports the results. Our placebo test using summer 2006 use supports the claim that randomization was effective within this subgroup: the treatment effect is small and insignificantly different from zero. Although we cannot reject the null hypothesis of zero effect in 2012 for this subgroup, we can reject the same null for every other year including 2013. Moreover, the estimated effect size is similar in 2009, 2010, 2011 and 2013. Thus, for the subgroup that remains treated throughout the entire panel, we find that a treatment effect persists through 2013. After seven summers, the difference between the water use in the treatment group and the control group remains policy-relevant and statistically different from zero.

Table 3. Average Treatment Effect: Owner-Occupied, Non-Mover Households (2007-2013)

	Utility's Minimum Desired Impact in First Year	(1) Summer 2006	(2) Summer 2007	(3) Summer 2008	(4) Summer 2009	(5) Summer 2010	(6) Summer 2011	(7) Summer 2012	(8) Summer 2013
Treatment 3	0.752	-0.277	-2.115***	-0.771***	-0.384**	-0.784**	-0.400*	0.0716	-0.335*
(Strong social norm)		(0.338)	(0.202)	(0.197)	(0.193)	(0.330)	(0.240)	(0.236)	(0.175)
Percent Reduction	2.00%	0.60%	5.62%	2.95%	1.34%	2.48%	1.26%	0.24%	1.43%
(compared to controls)									
Effect Size /1	0.026	0.009	0.074	0.041	0.019	0.032	0.016	0.003	0.020
Meter Route Dummy Variables		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Robust Standard Errors		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations		51,846	51,846	51,846	51,846	51,841	51,846	51,846	51,846
R-squared		0.161	0.659	0.290	0.397	0.106	0.416	0.380	0.227

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
/1/ Effect Size = (treatment effect)/(standard deviation of control group)
(i.e., mean reduction in use divided by SD of the counterfactual water use)

3.4 Implications for our Understanding of Total Impacts and Cost-effectiveness

Given the persistence of the nudge's impact on water use, we update Ferraro and Price's cost-effectiveness analysis that only looked at the first four months after treatment assignment. The nudge is far more cost-effective than their analysis implies. If we use the estimated treatment effects from Table 1, the nudge costs an estimated $0.235 per thousand gallons reduced, which is almost 60% lower than Ferraro and Price's original estimate ($0.58).[7] If we make the more conservative assumption that the average treatment effect was zero in 2012 and 2013, the cost is $0.25 per thousand gallons. Had the message been sent to all homes in the experimental sample (which is all customers with a pre-treatment water history from the year earlier), the utility could have expected to reduce water consumption by 453 million gallons over the 2007-2013 period (426 million 2007-2011). For comparison, the U.S. Geological Survey estimates that the average American uses between 80-100 gallons of water per day (http://ga.water.usgs.gov/edu/qa-home-percapita.html).

4. Conclusion

Economists have only recently begun to explore the effects of norm-based messages as a means to promote behavioral change. To date, this literature has focused largely on short-run effects. This study contributes to a growing body of work that explores whether and how such messages influence behavior over the long-run. We do so by investigating the effectiveness of social comparisons in a randomized control trial carried out in conjunction with a water utility system in the metropolitan Atlanta area.

Our analysis builds upon prior work by Ferraro et al. (2011) and Ferraro and Miranda (2013), but extends this earlier work along a two important dimensions. First, we include data for a longer time horizon than the earlier work and report results in terms of effect sizes rather than absolute levels. This allows us to control for temporal variations in baseline water use among control households and explore how the long-run effects of treatment compare to the utility's minimum desired impact. Second, we use updated data on movers and post-treatment assignment water use to uncover whether persistent changes in water use reflect longer-lived adjustments in the habits or mobile technologies of water users or fundamental changes in the capital stock of the home.

The empirical results are striking. We find that our nudge has a surprisingly persistent effect despite the fact that households received only a single message. Although the estimated effect

[7] Ferraro and Miranda find that there is also an effect in the winter months in 2007-2008, but not in subsequent years. To calculate cost-effectiveness, we make the conservative assumption that treatment effects only exist during summers 2007-2010 and during winter 2007/08.

size declines by approximately 50 percent in the year after intervention, it remains detectable and policy relevant four years later in the overall sample and six years later in the subgroup of owner-occupied homes in which the originally treated owners had not moved. Moreover, we find that the long-run impacts of our intervention exceed those observed in the initial, four-month target period. Adjusting for such effects, we find that our intervention is significantly more cost-effective than previously calculated. Specifically, we find that the cost per 1000 gallons saved is almost 60% lower when one accounts for the persistence of treatment ($0.24 per thousand gallons saved).

For policy-makers, these results are promising and suggest a potentially important role for behavioral nudges in environmental policy – they provide a low cost way to reduce residential consumption levels. Nevertheless, water utilities may find the persistence of the nudges undesirable if it they are intended to have only a short-run effect on demand during environmental emergencies like a drought. Given that many utilities are regulated, a structural reduction in demand may force them to raise prices, which could subsequently anger customers who had voluntarily changed their water use for the public (environmental) good as a result of the normative messaging campaign.[8]

Turning to the channels through which our strong social norm message affects water use, we find mixed evidence. The rapid decline in the estimate treatment effects suggests an important role for short-lived behavioral adjustments. However, the observed persistence of our intervention suggests the presence of longer-lived adjustments to either habits or capital stock in the home. Using data on movers, we find that changes in use appear to arise through the creation of new habits (or mobile capital stock) among the treated customers rather than changes in the capital stock of the treated homes. Future work should push this analysis further by tracking treated customers as they move from one home to another. Whether the patterns of effects we find in Georgia would be found in other contexts is unknown. For example, one might expect that customers in the arid West, where households rely upon in-ground sprinklers, might have more opportunities to adjust physical capital stocks that are incorporated into house. Likewise, more studies are needed to determine if the patterns we observe are also observed in other domains in which normative messaging has been shown to have short-run effects, like energy use and recycling. Finally, we see great promise in studies that elucidate the welfare implications of behavioral nudges – a topic which is currently absent in the literature but one for which economists are well placed to address.

[8] According to the Cobb County-Marietta Water Authority General Manager, "25 to 33 percent" of a scheduled 2009 rate hike was a result of a decrease in water demand (*Atlanta Journal-Constitution 7/21/08).*

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Appendix: Tip Sheet and Sample Treatment Letters

Simple Ways to Reduce Water Consumption

Outdoor Water Use

Did You Know?
In summer, household water use can double. Reducing outdoor water use is easy, better for your yard, and can be done without making big changes to your yard or lifestyle.

- **Fix leaking sprinklers, spigots and hoses.** One broken sprinkler can use an additional 100 gallons in a typical 10 minute watering cycle.
- **Raise your lawn mower blade to at least 3 inches.** This encourages grass roots to grow deeper, shades the roots and holds soil moisture better than a closely clipped lawn.
- **Water your lawn with only one inch of water every seven to ten days** (less often if we've had rain). Overwatered lawns and plants grow shallow roots and are more likely to die in periods of drought.
- **Don't water between 10 am and midnight.** The water evaporates before plants can use it.
- **Use a low-flow nozzle on your hose.** Using a standard nozzle on your hose to wash your car or plants can require hundreds of gallons more water than a low-flow nozzle.
- **Mulch!** Using pine straw, bark chips or ground hardwood mulch on the roots of plants and trees helps the soil retain water.
- **Use plants appropriate for our climate.** Ask your local nursery about drought-tolerant plants and trees appropriate for Georgia. See next page for more information.
- **Do not use a hose to clean your driveway or sidewalk.** Use a broom instead and save hundreds of gallons of water.

Toilets, Faucets, Showers and Washing Machines

Did You Know?
A showerhead or faucet leak of one drop per second adds up to 2,700 gallons/year!

- **Fix toilet leaks:** This can save you thousands of gallons of water each year!
- **Turn off the bathroom faucets when brushing and shaving:** Save up to 3,000 gallons/year!
- **Don't use your toilet as a wastebasket.**
- **Replace your old toilet.** If you have a pre-1993 toilet, you can save more than 16,000 gallons per year by purchasing a high-efficiency model (1.3 - 1.6 gallons per flush). Unlike the first generation of low-flow toilets, new models reduce water use without sacrificing performance.
- **Replace your old faucets and showerheads.** High-efficiency sink faucets (1.5 gallons per minute or less) and accessories (like aerators) can reduce this standard flow by more than 30 percent without sacrificing performance.
- **Take short showers rather than baths:** Taking a five-minute shower uses 10 to 25 gallons as opposed to 30 – 70 gallons for a bath. If you take a bath, stopper the drain immediately and adjust the temperature as you fill the tub.
- **Run full laundry loads** or use the appropriate load size selection on the machine.
- **When you replace your old washing machine, purchase a high-efficiency washing machine** that uses less than 27 gallons of water per load.

Everywhere You Look, You'll Find Another Easy Way to Reduce Water Consumption

Detecting Hidden Leaks

To detect hidden leaks:

- Read your water meter before and after a two-hour period when no water is being used. If the meter does not read exactly the same, you probably have a leak. To download a guide to reading your meter, please visit water.cobbcountyga.gov/files/meterhowto.pdf *

To tell if your toilet has a leak:

- Place a drop of food coloring in the tank; if the color shows in the bowl without flushing, you have a leak in the tank.
- To see if the leak is coming from the flush valve, shut off the water supply to the toilet. Mark the water level on the inside of the tank with a pencil. Check the water level in 10 or 20 minutes. If the water has fallen, you know the flush valve is leaking.
- If the water seems to run constantly in the toilet, your refill valve may be leaking. In this case, the tank overfills and the excess water runs into the overflow pipe and into the bowl.

For more information and repair tips, Ace Hardware has an excellent FAQ section, as well as installation guides, in the Projects & Solutions section of their website: www.acehardware.com/info-home/. Home Depot also has guides in the Know-How section of their website at homedepot.com.

Advice on Proper Yard Watering

Cobb County provides instructions on proper yard watering

- Call 770-419-6244, or
- Download the guide at water.cobbcountyga.gov/files/IrrigationAudit.pdf

ConserveWater Georgia offers plenty of information, tips, and creative ideas.

- Download their WaterWise Landscaping &Watering Guide at www.conservewatergeorgia.net/pdf/water-wiseguide.pdf.

Find the right plants and trees for your yard!

- Online guides to appropriate plants and trees for Georgia can be found at:
  -georgiagaces.caes.uga.edu Search for "drought-resistant" (georgiafaces.caes.uga.edu/getstory.cfm?storyid=1165)
  -www.marshalltrees.com Go to "Educational Information," then "Trees During Design & Develop ment." The "Tree Selection" section has a link for "Drought Resistance" (www.marshalltrees.com/articles.asp?p=2&id=26&cid=0)

How you design your landscape is also important. Check out the following guides:

- http://www.conservewatergeorgia.net/pdf/medc_water_saving_tips_ new_landscape.pdf
- http://pubs.caes.uga.edu/caespubs/pubcd/B1073.htm.

Audit Your Usage

To help you learn more about how much water you are using in your home, Cobb County has a quick, 2-page home water audit that you can complete: http://water.cobbcountyga.gov/files/waterauditpdf. By completing this questionnaire and submitting it to the Water Efficiency Program, you may qualify for FREE water saving devices and water efficiency information.

*Any documents on-line that have a ".pdf" extension require Adobe Reader. You can download it for free at: http://www.adobe.com/products/acrobat/readstep2.html

For More Information Visit: water.cobbcountyga.gov/efficiency.htm

Sample Letter – Strong Social Norm Treatment

Treatment 3

Cobb County...Expect the Best!

[redacted]

[redacted] May 2007

Dear Members of the [redacted] Residence,

As you may know, Cobb County's water resources are stretched because of population growth and many years of low rainfall. Cobb County residents consume almost one out of every ten gallons of Georgia's public water supply. As a result, our water use has a large impact on the ability of Georgia's waterways to protect wildlife and dilute pollutants that threaten human health. **We all need to work together to use water wisely.**

As we enter the summer months, we thought that you might be interested in the following information about your water consumption last year:

Your own total consumption June to October 2006:	**50,000 gallons**
Your neighbors' average (median) consumption June to October 2006:	*35,000 gallons*

You consumed more water than 72% of your Cobb County neighbors.

We have enclosed a tip sheet that lists proven ways to reduce your water consumption. You can obtain more information on-line (http://water.cobbcountyga.gov/efficiency.htm and http://www.wateruseitwisely.com/) or by contacting Ms. Kathy Nguyen, Water Conservation Coordinator, at 770-419-6244 or Kathy.Nguyen@cobbcounty.org.

We need your help. **Act on the tips listed in the enclosed tip sheet.** We all have to do our part to protect Cobb County's precious water resources. Reducing our water consumption today is important for preserving our environment and our economy for future generations. **Please don't waste water**. Remember: every drop counts!

Thank you for your attention.

Sincerely,

Kathy Nguyen

Kathy Nguyen
Water Conservation Coordinator

May/2007 Treatment Ltr #2

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Source: http://www.sawpa.org/wp-content/uploads/2014/01/8-Per-Capita-Water-Use.pdf

1.2. Per capita water use

1.2.1. What is it?

The Governor's Office of California issued the 20x2020 Water Conservation Plan in February 2010 that calls for a statewide reduction in water use, 20% overall by the year 2020 (California Department of Water Resources, et. al., 2010). Current statewide per capita water use is 193 gallons per day (gpd), and the 2020 target is 154 gpd. Table 2 below, taken from within the plan itself, reflects the baseline conditions and the targets laid out in the plan for the various regions of the state. Residents of the Santa Ana River Watershed reside within Region 4.

The plan includes regional interim targets for 2015, and final targets for 2020 that if met in each region will take the entire state to the goal of using 20% less water. This "road- map" will help the state achieve a more sustainable water practice, in response to multiple issues as laid out in the Plan's executive summary:

- Reduced stress on the environment of the Sacramento-San Joaquin Delta
- Delayed capital cost of new infrastructure to treat and deliver water
- Reduced demand for wastewater treatment, including capital costs and ongoing treatment costs
- Reduced water-related energy demands and associated greenhouse gas emissions
- Improved ability to meet environmental needs
- Improvements in the quality of receiving waters related to reduced discharge
- Reduced use of fertilizers, pesticides, and herbicides and reduced escape of these chemicals into surface waters through use of native plants and low water using varieties, reduced production of green waste, and improved habitat value of urban landscapes
- Enhanced flexibility in water management and delivery systems, especially during dry periods
- Better capacity to meet the challenge of California's growing population.

For the South Coast region, the plan calls for a decrease from the current all-uses 180 GPD to a goal of 149 GPD. An interim target of 165 GPD is sought for the year 2015.

1.2.2. Why is it Important?

As the 20x2020 plan encourages, decreasing per capita water use will have positive influence on a number of issues facing the watershed, the region, and the State. How water is used around the home/business and outdoors suggests attitudes towards the availability of water, and the associated value of particular water practice (landscaping, washing sidewalks and driveways, etc.) California's water resources are finite and need to be managed for long term sustainability.

1.2.3. What is the target or desired condition?

For Region four, which includes the Santa Ana watershed, the overall goal is 165 GPD by 2015, and 149 GPD by 2020. For residential-only, the baseline is 126gpd, however the 20x2020 Water Conservation Plan[1] does not call-out residential only goals. Using the overall baseline and goals, the Region four targets are an 8.3% reduction by 2015, and a 17.2% reduction by 2020. Using 126gpd as baseline, the 2015 target for residential-only in this region is 116gpd, and the 2020 target is 104gpd.

[1] http://www.water.ca.gov/wateruseefficiency/sb7/docs/20x2020plan.pdf

1.2.4. What can influence or stress the condition?

Per capita water usage is a statistic that includes water use within all the different sectors of the economy in the numerator, but only takes into account the residential population of the area in the denominator of the metric. This can make comparing regions challenging, as a heavily industrial or agricultural area will have large water needs and small populations, making the per capita number quite large. Even within sectors there can be great variability. Residential areas, for instance, can have significantly different patterns of water use, where the smaller plots in coastal subdivisions use much less water than do the more affluent, large-parcel single-family homes in the foothill communities.

The 20x2020 plan works at a broad regional scale, making many of the concerns addressed above not relevant. At the watershed scale, as in this analysis, it is possible to see the differences in land-use and affluence in the various data provided by the water companies. By creating a watershed-wide average, these variations should play a less significant role.

When comparing the water companies to one another, using the per capita rate without an awareness of either the raw population or total water usage values would be unfair. The few companies whose per capita numbers are very large are serving a very small portion of the population of the watershed. This suggests that efforts to make further changes be tailored to the users who are contributing these high values.

1.2.5. Basis of calculation and use

For this indicator, the reported per capita rates were normalized to the "Gross Water Use" (Method 1)[2] calculation provided by the SB x7-7 legislation, where residential use is split from commercial and industrial use, and the residential water use is used to calculate per capita rates. Each agency was then assessed for being over the baseline of 126gpd, below the baseline but above the target of 104gpd, or below the target of 104gpd. Each of these categories then counted population, yielding percentages of the population in each. For the indicator, each category was provided a weighting, where above baseline was zero, below baseline but above target was 0.5, and below target was 1. By multiplying the percentage times 100 and the weighting, we produced a score between 0 (no people under baseline) and 100 (all people below the target).

1.2.6. What did we find out/How are we doing?

About 8.9 million people use 1.02 billion gallons per day, providing an estimate of 114 gallons per day per person within the watershed. This value below the baseline and the 2015 interim target for the watershed, however, is still above the 2020 target.

[2] http://www.water.ca.gov/wateruseefficiency/sb7/docs/MethodologiesCalculatingBaseline_Final_03_01_2011.pdf

Table 2: Santa Ana River Watershed Water Retailers Per Capita Water Use Data (source: DWR DOST database)

Water Retailer	2010 Baseline GPCD	2020 Target GPCD	2010 Retail Population	Percent Reduction
Anaheim City of	202	161	364,921	25%
Big Bear Lake City of	101	101	25,462	0%
Brea City of	275	220	40,377	25%
Buena Park City of	200	160	84,141	25%
Chino City of	237	189	71,506	25%
Chino Hills City of	218	175	74,738	25%
Colton, City of	241	193	47,429	25%
Corona City of	264	212	150,416	25%
Cucamonga Valley Water District	285	228	199,225	25%
East Orange County Water District	329	263	3,656	25%
East Valley Water District	342	277	63,055	23%
Eastern Municipal Water District	212	184	695,932	15%
El Toro Water District	201	161	52,019	25%
Elsinore Valley Municipal Water District	248	240	123,375	3%
Fountain Valley City of	170	142	59,227	20%
Fullerton City of	222	178	138,000	25%
Garden Grove City of	162	142	177,020	14%
Golden State Water Company Placentia	167	142	49,342	18%
Golden State Water Company West Orange	151	140	111,418	8%
Hemet City of	176	141	23,537	25%
Huntington Beach City of	159	137	204,831	16%
Irvine Ranch Water District	213	170	337,876	25%
Jurupa Community Service District	248	199	101,700	25%
La Habra City of Public Works	159	142	63,118	12%
La Palma City of	156	136	15,544	15%
Laguna Beach County Water District	201	161	20,850	25%
Lake Hemet Municipal Water District	162	142	52,914	14%
Loma Linda City of	255	204	12,206	25%
Mesa Consolidated Water District	179	143	111,166	25%
Monte Vista Water District	211	169	52,488	25%
Moulton Niguel Water District	215	172	172,068	25%
Newport Beach City of	254	203	67,030	25%
Ontario City of	248	198	168,766	25%
Orange City of	224	179	130,325	25%
Rancho California Water District	416	333	133,691	25%
Redlands City of	365	292	77,852	25%
Riverside City of	264	211	287,000	25%
Rubidoux Community Service District	227	182	29,900	25%
San Bernardino City of	249	201	187,690	24%
San Jacinto City of	218	174	15,200	25%
Santa Ana City of	128	109	358,136	17%
Seal Beach City of	152	140	25,561	9%
Serrano Water District	466	373	6,641	25%
South Coast Water District	186	149	38,641	25%
Trabuco Canyon Water District	260	181	14,907	44%
Tustin City of	190	152	69,010	25%
Upland City of	273	218	73,732	25%
West Valley Water District	316	254	66,571	24%
Westminster City of	180	149	94,294	21%
Yorba Linda Water District	286	229	77,320	25%
Yucaipa Valley Water District	291	233	42,171	25%

1.2.7. How sure are we about our findings (Things to keep in mind)

The data used for this report relies on reporting from the various agencies, and has been normalized to residential-only values using Method 1. These calculations are sound, however, the 20x2020 goals are not solely for residential users. Future analyses of this indicator should move to calculate all water use, including commercial, industrial and agricultural alongside residential.

1.2.8. Analysts

Santa Ana Watershed Project Authority
Council for Watershed Health

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Forthcoming in Land Economics

Residential Water Demand Effect of Increasing Block Rate Water Budgets

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Increasing Block Rate Water Budgets

Abstract

We investigate the effect of introducing a fiscally neutral increasing block rate water budget price structure on residential water demand. We estimate that demand was reduced by around 17%, although the reduction was achieved gradually over more than three years. As intermediate steps we derive estimates of price and income elasticities that rely only on longitudinal variability. We investigate how different subpopulations responded to the pricing change and find evidence that marginal, rather than average, prices may be driving consumption. We also derive alternative rate structures that might have been implemented, and assess their estimated demand effects.

Key words

Block rate pricing, DCC model, residential water demand, water budgets.

As urban water utilities confront increasingly scarce and less reliable water supplies due to population growth, environmental regulation, and climate variability, water managers are seeking opportunities to reduce residential water demand. While the adoption of non-price instruments (e.g., short-term water restrictions, subsidies for water-saving technologies, and public-awareness campaigns) likely will continue to be wide-spread, volumetric pricing and, in particular, block-rate pricing is gaining traction. This is not surprising to economists who have long espoused the merits of pricing as an efficient and effective means to address water scarcity (e.g., Howe and Linaweaver 1967; Chesnutt and Beecher 1998; Renwick and Green 2000; Griffin 2001; Dalhuisen et al. 2003; Olmstead and Stavins 2009; Grafton et al. 2011). One challenge confronting water utilities that are considering switching to volumetric pricing is identifying the particular rate structure that is best suited to their needs. One structure that is increasingly being adopted by California water utilities is the increasing block-rate water budget.

Increasing block rate (IBR) water budgets (which we refer to herein more simply as "water budgets") are a particular type of escalating tiered price structure in which the block sizes are based on household-specific characteristics (e.g., household size, irrigated area), environmental conditions (e.g., evapotranspiration), and a judgment by the water utility with regard to what constitutes "efficient" water use given those characteristics and conditions. This means that price structures can differ across households at any given time, and through time for any given household. Water budgets are a relatively new pricing tool. One of the earliest adopters was the Irvine Ranch Water District (IRWD) in southern California which instituted such pricing in the early 1990s (IRWD 2013).

Water budgets are thought to have significant advantages over more commonly used rate structures.[1] Foremost, water budgets provide utilities with the means to promote conservation through appropriate price signals while also maintaining fiscal balance. Under water budget pricing, each

[1] We thank an anonymous reviewer for helping to improve this section.

household pays a higher price for additional water only when total consumption exceeds that household's "efficient" level of use for the current billing period (Mayer et al. 2008). Hall (2009) argues that the conservation incentives provided by water budgets are even stronger than those provided by standard IBR pricing with fixed volumetric blocks because water budgets adjust the blocks according to the size of each household. Thus both large and small households pay higher prices as consumption increases, whereas small households would rarely enter the upper blocks under a standard IBR price structure. Hall (2009) notes that this feature also improves the economic efficiency of water budgets because all households consume marginal water, and the marginal cost of water supply tends to be increasing. Furthermore, by more closely matching the price structure to the cost of supply, water budgets help utilities maintain fiscal balance despite potentially significant demand fluctuations. Water budgets also can accommodate equity concerns by charging lower prices for the most essential uses of water such as drinking, cooking and cleaning (Mayer et al. 2008). By keeping these prices low for every household regardless of size, water budgets tend to be more politically acceptable than standard IBR pricing (Hall 2009). Last, water budgets provide utilities with the ability to respond flexibly and immediately to evolving environmental and fiscal conditions with a price-based regulatory instrument (Mayer et al. 2008).

As of 2008, fewer than 14 California water utilities had implemented IBR water budgets (Mayer et al. 2008), even though around 50% of all California water utilities were utilizing IBR *pricing* as of 2005 (Hanak 2005). Recently, though, there appears to be renewed interest in water budgets. This trend has been driven, in part, by California's "20x2020 Water Conservation Plan" which aims to reduce statewide per-capita urban water use by 20% before 2020 (California DWR 2010). Between 2008 and 2011, at least nine southern California water utilities adopted water budgets as part of their efforts to comply with the plan (Ash 2011).

Despite the potential advantages offered by water budgets and renewed interest by utilities, there remain widespread uncertainties and concerns about switching to such a price structure. A prominent concern, and the focus of this study, is the extent to which water budgets actually reduce demand. Anecdotal evidence suggests that the demand effect may be quite large. For example, the Irvine Ranch Water District reports that in the 13 years following the introduction of water budgets, average per-acre outdoor water use declined by 61% (IRWD 2013). However, statistics such as this can be misleading because observed changes in demand are the product of multiple competing effects. For example, changes in the broader economy can drive per-capita water demand up or down as prices and incomes fluctuate. Changes in weather and climate, such as cyclical precipitation patterns or regional temperature trends, are important drivers of outdoor water use. Changes in the availability of, and preferences for, water conserving technologies (such as weather-based irrigation systems and low-flow toilets and sprinkler heads) can reduce demand. And even population *growth* can reduce per-capita demand if new homes must be built with such water-efficient technologies. To determine the effect of introducing a water budget rate structure on demand, these other factors must be accounted for.

Another related issue is the transferability of results from one water utility, such as IRWD, to others. The extent to which a water budget rate structure impacts demand depends on the features of the rate structure and how those features compare to the rate structure that it replaces: water budgets with smaller blocks and higher prices should have greater effects on demand, *ceteris paribus*. Therefore we might not expect the outcome for a particular water utility to be relevant for other utilities, unless those utilities intend to adopt similarly structured water budgets and have similar customer bases. Although rate structures clearly will differ across utilities, there is one fairly common feature that can be used as a convenient benchmark to increase the transferability of results across utilities. In many cases, such as the southern California examples cited above, utilities will desire to maintain fiscal neutrality when switching from uniform rates to water budgets in order to avoid incurring budgetary surpluses or

deficits. Indeed, under California's Proposition 218, revenues derived from water fees cannot exceed the funds required to provide the service (ACWA 2007); in other words, utilities must set their rates to balance revenues with costs. Focusing on fiscally neutral rate structures thus narrows the scope of the investigation while promoting broader applicability of the results.

With these issues in mind, this study estimates the effect of introducing a fiscally neutral water budget rate structure on residential demand in the Eastern Municipal Water District (EMWD) of southern California. The dataset follows over 13,000 single family households with continuous monthly water use records from 2003-2012. We account for socio-economic differences across households and through time with data from the U.S. Bureau of the Census and Bureau of Economic Analysis. We control for climate variability with spatially and temporally variable estimates of evapotranspiration. We include a time trend to capture changes in preferences and technologies, and we hold the housing stock fixed in our sample to control for vintage effects.

We estimate that EMWD reduced water demand by approximately 17% by switching to a fiscally neutral water budget rater structure, although the reduction was achieved gradually over more than three years. As intermediate steps we derive estimates of price and income elasticities that rely only on the longitudinal variability in our panel dataset. We investigate how different subpopulations of households responded to the pricing change and find convincing evidence that marginal, rather than average, prices are driving consumption choices. We also use a discrete-continuous choice model of water demand under IBR pricing to derive alternative rate structures that might have been implemented, and compare their estimated demand effects with the actual rate structure that was implemented. We find that additional demand reductions could be achieved by increasing particular block prices or decreasing particular block volumes, or by removing, splitting, or adding additional blocks in simple ways, while maintaining stable revenue per unit. From these observations we draw some

implications for water utilities that are considering implementing water budgets and discuss directions for future work.

Related Literature

The literature on residential water demand and pricing is large. Dalhuisen et al. (2003) provide an overview as part of their meta-analysis of 64 pricing studies between 1963 and 2001. A significant analytical innovation was provided by Hewitt and Hanemann (1995) who demonstrate how the discrete-continuous choice (DCC) framework of Burtless and Hausman (1978) can be applied to structural analysis of water demand under block rate pricing. Recent empirical studies using the DCC framework include Pint (1999), Olmstead et al. (2007), Olmstead (2009), and Miyawaki et al. (2011). However many studies continue to use reduced-form demand estimation for block-rate analysis (Fordyce 2005, cited by Olmstead 2009), perhaps due to the computational difficulty of estimating the DCC model.

The DCC model has been critiqued recently by Strong and Smith (2010) who argue that applied welfare analysis is problematic within a DCC framework because, as noted by Bockstael and McConnell (1983), the Marshallian demand function does not exist when the budget constraint is nonlinear. Strong and Smith instead propose estimating the structural parameters of the direct utility function for purposes of welfare analysis. However, largely due to the nature of their data, their approach stops short of a framework that permits individual consumers to locate at the kink points on their budget constraints, or that permits simulating changes in any aspect of the price structure, including scenarios that might cause consumers to move consumption to different facets of their budget constraints.[2]

The main thrust of the most recent empirical work on IBR water pricing has been investigations of consumer price responsiveness, and whether price elasticities appear to differ across price structures.

[2] While the ability to conduct welfare analysis within the DCC framework is clearly a fundamental issue, and development of a theoretically consistent approach would be an important contribution, this study does not undertake welfare estimation and therefore adopts the established DCC model for block-rate price analysis.

Olmstead et al. (2007) find evidence that price elasticity does appear to differ between uniform and block rate price structures but they are unable to provide a definitive conclusion due to unresolved endogeneity issues in their data. The main focus of our study is related to but distinct from this work. Rather than comparing parameter estimates under uniform and block rate structures, we estimate a uniform rate model that then is used to predict what demand would have been had IBR water budgets not been adopted. We then investigate the differences between observed and predicted demand to characterize the demand effect of water budgets. To our knowledge this is the first study to utilize IBR *water budget* pricing data, and the first to estimate the demand effect of introducing such a price structure.

Empirical Situation and Data

The data for this study come from the Eastern Municipal Water District of southern California. EMWD is a member agency of the Metropolitan Water District of southern California, and serves a diverse region of western Riverside County that includes the cities of Moreno Valley, Perris, Hemet, Murrieta and Temecula. This region covers 542 square miles and has a population of over 768,000 (EMWD 2013). As of 2012, EMWD provided around 90,000 acre-feet of water to approximately 136,000 domestic water service accounts and a much smaller number of agricultural and irrigation water service accounts (EMWD 2013).

EMWD is trying to achieve a state-mandated 20% reduction in per-capita water use before 2020. Prior to April 2009, EMWD charged each household a fixed "daily service charge" (DSC) plus a uniform price per unit of water consumed. Beginning in April 2009, EMWD changed from uniform-rate pricing to household-specific water budgets to help achieve the 20% reduction. There are four blocks in this IBR price structure. The cumulative block sizes are calculated as follows:[3]

[3] The block labels (i.e., indoor, outdoor, excessive, and wasteful) are EMWD's terms.

Block 1. Indoor water use: $w_1 = (HHS \times PPA) \times DF + IV$

Block 2. Outdoor water use: $w_2 = w_1 + (ET \times CF \times IA + OV) \times DF$

Block 3. Excessive water use: $w_3 = 1.5 \times w_2$

Block 4. Wasteful water use: water use in excess of w_3

Variables used to calculate block sizes are household size (HHS), per-person allowance (PPA), drought factor (DF), indoor variance (IV), evapotranspiration (ET), conservation factor (CF), irrigated area (IA), and outdoor variance (OV). HHS is reported to EMWD by each household;[4] PPA is set by EMWD at 60 gallons per day; DF is set less than or equal to 1 depending on environmental conditions;[5] IV is negotiated between EMWD and households that report unusual indoor circumstances such as medical need or in-home daycare; ET is derived from real-time measurements for a reference crop which are then adapted to 50 designated microclimate zones within the EMWD service area; CF converts the reference crop ET to turfgrass ET;[6] IA is reported to EMWD by each household;[7] and OV is negotiated between EMWD and households that report unusual outdoor circumstances such as maintenance of large animals or turfgrass establishment.

Block-specific prices are set such that $p_1 < p_2 < p_3 < p_4$, where p_k is the price charged for block k. A household's "water budget" is defined as the first two blocks, or cumulative consumption of w_2. Consumption above w_2 is deemed to be "excessive" or "wasteful" and is thus charged a significantly higher price than consumption below w_2. It is worth emphasizing that w_2 and w_3 are functions of ET and

[4] EMWD uses a default value of 3 if a household does not report the household size, and requires verification if a reported value exceeds 9 people.

[5] In our dataset, DF = 1 for all observations.

[6] Most water districts assume a baseline of turf grass given its high ET relative to most other grasses and plants; consequently, these districts are providing an overly-generous allocation for ET.

[7] EMWD uses Riverside County Assessor data to calculate a default value (up to a maximum of 6000 sq-ft) if a household does not report the irrigated area, and requires verification if reported values seem excessive.

thus fluctuate from month-to-month. When ET is high, households are allocated larger monthly water budgets (i.e., more water in blocks 2 and 3); when ET is low, households are allocated smaller budgets.

To analyze the demand effect of introducing water budgets, we identified 13,565 residential accounts with uninterrupted monthly water consumption records between January 2003 and September 2012. The fact that these accounts remained open is a good indication that there were no tenancy changes in these households during this period.[8] In addition to monthly water consumption data, EMWD also provided information on prices paid by each account, the household size (HHS) and irrigated area (IA) associated with each account, dates when households were asked to increase their water conservation efforts (e.g., due to system maintenance or local supply scarcity), monthly ET under water budgets for each of the 50 microclimates, and the relevant microclimate for each account. EMWD also provided the latitude and longitude of the meter for each account which enables us to georeference against census data to obtain information on income and education at the tract level.

A crucial piece of missing data is microclimate ET during uniform-rate pricing. During this period EMWD had no need for ET data and thus did not track it. Obtaining this data directly from the commercial provider was prohibitively costly, so we developed a simple but effective model to estimate it. First we obtained publicly available ET data from three CIMIS stations in western Riverside County.[9] We then regressed EMWD's available ET data for each of the 50 climate zones on the CIMIS ET data and a set of 12 monthly dummy variables as follows:

$$ET_{zt} = \beta_{zm} + \beta_{z1}ET_{1t} + \beta_{z2}ET_{2t} + \beta_{z3}ET_{3t} + \varepsilon_{zt}. \qquad [1]$$

Here, ET_{zt} is observed ET for climate zone (z) during month (t); β_{zm} is a constant term that applies only to a given zone (z) and month (m) – in other words, there are 12 such coefficients for each zone; β_{z1} is a

[8] An exception could be rental properties for which the utility accounts are registered to the owner rather than the tenants. We are not able to identify such accounts in our dataset.

[9] CIMIS is the California Irrigation Management Information System, developed and maintained by the California Department of Water Resources (www.cimis.water.ca.gov).

slope coefficient that is specific to zone (z) and that relates changes in ET at the first CIMIS station to observed changes in ET for zone (z); β_{z2} and β_{z3} are defined similarly for the other two CIMIS stations; ET_{1t} is monthly ET at the first CIMIS station, and similarly for the other stations; ε_t is the residual.

Equation 1 is estimated separately for each of the 50 climate zones using ordinary least squares to produce a set of coefficient estimates that is specific to each zone. Estimation results are very good. The mean absolute prediction error across all regressions is only 2.2%. The highest error for any month is 7%; the highest error for any zone is less than 4%. Adjusted R^2 values for the 50 zones are all between 0.976 and 0.992. We then use the coefficient estimates to predict ET values for the entire observation period and use these predictions in our analysis. Figure 1 presents a typical comparison of observed and predicted ET monthly values for a representative climate zone.

Summary statistics for the data used in the regression analyses that follow are presented in Table 1.[10] Conservation requests refer to the fraction of months in which households were asked to increase water conservation efforts, typically due to system maintenance or heat waves. We do not include data on EMWD's other water conservation program efforts (e.g., rebates for high-efficiency toilets, washers, shower heads, and sprinkler nozzles) because the estimated savings from such programs amounts to less than 0.5% of residential deliveries. Nominal and real prices are the prices charged per hundred cubic feet (CCF) of water (one uniform rate from 2003-08; four increasing block rates from 2009-12). Under uniform-rate pricing, these prices are the same as the average prices paid by households. However under water budgets, the average price paid is a function of water consumed and thus is listed separately in the table. [11] As in Strong and Smith (2010), budgets are based on census

[10] Data for 2012 is from January through September only and is thus omitted from the table for purposes of comparison. However it is worth noting that nominal block prices in 2012 are unchanged from 2011 and thus real block prices in 2012 are slightly lower than for 2011. Data for 2012 is included in the regression analyses.

[11] Average price paid in 2009 is a blend of uniform rates for January through March (nominally unchanged from 2008) and block rates for April through December (shown in the table).

income (Minnesota Population Center 2011) and are adjusted for the fraction of income typically spent on the category of "utilities, fuels, and public services." (U.S. Bureau of the Census 2012).[12] Budgets also are adjusted for temporal changes in per-capita personal income for the Ontario-Riverside-San Bernardino metropolitan statistical area (U.S. Bureau of Labor Statistics 2013). Education is expressed as the fraction of the census tract reporting "some college" or more education (U.S. Bureau of the Census 2012). Household size, irrigated area, and education are treated as constant characteristics because we lack information on monthly changes in these variables.[13] Figure 2 presents selected summary statistics as relative trends through time, with 2003 values normalized to unity. As can be seen in the figure, ET and real budgets changed little during the period of analysis while there are noticeable changes in demand and prices, particularly after 2007.

Summary statistics under water budgets are shown by marginal consumption block in Table 2. The table shows that marginal consumption is within a household's water budget (block 1 or 2) in 82% of our observations.[14] Only 18% of our observations have marginal consumption in block 3 or 4. The table shows that household consumption increases with the marginal block but water budgets do not: water budgets are largest for block 2 consumers and smallest for block 1 and 4 consumers. The large water budgets associated with block 2 consumption appear to be explained by higher ET and irrigated area, whereas the household size is slightly below average. Block 3 and 4 consumers appear to be somewhat wealthier and thus perhaps less sensitive to the higher prices in those blocks; consequently they may be less inclined to make an effort to better match their water use with their water budgets.

Estimation Strategy

[12] Using data from the 2010 Consumer Expenditure Survey, we estimate the following relationship between budget (y) and income (m) for the range of incomes observed in our sample: $y = 99.8941m^{0.3339}$, $R^2 = 0.9915$.

[13] Census data suggests that overall education levels in the study area remained fairly constant from 2000-2010.

[14] This does not imply that 82% of households always consume within their water budgets. Marginal consumption for a given household tends to move across blocks through time.

To facilitate comparisons, our analysis is based on a log-linear demand model similar to that used in previous studies of block-rate water pricing (e.g., Hewitt and Hanemann 1995; Pint 1999; Olmstead et al. 2007; Olmstead 2009):

$$ln(w_{it}) = \boldsymbol{\delta z}_{it} + \alpha ln(p_{it}) + \gamma ln(y_{it}) + \eta_i + \varepsilon_{it} \quad [2]$$

Here, w_{it} is demand by household (i) during month (t); $\mathbf{z}_{it}$ is a vector of household, economic, and environmental characteristics that are thought to affect demand; p_{it} is the marginal water price faced by the household; y_{it} is the household's budget for utilities and related expenditures; η_i captures unobserved preference heterogeneity; ε_{it} is an error term capturing the remaining unexplained variation in demand; and $\{\boldsymbol{\delta}, \alpha, \gamma\}$ are parameters to be estimated.

Equation 2 forms the basis for two separate estimations: (1) a uniform-rate demand model estimated using 2003-08 data, and (2) an IBR demand model estimated using 2009-12 water budget data.[15] For the uniform-rate demand model, we model unobserved preference heterogeneity as fixed effects and derive parameter estimates from an OLS regression on deviations of the variables in equation 2 from their respective means.[16] The model is then used to predict demand during 2009-12 if uniform-rate pricing had remained in effect. The predicted demand is then compared to the actual demand under water budgets and the difference is analyzed to estimate the demand effect of the water budget rate structure.

For the IBR demand model, we implement a standard DCC model that assumes the unobserved preference heterogeneity is randomly distributed. The DCC framework models demand as a joint choice

[15] Olmstead et al. (2007) also use equation 2 as the basis for a combined estimation including both uniform and block rate pricing data, but find evidence that some parameter estimates (notably price and income elasticities) may differ across pricing structures. To allow for this possibility, we forego the combined estimation and perform two separate estimations.

[16] We also estimated a random effects uniform-rate model which is structurally more similar to the DCC framework. Coefficient estimates generally were similar to the fixed effects estimates, but the fixed effects model exhibits better overall predictive accuracy.

involving selection of a price block and the amount to consume within that block. The framework allows a household to optimally select a consumption level within a block or at the edge of a block (also called a "kink point" because the consumer's budget constraint has an abrupt change of slope at these points). Within a block, demand is given by equation 2 but is implicitly conditional on the choice of that block and thus is referred to as a "conditional demand." For expositional purposes below, we rewrite equation 2 as: $\ln(w_{it}) = \ln(w_{it}^*) + \eta_i + \varepsilon_{it}$, where $w_{it}^* = \exp(\boldsymbol{\delta}\mathbf{z}_{it})p_{it}^{\alpha}y_{it}^{\gamma}$ is estimated demand.

Under IBR pricing, the marginal water price p_{it} differs across blocks. Due to the nonlinear budget constraint, the effective household budget y_{it} also will differ across blocks to account for the fact that consumption is cheaper in the lower blocks. Thus unconditional demand with *K* price blocks can be written as (dropping the subscripts *i* and *t* for simplicity):

$$\ln w = \begin{cases} \ln w_0 + \varepsilon, & -\infty < \eta \leq \ln w_0 - \ln w^*(p_1, y_1) \\ \ln w^*(p_1, y_1) + \eta + \varepsilon, & \ln w_0 - \ln w^*(p_1, y_1) < \eta \leq \ln w_1 - \ln w^*(p_1, y_1) \\ \ln w_1 + \varepsilon, & \ln w_1 - \ln w^*(p_1, y_1) < \eta \leq \ln w_1 - \ln w^*(p_2, y_2) \\ \ln w^*(p_2, y_2) + \eta + \varepsilon, & \ln w_1 - \ln w^*(p_2, y_2) < \eta \leq \ln w_2 - \ln w^*(p_2, y_2) \\ \ln w_2 + \varepsilon, & \ln w_2 - \ln w^*(p_2, y_2) < \eta \leq \ln w_2 - \ln w^*(p_3, y_3) \\ \vdots & \vdots \\ \ln w^*(p_K, y_K) + \eta + \varepsilon, & \ln w_{K-1} - \ln w^*(p_K, y_K) < \eta < \infty \end{cases} \quad [3]$$

Here, p_k is the price associated with block k; y_k is the consumer's budget associated with block k; $w^*(p_k, y_k)$ is the estimated demand conditional on block k; w_k is the quantity associated with kink point k; and the other notation is the same as in equation 2. It is apparent from equation 3 that the unobserved preference heterogeneity (η) influences the block or kink point on which the consumer desires to consume; and the additional error term (ε) explains the deviation of actual consumption from estimated or "planned" consumption. Equation 3 is the basis for maximum likelihood estimation of the parameters in equation 2. Waldman (2000, 2005) provides a general statement of the likelihood function for the DCC model, which also forms the basis for predicting demand under IBR pricing. We also use this model to derive alternative rate structures that generate equivalent revenue per unit, and

compare their estimated demand effects against the actual rate structure that was implemented by EMWD.

Results and Discussion

Uniform-Rate Model

We estimated several different specifications of the demand model in equation 2, and found that the performance of a relatively simple specification with few regressors was nearly indistinguishable from that of more complicated (and, for the DCC model, computationally burdensome) specifications.[17] Table 3 shows the variables used in the analysis along with the parameter estimates and standard errors for the uniform-rate model. Note that a constant term, education, household size, and irrigated area do not appear in the table because they drop out of the fixed effects estimation; however, these terms do appear later in the DCC model. Table 3 summarizes results for seven different samples: the full sample (all 13,565 accounts); high, moderate, and low usage accounts (i.e., 2003-08 average usage in the top, middle, and bottom thirds); and high, moderate, and low income accounts (i.e., 2010 census income in the top, middle, and bottom thirds). All estimated parameters are significantly different from zero at well above the 99% confidence level. Signs and magnitudes generally are intuitive and exhibit similarities across subsamples. Some noteworthy observations include the following.

Requests by the water district for increased water conservation efforts appear to produce a 5% reduction in demand during the month in which a request is made. This is not an insignificant response to a request for voluntary action to support a public good.

[17] It is also worth noting that both the uniform rate and water budget models include the appropriate Slutsky restriction as a constraint on the estimation. Slutsky restrictions are not always imposed on standard demand models (or, at least, not discussed in the subsequent analysis), but here it plays an essential role in proper estimation of the DCC framework. In both models the restriction binds; without it, income effects appear much larger and some of the estimated block probabilities in equation 3 are negative.

There appears to be a slight *upward* trend in overall water consumption through time (0.7% per year) after controlling for other variables affecting demand; however the high usage subsample exhibits a downward trend. For the full sample, this amounts to a 4.3% *increase* in household demand during the observation period. This unexpected result could reflect the housing bubble of the mid 2000's, to the extent that (1) rapidly rising home values through 2006 created an additional income effect and/or increased the perceived marginal benefit of investing in one's home (including landscaping and swimming pools), and (2) such investments and the associated increased water use were relatively permanent and thus not reversed during the period of rapidly declining home values beginning in 2007. However this is speculative and cannot be inferred directly from our dataset.

The estimated price elasticity (coefficient on $ln(p_{it})$) for the full sample is -0.76. This estimate and the others for the subsamples are consistent with, though somewhat higher than, estimates from previous work that tend to average around -0.4 to -0.5, or around -0.6 for longer time periods (Espey et al. 1997, Dalhuisen et al. 2003). Considering the subsample regressions, price elasticity appears to decrease monotonically with usage but exhibits a non-monotonic trend with income. In absolute terms, we estimate that a 1% price increase would produce expected reductions of 0.159 CCF/month from a high usage account, 0.143 CCF/month from a moderate usage account, and 0.095 CCF/month from a low usage account. Thus the high usage group is the most responsive in absolute terms, even though its price elasticity is lowest. The observed pattern in price elasticities across usage groups may reflect differing preferences for outdoor water use. Average irrigated areas for the high, moderate, and low usage groups are 5985, 3512, and 3034 square feet, respectively. The high usage group appears qualitatively different in this regard, suggesting that it may be comprised of households with strong preferences for outdoor landscaping who are more reluctant to reduce irrigation in response to price increases.

Income elasticities are estimated by interacting the budget elasticity (coefficient on $ln(y_{it})$) with the derived relationship between budget and income (see footnote 12). The estimated income elasticity for the full sample is 0.1616. This is close to but somewhat lower than most previous estimates: in a meta-dataset used by Dalhuisen et al. (2003), the mean and median income elasticities were 0.43 and 0.24, respectively. Although our analysis exhibits several of the characteristics that were found by Dalhuisen et al. (2003) to be significantly correlated with *higher* income elasticity estimates, it appears that the Slutsky restriction is causing our estimate to be lower.[18]

The model generally fits the data well, particularly when we consider average consumption through time, which is important for generating predictions beyond the observation period. Figure 3 shows the average monthly observed and predicted usage for the full sample. Analogous graphs for the six usage and income subsamples (not shown) exhibit similarly good predictions.

Demand Effect of Water Budgets

The uniform-rate model can be used to estimate the demand effect of introducing water budgets in 2009. To do this, we create a new dataset that includes the same explanatory variables as in table 3 but with values updated for the prediction period (2009-2012). We update conservation requests, ET, and household budgets accordingly. We also create new seasonal dummies and extrapolate the time trend into the prediction period. Finally we set prices equal to the annual average real prices paid under water budgets (shown in table 1). Predicted demand thus corresponds to the hypothetical case where uniform-rate pricing continued beyond 2008 and prices were increased such that they matched the average annual prices paid under water budgets. From the perspective of a water utility, this is a useful baseline from which to judge the demand effect of water budgets since such a uniform-rate structure

[18] When we relax the Slutsky restriction, the estimated income elasticity for the full sample is 1.16.

would produce revenues equal to those of the water budget structure under the null hypothesis that there is no demand effect.

Figure 4 summarizes the estimated demand effect. Panel A shows the 12-month moving averages for observed and predicted demand from December 2003 to September 2012, normalized to the 12-month period of April 2008 – March 2009. The vertical dashed line corresponds to April 2009, when water budgets were introduced. Panel B shows, beginning in April 2009, the difference between the two moving averages in panel A, expressed as a percent. Both panels demonstrate that water budgets initially had a relatively small effect on residential water demand: between April 2009 and March 2010, both observed and predicted demand exhibit similar declines. As of March 2010, observed demand is only 1.4% lower than predicted demand. However, the demand effect clearly grows through time. As of March 2011, two years after implementation, the 12-month moving average for observed demand is 5.2% below that for predicted demand. As of March 2012, three years after implementation, there is a 13.1% difference. More recently, as of September 2012, the difference grows to 16.8%. Water budgets appear to have had a significant effect on demand, however it has required a substantial amount of time for that effect to be realized.[19] This result is consistent with Dalhuisen et al. (2000) who find that households appear more responsive to price changes when they have had more time to adapt.

Another way to gauge the water budget effect is as follows. During the most recent 12 month period in our data, the average price paid per CCF under water budgets is 3.7% higher (in real terms) than the average price paid in 2008. Our model predicts that uniform rates would have had to increase by 34% to achieve the same level of demand observed during this period. Notably, the average *marginal* price paid during this period is 34% higher than in 2008. This suggests that marginal prices may be

[19] Omitting the time trend from the predictions decreases the estimated demand effect by around 2%. Residential water conservation programs also appear to have had a negligible impact on the estimated demand effect: the annual water savings from these programs were less than 0.5% of residential deliveries and decreasing from 2009-12.

having a stronger influence on consumption than average prices, and helps to inform the ongoing debate on this subject.[20]

Also of interest, average prices paid under water budgets declined from 2010 through 2012. This largely explains the corresponding increase in the 12-month moving average for predicted demand beginning in January 2011 (weather also played a role but incomes were quite stable). However the 12-month moving average for observed demand remains essentially unchanged during 2011 and only begins to turn up moderately in 2012. During this period of price decreases, predicted demand increases by 15.7% but observed demand increases by only 3.6%. This suggests that under water budgets, households may be gradually adopting relatively permanent water conservation habits as they learn how to use water more efficiently—habits that are largely retained even when prices subsequently decrease. This observation could motivate adding a subjective learning component to Borenstein's (2009) hypothesis about utility demand being driven by consumption "rules" that are fixed prior to a consumption period and updated only when feedback is received in the form of a bill.

Results for the high and moderate usage and income subsamples are generally the same as for the full sample: the introduction of water budgets caused consumption to decrease more than predicted if uniform rates had been set equal to the average prices paid under block rates. For the low usage and income subsamples, the water budget effect was strong enough to overcome *decreases* in average prices paid by these groups under increasing block rates. In other words, our model predicts increased demand by these groups if uniform rates were set equal to average prices paid under block rates, but we observe decreased demand. Not surprisingly, average *marginal* prices paid by these groups did

[20] Ito (2014) finds strong evidence of consumer responsiveness to average rather than marginal prices for the case of electricity demand. Borenstein (2009) also finds evidence that electricity consumers are responding either to average price or expected marginal price (which entails averaging over uncertain consumption) rather than the actual marginal price paid. Nataraj and Hanemann (2011) conclude that water consumers do respond to changes in marginal price. The extent to which these discrepancies are due to fundamental differences between water and electricity consumption, and/or between the price structures under investigation, is a topic for future work.

increase under block rates. This again is strongly suggestive of the importance of marginal rather than average prices in determining residential water consumption levels.

Block-Rate Model

Estimation results for the DCC model are shown in table 4. Parameter estimates can be interpreted directly as the effect of each regressor on *conditional* demand (i.e., holding block choice fixed); simulations are needed to interpret the effect of each regressor on unconditional demand. As with the uniform-rate model, the parameter estimates generally have intuitive signs and magnitudes and are all significantly different from zero at well above the 99% level. Similar to Gilg and Barr (2006), we find a positive relationship between water use and education and, somewhat unexpectedly, a slightly larger coefficient on the fall dummy than on the summer dummy. Conservation requests appear to have a larger effect under water budgets (though only one such request was made, in January 2011), and the time trend is now negative.

At the household level, the model fit is not particularly good. When we evaluate expected household consumption as $\widehat{w}_{it} = E_{\eta,\varepsilon}[w_{it}^{*} \exp(\eta) \exp(\varepsilon)]$, where $w_{it}^{*} = \exp(\boldsymbol{\delta}\mathbf{z}_{it}) p_{it}^{\alpha} y_{it}^{\gamma}$ and different portions of the distribution of η correspond to different conditional demand curves, we get an adjusted R^2 value less than zero.[21] When we set η and ε equal to their means (zero) and evaluate expected household consumption as $\widehat{w}_{it} = w_{it}^{*}$, we get an adjusted R^2 value of 0.1661. Although the first approach is the correct one, close inspection of the results reveals that the disturbance term simulations, in conjunction with our convex demand function, produce some very large simulated consumption values that tend to reduce the model fitness. However this approach provides a good fit to the average monthly data, as can be seen in figure 5.

[21] We use multidimensional quadrature (Judd 1999) to evaluate the expectation. We use Gauss-Legendre quadrature to integrate over the piecewise distribution of η and Gauss-Hermite quadrature to integrate over ε.

Price and income elasticities are estimated by simulating the demand effects of a 1% increase in all prices, and a 1% increase in household incomes, throughout the water budget observation period. Results are shown in table 4. Both estimates are less than their uniform rate counterparts. The price elasticity estimate (-0.58) is very close to those reported by Olmstead et al. (2007) for a log-linear DCC model of IRB pricing, which range from -0.59 to -0.61. The income elasticity estimate (0.05) is close to that estimated by Olmstead et al. (2007) in a random effects model of uniform-rate pricing (~0.04) but below their DCC estimates for IBR pricing (~0.18), all of which they note are low compared to previous estimates. Those authors cite evidence that omitting household characteristics from the regression (as is common in previous studies) tends to increase the estimated income elasticity due to correlations between those characteristics and income. Because our fixed (uniform rate) and random effects (water budgets) panel data specifications implicitly capture all constant household characteristics, this may help to explain our relatively low income elasticity estimates.

Demand Effects of Alternative Water Budget Rate Structures

As described above, EMWD has implemented a relatively sophisticated water budget rate structure with four blocks that vary in magnitude across households and through time. The rate structure was designed, in part, to be fiscally neutral. Although we cannot use our limited data on household demand to rigorously test for fiscal neutrality, we can investigate how the existing rate structure could be modified such that demand is further reduced with limited fiscal impact. To address this question we consider alternative rate structures that maintain equivalent revenue per unit. Although this does not guarantee fiscal neutrality in all cases, such rate structures should have small fiscal impacts for utilities operating on relatively uniform average costs curves that are characteristic of industries with economies of scale, while also being politically acceptable to implement. The demand effects of such alternative rate structures could be of interest not only to utilities that already have implemented water budgets and are now facing relatively extreme circumstances (e.g., acute drought,

rapid population growth, prolonged supply scarcity), but also to utilities that are in the process of designing or redesigning their water budgets. While there are many alternative structures to consider, here we focus on some relatively simple modifications to EMWD's existing rate structure that intuitively could be of interest. For each scenario, we find the parameters of the hypothetical rate structure that produce the same expected revenue per CCF as the current rate structure, and we compare the associated expected demand against that for the current rate structure. For all scenarios we use the data from the most recent 12-month period in our dataset as the basis for the simulations.

Figure 6 summarizes the effects of several rate structures that reduce demand below the current baseline while maintaining stable revenue per unit.[22] Scenarios 1-7 maintain the existing rate structure but make changes to its quantity and price parameters. Utilities might take such actions in response to intense short-term drought conditions or unexpected reductions in supply. A simple but effective alternative is scenario 2 (20% decrease in block 2 size) which would decrease expected demand by 4.3% while maintaining stable revenues per unit of water consumed. This has about the same demand effect as scenario 5 which reallocates ¼ of block 2 into block 3 but leaves the sum of blocks 2 and 3 unchanged (whereas scenario 2 reduces this sum by decreasing the size of block 2). Scenarios 6-7 examine the demand effect of reallocating additional block 2 water into block 3, and show that the effect increases sharply. Reallocations like these might be justified by a water utility as a means to implement new expectations for irrigation efficiency and use of native landscaping in place of turfgrass. Scenario 8 considers simplifying the rate structure by removing the "wasteful" water use block, and shows that a simultaneous 35% increase in the block 3 price would reduce demand slightly while maintaining stable average revenue. Alternatively, scenario 9 considers complicating the rate structure

[22] In all cases the expected revenue per CCF is within 0.5% of the baseline. We investigated other rate structures that ultimately could not maintain similar revenue per unit and are thus not reported here.

by adding a new block between blocks 2 and 3 with a price that maintains the increasing block rate structure and finds a demand effect similar to that in scenario 8.

Overall these simulations suggest that there are relatively small conservation gains to be realized from fundamentally changing the existing rate structure by adding or removing blocks when fiscal neutrality must be maintained. Rather, most of the conservation potential appears to be associated with changes in the existing blocks 2 and 3. This is perhaps not surprising because the marginal consumption of most households occurs within these blocks.

Conclusions and Implications

This study utilizes a high quality panel dataset of household water consumption for a large southern California water district to estimate the demand effect of switching from uniform-rate pricing to fiscally neutral increasing block rate water budgets. More than three years after the rate structure changed, we estimate that demand under water budgets was 17% below where it would have been under a comparable uniform-rate price structure. Whereas average prices paid rose by less than 4% under the block rate structure, average prices paid under the uniform-rate structure would have had to rise by nearly 34% to achieve the same demand reduction. These results suggest that water budgets are potentially a highly effective conservation tool although a substantial amount of time is required for demand reductions to be realized. Furthermore, to the extent that more complicated water budget structures are both more costly to implement and harder for consumers to understand (and thus respond to), our findings suggest that utilities can safely pursue relatively simpler rate structures, with perhaps only three blocks, without foregoing significant conservation opportunities.

Our analysis also finds some evidence of a price-induced “ratcheting effect” whereby households that are faced with higher water prices—particularly higher *marginal* prices that are characteristic of IBR structures—learn how to be more water efficient, adopt those new habits, and thus are less prone to “back-sliding” if and when prices decline in the future. This finding, although somewhat

circumstantial, is consistent with Borenstein's (2009) hypothesis about the formation of consumption "rules" in electricity demand analysis and lends additional legitimacy to related modeling efforts including formal investigations of learning and habit formation in utility demand contexts.

For water utilities that are considering adopting water budgets as a conservation tool, this study provides strong support for doing so and also facilitates effective communication to stakeholders of the benefits provided by such rate structures. An important caveat is that conservation goals may take years to achieve. Efforts to promote quicker re-learning of water consumption habits should hasten the attainment of those goals, but exactly how to go about doing this is a topic for future work. A potentially fruitful line of research would investigate the extent to which non-price instruments and/or neighborhood effects influence learning and habit formation. Some water utilities have begun reporting local average water consumption on individual bills to give households a better idea of how their own consumption compares to a relevant peer group. Such information, combined with a high marginal price for "excessive" water use, could prove to be a highly effective approach to encouraging urban water conservation.

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Table 1: Summary statistics.

Variable	2003	2004	2005	2006	2007	2008	2009	2010	2011
Consumption (CCF/month)[a]	20.70	21.14	20.12	20.77	20.99	19.74	17.77	15.99	15.73
ET (in/month)[b]	4.67	4.87	4.59	4.73	4.87	4.81	4.70	4.55	4.85
Conservation requests	0.17	0.00	0.08	0.25	0.08	0.08	0.08	0.00	0.08
Nominal price ($/CCF)	1.43	1.46	1.53	1.62	1.69	1.85	1.27 2.33 4.17 7.63	1.43 2.61 4.68 8.56	1.44 2.64 4.73 8.65
Nominal average price paid ($/CCF)							1.93	2.10	2.05
Real price (2010$/CCF)	1.66	1.66	1.68	1.72	1.77	1.86	1.30 2.37 4.25 7.78	1.43 2.61 4.68 8.56	1.39 2.54 4.55 8.33
Real average price paid (2010$/CCF)							1.98	2.10	1.98
Real budget (2010$/month)	316.26	317.45	318.05	319.20	320.78	316.70	311.07	309.96	309.44
Household size (#)	3.53								
Irrigated area (sq-ft)	4,177								
Education[c]	0.50								

[a] CCF = hundred cubic feet.

[b] A principle components analysis on all available weather data during the observation period for one of the CIMIS stations reveals that ET captures 94% of the total weather variability.

[c] Fraction of residents reporting at least some college education.

Table 2: Summary statistics under water budgets by marginal consumption block.[a]

Variable	Full Sample	Block 1	Block 2	Block 3	Block 4
Fraction of observations	1.00	0.26	0.56	0.15	0.03
Consumption (CCF/month)[b]	16.92	6.26	17.88	27.05	37.97
Water budget (CCF/month)	25.84	20.69	29.52	22.41	20.34
ET (in/month)	5.03	4.34	5.33	5.17	4.81
Budget (2010$/year)	310.27	299.89	312.08	319.39	319.11
Household size (#)	3.53	3.60	3.48	3.53	3.60
Irrigated area (sq-ft)	4176.95	3481.27	4753.42	3364.07	3700.60
Education[c]	0.50	0.49	0.49	0.52	0.52

[a] Includes 569,730 observations. Average consumption and ET values for the full sample are above annual means because the sampling period (April 2009 – September 2012) includes a relatively larger share of warmer, drier months. Block-weighted averages may not match full sample averages due to rounding error.

[b] CCF = hundred cubic feet.

[c] Fraction of residents reporting at least some college education.

Table 3: Uniform-rate model parameter estimates and standard errors.

Variable	Description	Full Sample	High Usage	Moderate Usage	Low Usage	High Income	Moderate Income	Low Income
Spring	Dummy for Apr-Jun	0.1598 (0.0015)	0.1818 (0.0029)	0.1739 (0.0029)	0.1387 (0.0029)	0.1873 (0.0030)	0.1543 (0.0028)	0.1426 (0.0029)
Summer	Dummy for Jul-Sep	0.4324 (0.0019)	0.4741 (0.0035)	0.4548 (0.0034)	0.3827 (0.0034)	0.4911 (0.0035)	0.4159 (0.0034)	0.3961 (0.0033)
Fall	Dummy for Oct-Dec	0.3384 (0.0011)	0.3840 (0.0020)	0.3550 (0.0020)	0.2943 (0.0022)	0.4131 (0.0020)	0.3155 (0.0019)	0.2963 (0.0020)
Conserve	Dummy for conservation request	-0.0514 (0.0012)	-0.0552 (0.0021)	-0.0538 (0.0022)	-0.0485 (0.0034)	-0.0559 (0.0026)	-0.0448 (0.0026)	-0.0542 (0.0019)
ET	ET (in/month)	0.1001 (0.0005)	0.1128 (0.0008)	0.1047 (0.0008)	0.0861 (0.0009)	0.1097 (0.0009)	0.1003 (0.0008)	0.0918 (0.0008)
Time trend	Linear annual increments	0.0069 (0.0001)	-0.0173 (0.0006)	0.0048 (0.0002)	0.0232 (0.0007)	0.0160 (0.0008)	0.0045 (0.0007)	0.0040 (0.0007)
$ln(p_{it})$	log real price	-0.7648 (0.0055)	-0.5101 (0.0193)	-0.7293 (0.0052)	-0.8296 (0.0232)	-0.9507 (0.0266)	-0.7511 (0.0240)	-0.7915 (0.0262)
$ln(y_{it})$	log real budget	0.4840 (0.0279)	0.3084 (0.0260)	1.6973 (0.1509)	3.3045 (0.1818)	1.1395 (0.0818)	0.8134 (0.0604)	0.5231 (0.0338)
Adjusted R^2	Model fit	0.3438	0.3860	0.3838	0.2721	0.3905	0.3459	0.3006
Income elasticity	1% change in income	0.1616	0.1030	0.5667	1.1034	0.3805	0.2716	0.1747

Table 4: Block-rate model parameter estimates and standard errors.

Variable	**Description**	**Estimate (Std Err)**
Constant	Constant	0.1135 (0.0134)
Education	Fraction of census tract residents reporting "at least some college" or more education	0.5355 (0.0087)
HHS	Household size (# of persons)	0.1309 (0.0012)
IA	Irrigated area (1000 sq ft)	0.0303 (0.0006)
Spring	Dummy for Apr-Jun	0.2392 (0.0053)
Summer	Dummy for Jul-Sep	0.5352 (0.0072)
Fall	Dummy for Oct-Dec	0.5731 (0.0051)
Conserve	Dummy for conservation request	-0.1412 (0.0053)
ET	ET (in/month)	0.1545 (0.0016)
Time trend	Linear annual increments	-0.0906 (0.0031)
$ln(p_{it})$	log real price	-1.0505 (0.0090)
$ln(y_{it})$	log real budget	0.2921 (0.0022)
σ_η	Standard deviation for η	0.8486 (0.0025)
σ_ε	Standard deviation for ε	0.2998 (0.0017)
Price elasticity	Demand response to 1% change in all prices	-0.5759
Income elasticity	Demand response to 1% change in income	0.0520

Figure 1: Comparison of observed and predicted ET for a sample climate zone

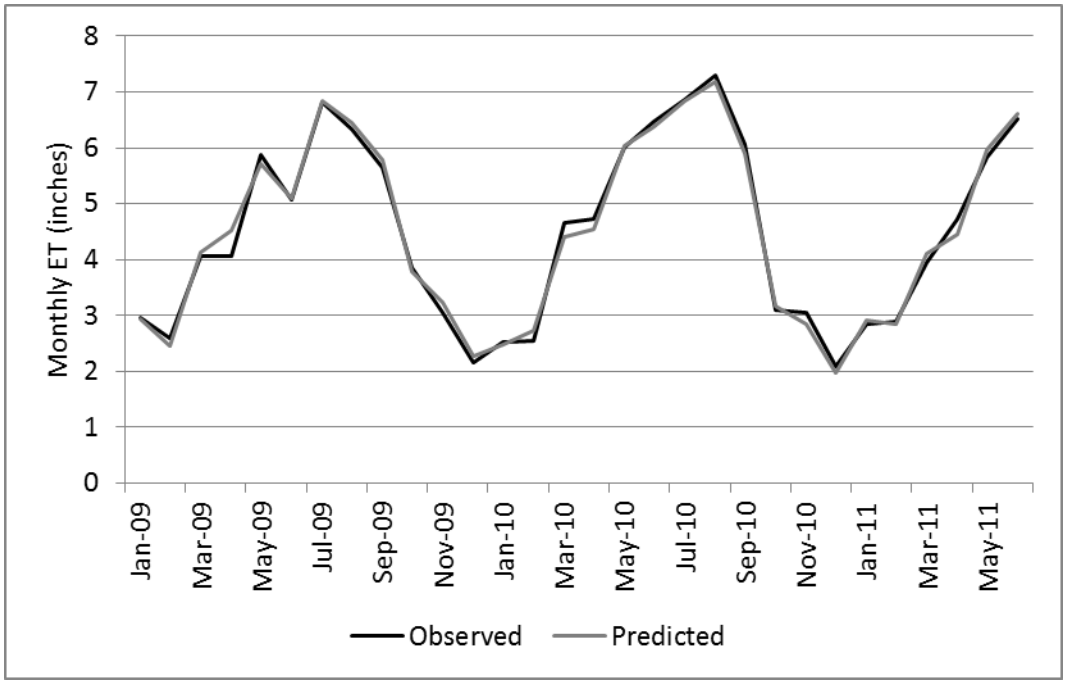


Figure 2: Selected statistics in relative terms.

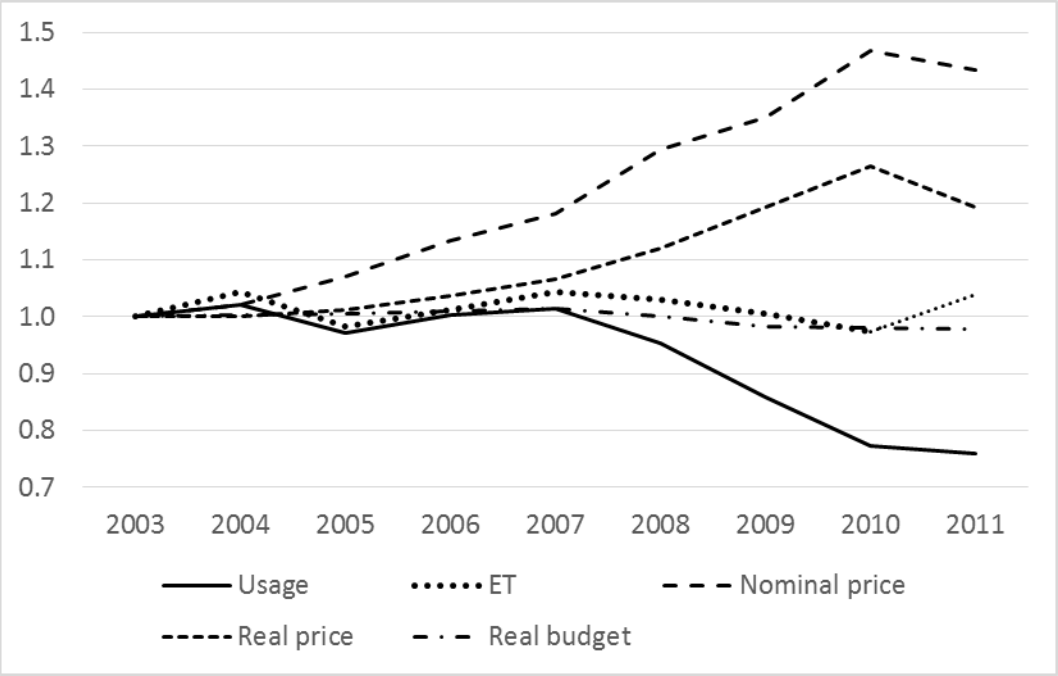


Figure 3: Observed and predicted average monthly household consumption for the full sample under uniform-rate pricing.

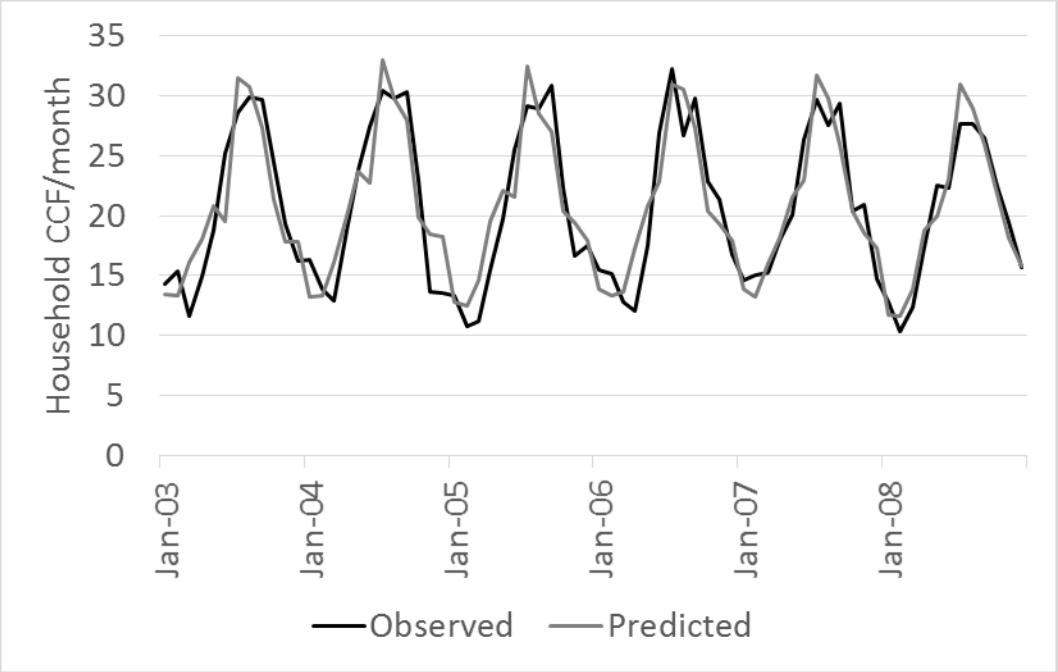
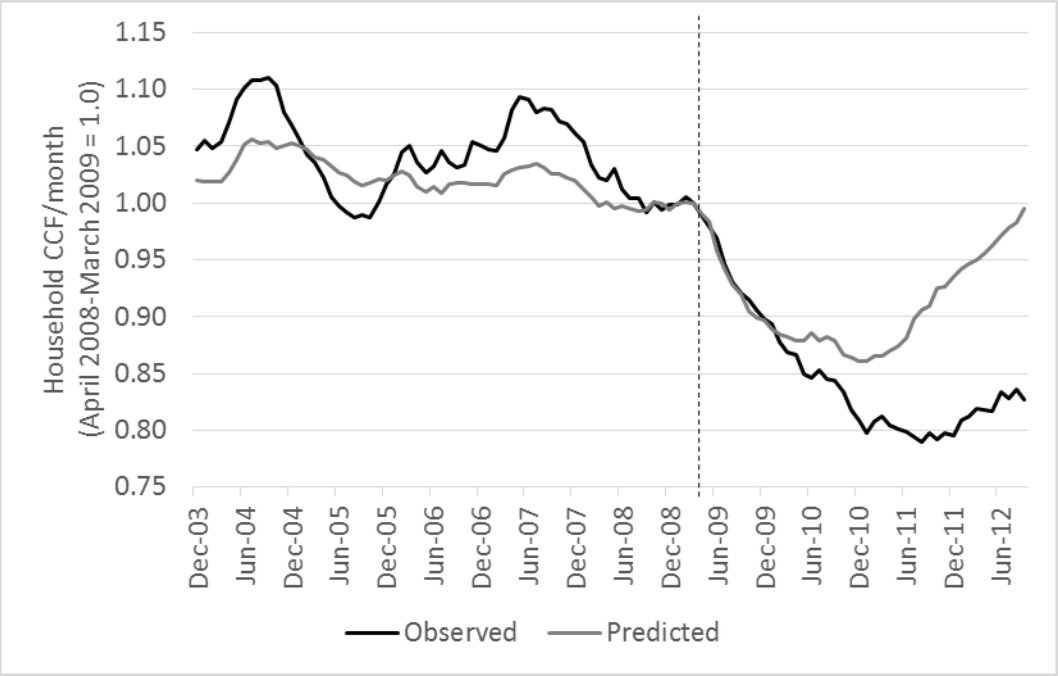
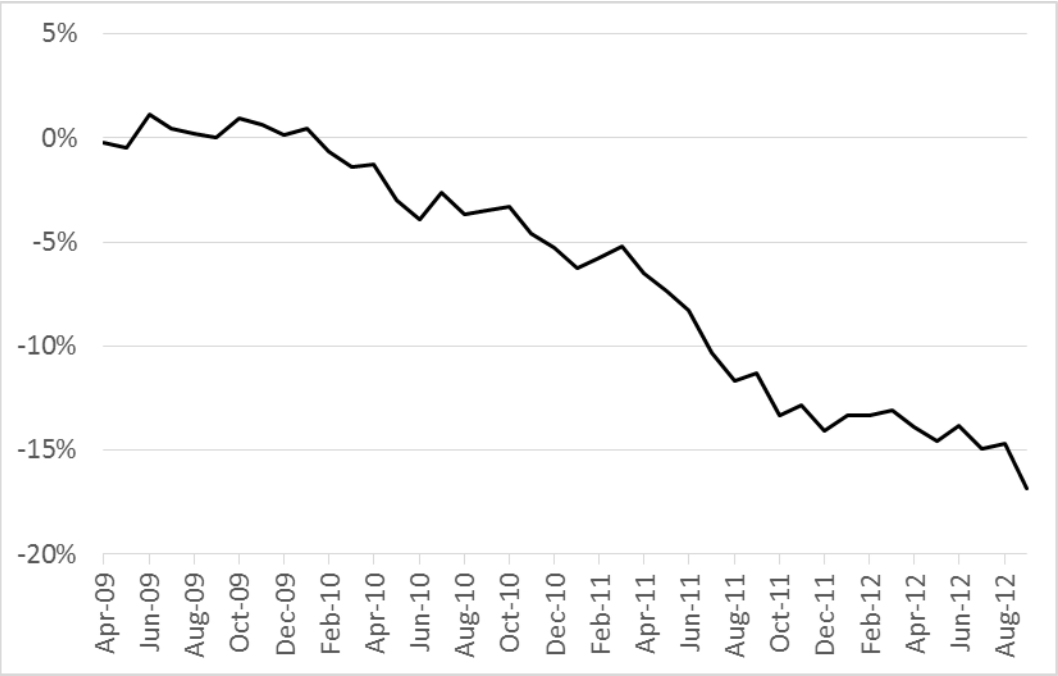


Figure 4: Estimated demand effect of IBR water budgets.

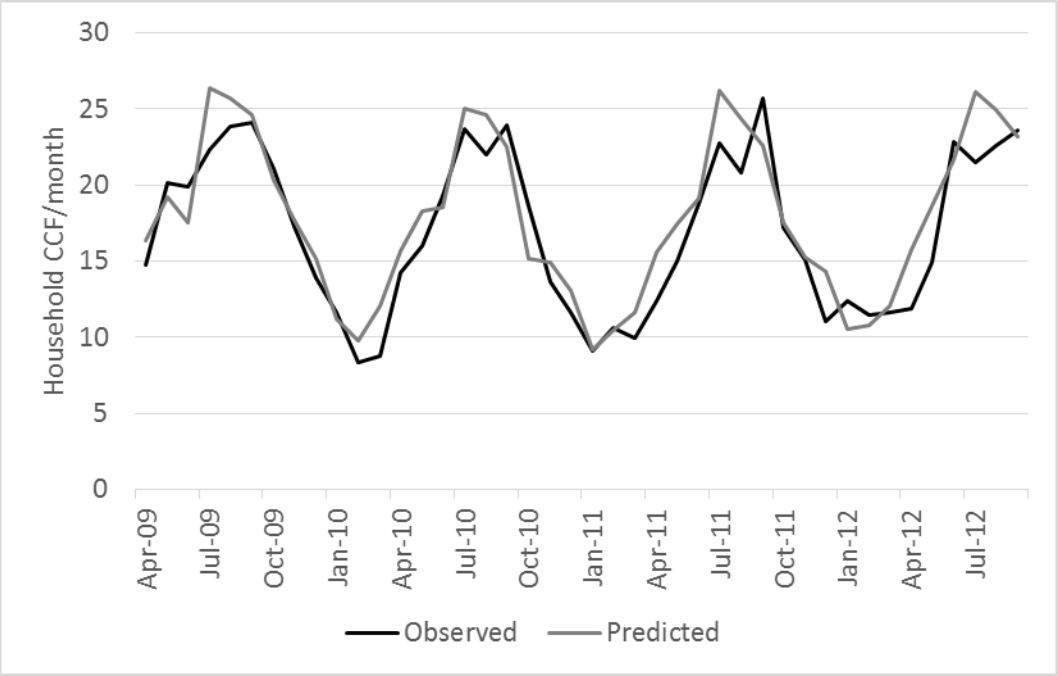


Panel A: Observed vs. predicted demand, 12-month moving average.

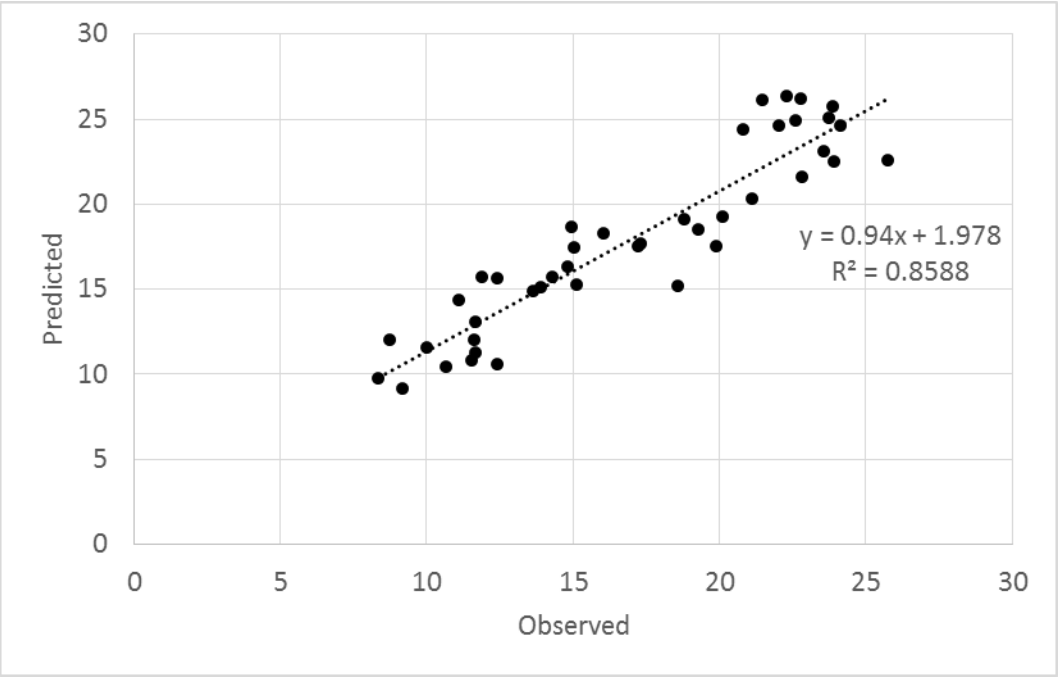


Panel B: Estimated demand effect of IBR water budgets, 12-month moving average. Measured as the difference between observed demand under water budgets and predicted demand under comparable uniform rate pricing, expressed as a percentage.

Figure 5: Observed and predicted average monthly consumption under block-rate pricing.



Panel A: Time trends.



Panel B: Linear regression of predicted average values on observed average values.

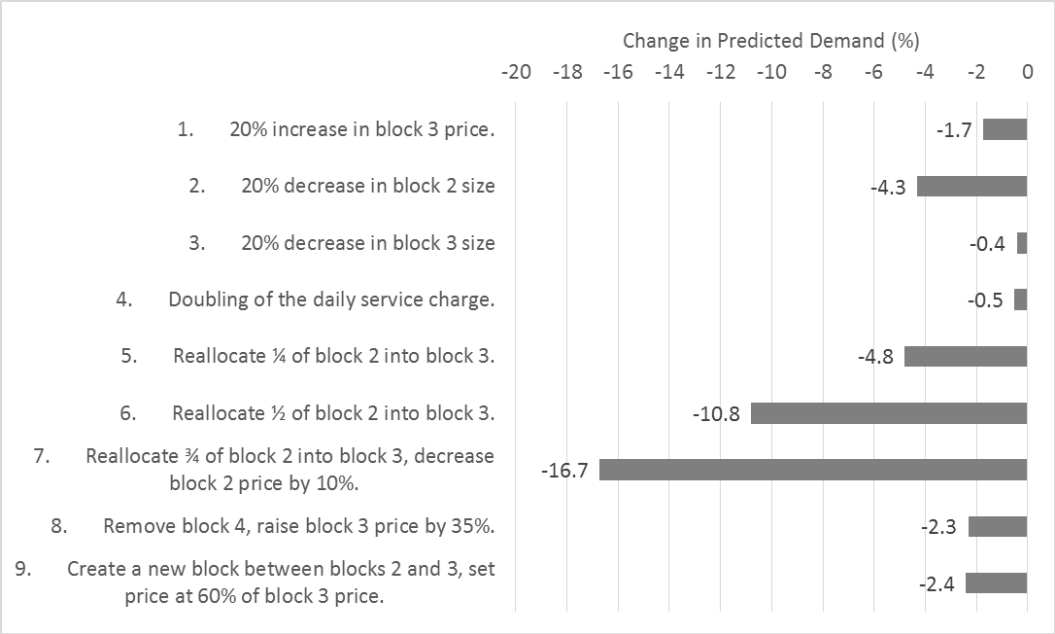



Figure 6: Demand Effects of Alternative Water Budget Rate Structures.