Chapter 3. Urban Water Use Efficiency

Urban water use efficiency focuses on reducing water waste and accomplishing tasks using the least amount of water possible in municipal and industrial settings. Californians have made great progress in urban water use efficiency over the past few decades. At the individual level, the benefits of water use efficiency may appear small, incremental, or difficult to see; but when Californians act together as a community to conserve water, the cumulative effect is significant and the benefits are widespread.

Increased efficiencies can be attributed to several factors; urban water suppliers' implementation of Best Management Practices, plumbing codes requiring more efficient fixtures, the model water efficient landscape ordinance, new technologies in the commercial/industrial sector, and mandates for converting unmetered connections to metered.

However, with tighter environmental constraints on the delta, increasing population, and the necessity of adapting to climate change, even greater efficiencies will be needed, and are achievable. When faced with an increasing demand for water, water agencies can consider options for increasing supplies or reduce demand, or a combination of both, to meet this need. Increasing the water supply includes the possible costs of purchasing additional water, capital cost of production and distribution systems, water supply treatment facilities, energy costs, and wastewater treatment facilities. Reducing demand through increased water use efficiency is generally a lower cost method for meeting increased demand.

In November 2009, The Water Conservation Act of 2009, Senate Bill Number 7 of the 7th Extraordinary session (SBX 7-7), was enacted as part of a five bill package that focused on improving the reliability of California's water supply and restoring the ecological health of the Sacramento-San Joaquin Delta. SBx7-7 had multiple urban and agricultural water use efficiency provisions. The key urban conservation measure established a statewide goal of reducing urban per capita water use by 20% by 2020. To achieve this goal, the legislation directs urban retail water suppliers to set individual 2020 per capita water use targets and begin implementing conservation measures to achieve those goals. Meeting this statewide goal of 20% decrease in demand will result in almost 2 Million Acre Feet (MAF) reduction in urban water use in 2020.

Beyond the goal of achieving 20% reduction by 2020, there are important benefits to increasing urban water use efficiency, including:

- Reduced stress on the environment of the beleaguered Sacramento-San Joaquin Delta
- Reduced landscape runoff (contaminated with fertilizers, pesticides, and road debris) to surface waters
- Ability to stretch existing water supplies
- Ability to provide water for surface or groundwater storage in wet years
- 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
- Better capacity to meet the water demand of California's growing population

This chapter will present the practices already employed in urban water conservation, as well as describing how further efficiencies can be made, and how the goal of 20% reduction by 2020 can be met.

MILESTONES IN URBAN WATER USE EFFICIENCY

1983 Urban Water Management Planning Act (UWMP Act)
The UWMP Act requires urban water suppliers to report water availability and use, long-range planning activities, and the implementation of fourteen Demand Management Measures. The Act has been updated numerous times in its nearly 30 year history.

1991 Formation of California Urban Water Conservation Council (CUWCC)
Water suppliers who sign the CUWCC Memorandum of Understanding (MOU) pledge to implement the Best Management Practices (BMPs) (adapted from the Demand Management Measures of the UWMP Act).

1992 – Present Toilet Retrofits
Plumbing codes for toilets have steadily increased toilet efficiencies. Before 1980 toilets typically used 5.0 gallons per flush (gpf). In 1980 the plumbing codes set the standard toilet flush volumes to 3.6 gpf. And in 1992 any toilet sold could only use a maximum of 1.6 gallons per flush. Beginning 2014 no toilet sold or installed can use more than 1.28 gallons per flush. Residential toilet retrofits have had the greatest impact on urban water use, accounting for almost half of all BMP water savings through 2004.

Urban Planning
(Senate Bills 610 and 221)The approvals of large new developments in California must be linked to assurances that there is an adequate water supply over a twenty year period. Without assurances that there is a reliable source of water, even in dry years, large development projects cannot proceed.

2009 SBX 7-7
This legislation requires the state to reduce urban per capita water use by 20% by 2020.

2010 Model Water Efficient Landscape Ordinance (MWELO)
This ordinance requires cities and counties to adopt a water efficient landscape ordinance at least as effective in water savings as the Model Ordinance by January of 2010.

2011 Cal Green Building Code
Requires a 20 percent reduction in indoor water use, separate water meters for indoor and outdoor water uses in nonresidential buildings, and moisture-sensing irrigation systems for larger landscape projects

2025 Mandatory Metering
All urban water suppliers are required to install water meters on all municipal and industrial water service connections within their service area by 2025. Cities receiving federal water must install water meters by 2013.

Water Supply Costs

Water use efficiency is generally the most cost effective option water suppliers have to improve water supply reliability. Decreasing water demand by an acre-foot has the same benefit as increasing supply by an acre-foot and the efficiency measures are usually less costly to implement.

A position paper written in 2008, *Transforming water: Water efficiency as stimulus and long-term investment. (*Alliance for Water Efficiency) estimated the range of cost for water use efficiency programs from a low of $57/AF for rate and water budgets programs to $533/AF for industrial process water efficiency programs. The cost and type of efficiency programs implemented will vary from supplier to supplier, the Alliance paper estimated that a typical suite of programs that a supplier might implement would cost between $333-$500/AF.

Compare this cost per acre foot to other measures used for increasing water supply:

Urban Water Use Efficiency	- $ 333 - $ 500/AF
Surface Storage	$1,301 - $3,811/AF* *(based on estimates for potential new projects)*
Recycled Water	$ 300 - $1,300/AF*
Desalination of Groundwater	$ 500 - $ 900/AF*
Desalination of Wastewater	$ 500 - $2,000/AF*
Desalination of Seawater	$1,000 - $2,500/AF*

**From the California Water Plan 2009 – to be updated with data from 2013 Water Plan*

Best Management Practices (BMPs)

BMPs have been the major driving force behind water conservation efforts in the State of California since they were adopted in 1991. After adopting the California Urban Water Conservation Council's Memorandum of Understanding (MOU) in 1991, many urban water suppliers undertook water conservation programs identified as Best Management Practices (BMPs) that were detailed in the MOU. Urban water suppliers report progress on BMP implementation biannually to the CUWCC through its website.

Since the MOU's initial signing in 1991, BMP water savings have been driven by three BMPs: Large Landscape, Commercial Industrial, Institutional, and Residential Toilet Retrofits.

By 2004, these three BMPs accounted for almost 90% of annual water savings. Of these three, residential toilet retrofits has clearly had the greatest impact on urban water use, accounting for almost half of all water savings from BMPs.

Foundational BMPs		Programmatic BMPs	
Utility Operations – Operations	Implements a water conservation coordinator for the agency. Water waste prohibition ordinance is in effect in the service area. Implementing prohibitions on gutter flooding, single-pass cooling systems, non-recirculating water. Monitors water softener efficiency and usage. *Old BMP Numbers 10, 12, and 13*	Residential	Includes indoor and outdoor residential surveys. Surveys scheduled to check for leaks, flow rates, irrigation systems and schedules. Implement an enforceable ordinance to replace high-flow water use fixtures with low-flow counterparts. Offers rebates for high-efficiency washers. Offers rebates for high-efficient, low-flow toilets. *Old BMP Numbers 1, 2, 6 and 14*
Utility Operations – Pricing	Implements rate structure and volumetric rates for water service by customer class. *Old BMP Number 11.*	Landscape	Developing marketing and targeting strategies for landscape surveys. Implementing a water use budget. *Old BMP Number 5.*
Utility Operations – Water Loss Control	Implement a full-scale system water audit, maintain in-house records of audit results or completed AWWA audit worksheets. *Old BMP Number 3*	Commercial, Industrial, and Institutional	Rank commercial, industrial, and institutional customers according to use. Implement either CII Water Use Survey and customer incentives program, or CII conservation program targets. *Old BMP Number 9*
Utility Operations – Metering	Implement meters for all new connections and bill by volume-of-use. Implement program for retrofitting existing unmetered connections and bill by volume-of-use. *Old BMP Number 4.*		
Education – Information Programs	Agency is to maintain an active public information program to promote and educate customers about water conservation. Implement a school information program to promote water conservation. *Old BMP Numbers 7 and 8*		

The BMPs lend themselves to tracking on the basis of activities performed and fixtures replaced. The Urban Water Management Planning Act requires water suppliers to report their implementation of BMPs and demand management measures to DWR every five years in Urban Water Management Plans.

20% by 2020: A New Direction

History

In February 2008, a seven-part comprehensive plan for improving the Sacramento-San Joaquin Delta was introduced. A key component of this plan was a goal to achieve a 20 percent reduction in per capita water use statewide by the year 2020. The inclusion of water conservation in the Delta plan emphasizes the importance of water conservation in reducing demand on the Delta and in reducing demand on the overall California water supply.

In response to this call for statewide water savings, a 20 x 2020 State Agency Team on Water Conservation was convened. In April 2009 this agency team released a draft 20 x 2020 Water Conservation Plan which outlined recommendations on how a statewide per capita water use reduction plan could be implemented.

In November 2009, The Water Conservation Act of 2009, Senate Bill Number 7 of the 7th Extraordinary session (SBX 7-7), was enacted. The urban water conservation provisions of SBX 7-7 reflect the approach taken in the 20 x 2020 Water Conservation Plan and set an overall goal of reducing per capita urban water use statewide by 20% by 2020.

The legislation also directed DWR to address the following urban water use efficiency issues:

- Convene a task force to investigate alternative best management practices for the commercial, industrial and institutional sectors (CII Task Force)
- Establish a standardized water use reporting form
- Promote regional water resource management through increased incentives and decreased barriers
- Develop statewide targets for regional water management practices like recycled water, brackish groundwater, desalination and urban stormwater infiltration and direct use.

The 20% by 2020 Process

Key to the SBX 7-7 legislation is the determination of baseline and target water use, which is calculated in gallons per capita per day (gpcd).

- Urban retail suppliers calculate average baseline per capita water use based on 10 consecutive years chosen between 1995 and 2010.
- Suppliers set 2015 and 2020 water use targets using one of four target calculation methods. Average baseline water per capita water use, the 2015 target and 2020 target are reported in the 2010 urban water management plan.
- For 2015 and 2020, suppliers calculate the actual per capita water use and report in their 2015 and 2020 UWMP if they have met the water use target for that year.

Suppliers are given the option of excluding recycled water, potable water supplied for agricultural use, and in some cases industrial process water from their calculations of water use. Suppliers are also permitted to adjust their 2015 and 2020 water use targets if there are significant differences in rainfall and climate or significant documented increases in the CII sector between the baseline years and the compliance year. Wholesale suppliers are not required to set targets, but are directed to assist their retail suppliers in meeting the targets.

It is important to note that the legislation does not require a reduction in the total volume of water used in the urban sector, because other factors, such as changes in economics or population, may have greater effects on water use.

Impact of 20x2020

Projecting forward to the year 2020, with statewide population expected to be in the range of 44 million people, a decrease in per capita water use of 20% will equate to an annual demand reduction of 2 million acre feet of water.

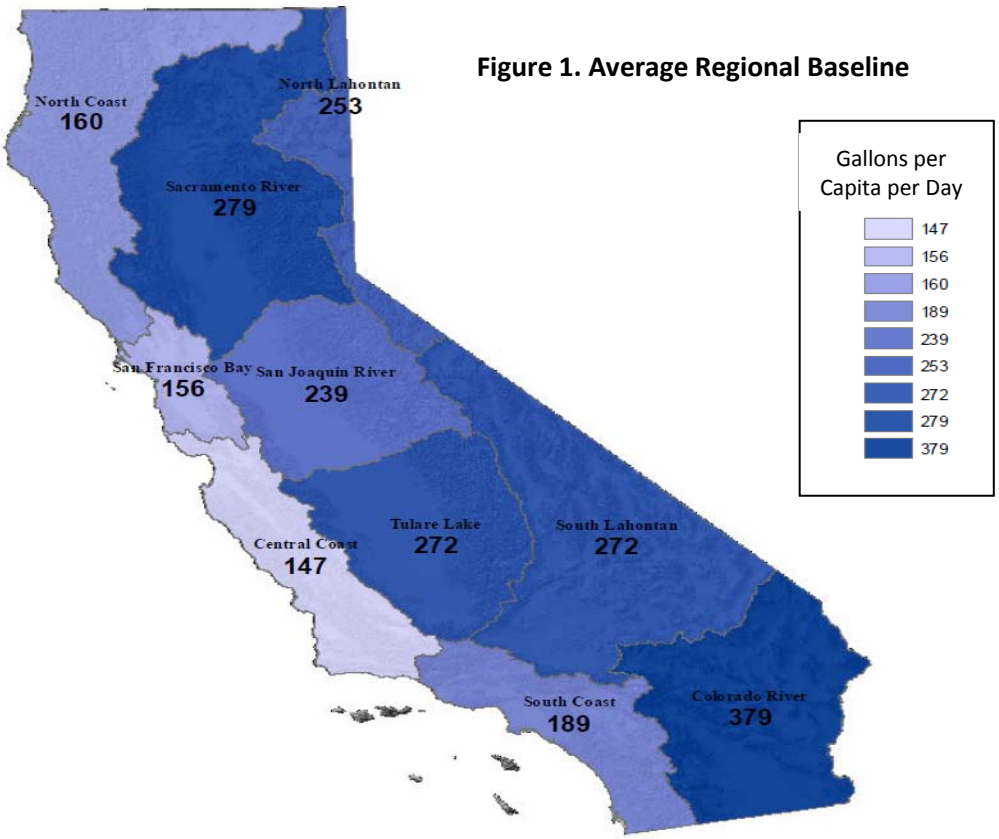
The requirement that all urban retail water suppliers quantify per capita baseline water use, set water use targets, and then show actual reductions in 2015 and 2020 has caused suppliers across the state to rethink their conservation programs and service area water use. 20x2020's emphasis on quantification forces suppliers to ensure the effectiveness of water conservation actions.

Baseline Water Use Reported in Urban Water Management Plans

The statewide average baseline water use is 198[1] gallons per capita per day (gpcd) based on UWMPs from 342 retail water agencies. Though suppliers could choose any 10 consecutive years from between 1995 and 2010, most of the suppliers choose baseline periods from 1996 to 2004.

The California map below (Figure 1) shows how baseline water use differs regionally across the state with generally lower water use along the coast and increasing water use in the inland valleys. The coastal areas generally have lower water use due to the marine climate and lower evapotranspiration rates, smaller irrigated landscape areas, and previous conservation program. Many of the coastal communities along the central coast and southern California were strongly impacted by the 1988-92 drought and subsequently implemented a number of water use efficiency programs to improve their water supply reliability. Low or high per capita water use is not necessarily an indicator of efficiency as the climate and land use factors listed above can have a significant effect on water use

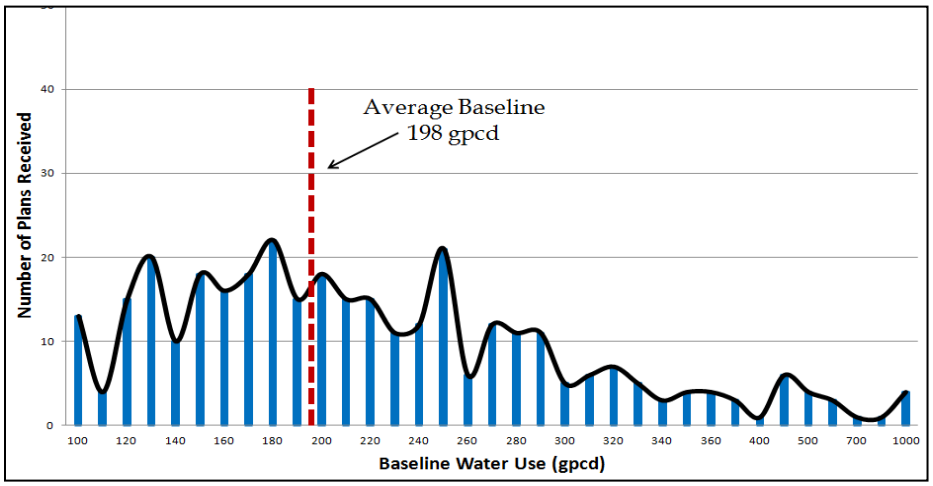
Figure 1. Average Regional Baseline



[1] Population weighted

Figure 2 shows the range of per capita water use by water agency. 15 suppliers had water use below 100 gpcd while four suppliers had water use greater than 1000 gpcd. The 15 suppliers below were generally near the coast in dense urban environments with smaller landscape areas. The suppliers on the right side of the chart with higher water use are typically supplying water to homes or ranchettes in suburban or rural areas with large areas of irrigated landscape or pastures.

Figure 2: The Distribution Range of Baseline Water



Water Use Targets

Water suppliers also reported their 2020 per capita water use targets in the 2010 Urban Water Management Plans. The average target reported was 166 gpcd. This target is a 16.2% reduction from the statewide average baseline of 198 gpcd, which is lower than the 20% goal. The legislation provided four methods for calculating the 2020 target and this allowed some suppliers to select targets lower than the 20% goal, but none of the methods require suppliers to select targets higher than 20%.

After receiving the 2015 UWMPs, DWR is required to report to the legislature on progress towards the 20% goal. If the state is not on track to meet the 20% target, DWR is directed to provide recommendations to the legislature on how the goal can be achieved. A list of the individual water supplier's baselines and targets and more information on statewide and hydrologic region averages is available in DWR's report to the legislature on the 2010 Urban Water Management Plans.
Http://xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

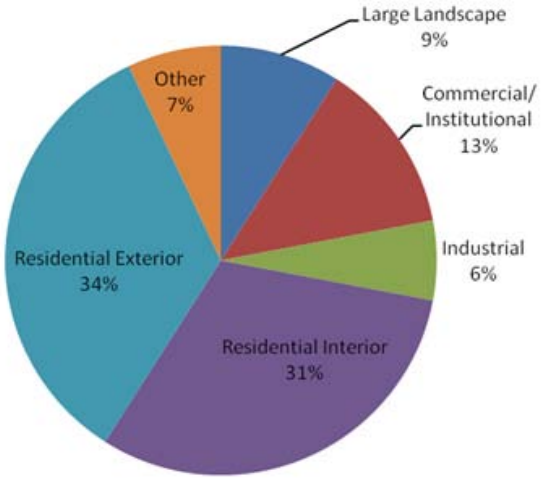
Volume of Urban Water Use

The data in Table 1 and Figure 3 (below) represents the California Water Plan's estimate of urban water use by sector, for the time period of 1998-2005. The average annual volume of water supplied for that period was 8.8 million acre feet (MAF). This 8.8 MAF is subdivided into water use by sector in Table 1 below.

The Water Plan estimates of urban water use include recycled water, self supplied industrial, potable water supplied to agriculture, conveyance losses, and water used for groundwater recharge. These water uses are typically not included in the 20x2020 water use calculation.

The relative volume of water use by sector is important to estimate potential 2020 water conservation savings.

Statewide Urban Water Uses	
Large Landscape	0.8 MAF
Commercial/Institutional	1.1 MAF
Industrial	0.5 MAF
Residential Interior	2.7 MAF
Residential Exterior	3.0 MAF
Other	0.6 MAF
TOTAL	**8.8 MAF**



2010 Water Use

2010 water use as reported in the 2010 UWMPs is xxxx gpcd (still being calculated). Many urban suppliers have seen water use drop significantly starting in 2007 through 2010. The decreased water use is attributed to the 2007-2009 drought, the economic downturn and late spring rains and a cooler than normal summer in 2010. Many suppliers have reported decreases in water use as high as 20%, high enough that a number of suppliers are already below their 2020 water use target. Many suppliers are now focused on ways to keep water use low once the economy improves and a more typical weather pattern returns.

Meeting 2020 Targets - Opportunities for Conservation

Voluntary implementation of BMPs, codes, and regulations has been the main driver of water use efficiency since the early 1990's. However, abundant opportunities exist to increase urban water use efficiency, and many of these opportunities will need to be tapped in order for California to achieve its 20% reduction goal by 2020. Descriptions of actions that can be taken, and their potential for increased savings, are presented below.

All water savings noted in the following sections are comparisons to the baseline water use during the period 1995 – 2010. Because baselines and targets are reported in gallons per capita per day (gpcd) the descriptions presented below will state the current water use and potential savings in GPCD.

Landscape Irrigation

Referring to Table 1 and Figure 3 (above) water demand for landscape irrigation in residential, large landscapes, and CII landscapes amounts to approximately 4 million acre feet, about 43% of urban demand. Regardless of the method, demand reduction in landscape water use carries a high potential.

Landscape irrigation water waste is common and easily seen on all types of landscapes and often manifests as water running down street gutters, sprinklers spraying off target, broken heads and risers spraying water into to the air, and watering when it is raining. These events can be attributed to several causes; poor design and installation, lack of routine maintenance, inappropriate scheduling and delayed repairs after malfunction or breakage.

The most cost effective method for reducing water waste from landscape irrigation is increasing irrigation efficiency with regular system repairs, maintenance and scheduling refinements. Another important method for reducing irrigation demand is through selection of low water using plants with a corresponding reduction in water application. Plant choices and landscape styles are driven by economic factors and esthetic concerns. Initially some low water using landscapes may cost more to install, but over time the decreased water and maintenance demands offset the higher installation costs. Esthetic needs are difficult to quantity, but there is increased interest in using California natives, and other Mediterranean climate plants and desert plants. Research and development by universities and sod producers have led to the introduction of lower water using varieties of turfgrasses.

Dry season irrigation runoff is influenced both by irrigation system inefficiency and landscape design. Runoff wastes water and contributes significant non-point pollution to receiving waters. The *Residential Runoff Reduction Study* (MWDOC and Irvine Ranch Irrigation District 2004) cites an observed reduction of 50% of runoff volume after intervention in the study group consisting of 138 residential and non-residential landscapes. These landscapes were retrofitted with Evapotranspiration based (ET) controllers along with education of water users. The retrofit group had a runoff volume of 71% lower in comparison to a control group of 461 landscapes receiving no intervention. While irrigation system inefficiency drives dry season irrigation runoff, landscape design can lessen stormwater runoff and increase stormwater retention. Through design of rain gardens and swales and redirecting downspouts from buildings into the landscape, significant water savings can be achieved through stormwater infiltration. Stormwater retention will shorten the irrigation season and recharge groundwater.

Each of these opportunities varies in degree depending on landscape size, local climate, maintenance budgets and the functions of landscapes.

Residential Landscapes

Outdoor residential water use represents the single largest end use of urban water, accounting for 34% of total urban use. Summer outdoor water use from landscape irrigation and swimming pools commonly drives the peak system capacity requirements.

Many factors contribute to the large amount of water used in landscapes, including population shifts to hotter interior regions which often have larger residential landscapes, the prevalence of cool season turfgrasses and other high water use plants, and irrigation systems that are inefficient and poorly maintained. The routine use of automatic irrigation controllers has been shown to increase water use at single family homes by more than 50% over the use at homes with manually operated irrigation systems.

On closer examination, several studies show that water users irrigating at a rate less than a theoretical water budget frequently offset those that apply too much water. It can be assumed that most of those that under irrigate are nevertheless satisfied with the quality and appearance of their landscapes, otherwise those irrigators would have increased their water use. This leads to the conclusion that many landscapes can be maintained at a rate well below a theoretical water budget of 100% or even 80% of ETo.

Plant choices, cultural practices and managing the rate of soil water depletion all contribute to the ability of some landscapes to be maintained on low application rates. In the report “Evaluation of California Weather-Based “Smart” Irrigation Controller Programs” 41.8 % of sites had an increase in water use over the historical application ratio. This can be attributed to the fact that many landscapes need less water than the theoretical requirement.

There are at least two possible explanations for this phenomenon; either some landscapes require less water than previously thought because of actual plant water needs, soil conditions and cultural factors contribute to

a lower demand or the standard used to estimate water requirements needs to be reevaluated. Prior to 2010, landscapes that were installed in compliance with the AB 325 Model Water Efficient Landscape Ordinance were allowed a water budget that did not exceed an Evapotranspiration Adjustment Factor (ETAF) of 0.8. Currently, the Model Water Efficient Landscape Ordinance (MWELO) water budget for non-recreational landscapes is calculated with an ETAF of 0.7. In the report "Water Smart Landscapes for California", the AB 2717 Landscape Task Force recommended (Recommendation 12) that the ETAF be reviewed every ten years for possible further reduction. After more research is done in plant water use it may be possible to lower the ETAF used in the water budget calculation.

In light of these findings, water suppliers should focus their efforts and resources on water users with high application rates per landscape area. As a marketing tool, a cost benefit analysis based on water rates and other factors can pre-determine which customers would be the best candidates for intervention, both in terms of maximizing water supplier resources and customer buy-in. Furthermore, because most residential users underestimate the quantity of water used in their landscape, education components remain a vital tool in that they either increased the water savings potential or increased persistence of water savings.

Several water use studies (*Waste Not, Want Not*, Pacific Institute; *Residential Weather Based Irrigation Scheduling*, Irvine Ranch; *Lawns and Water Demand*, Public Policy Institute) indicate that residential landscape water demand can potentially be reduced by at least 20%-25% with some researchers estimating savings potential of 45% or more. The methods for water savings include the use of ET Controllers, reduction of cool season turf, and education. The California Single Family Water Use Efficiency Study estimates that solely by preventing over-irrigation in single family homes, the State can reduce water demand by approximately 0.6MAF or 28%.

The baseline rate of residential outdoor water use is estimated at 81 GPCD. A conservative estimate of 20% reduction would represent an annual reduction of 0.79 MAF by 2020, or savings of 16.2 GPCD.

Large Landscapes (Dedicated Meters)

Large landscapes are CII landscapes that are a category set apart by the presence of dedicated irrigation meters. Dedicated metering serves the purpose of accurately measuring the water use of a landscape and making it possible to assign and monitor water budgets and detect leaks. The CUWCC landscape BMP (formerly BMP 5) requires water use budgets to be assigned at 70% of local ETo. Based on an eight year average of DWR data (see Table 1 and Figure 3), large landscapes with dedicated meters accounted for 9% of urban water use or .8 MAF. Water use through the dedicated meter can be monitored by the irrigator and can provide immediate feedback on the amount of water moving through the meter. Programs such as the California Landscape Contractors Association (CLCA) Water Management Certification Program enable irrigation managers to monitor and track water use and manage a landscape at 80% of Reference Evapotranspiration (ETo) or less.

Dedicated Water Meters

Water Code 535

Since 2008, water suppliers must install a dedicated landscape meter on new non-residential water service with a landscape area over 5000 sq. ft. The Cal Green Building Code requires dedicated meters, metering devices or sub-meters to facilitate water management on non-residential landscapes from 1000 sq. ft. up to 5000 sq. ft.

The numbers of sites and acreage of large landscapes will increase over time as existing CII landscapes with mixed use meters are retrofitted to dedicated meters. All new CII landscapes over 5000 square feet require a dedicated irrigation meter.

A CII Landscape Water Use Efficiency study (CLCA 2003) collected data collected from 449 CII landscapes. The results indicate that approximately 50% of CII landscapes are irrigated at an excess of 100% ETo. If those sites reduced water use to maintain a water budget of 100% ETo, the author estimates a 15%

demand reduction can be achieved. Potential landscape efficiency gains could be much greater than 15% if conversions from cool season turf to water efficient plants were included and if the water budget were reduced to 70% or 80% of ETo.

Baseline water use on large landscapes is estimated at 21 GPCD. Using a conservative estimate of a 15 % reduction (3 GPCD), annual demand reduction by the year 2020 will be approximately 0.15MAF.

Commercial/Industrial/Institutional Landscapes (Mixed Use Meters)
Water use studies indicate that the opportunities for water savings in CII landscapes with mixed use meters are at least as high as residential landscapes. Some landscapes, especially golf courses, have the advantage of having professionally designed and installed irrigation systems, weather based irrigation controllers, and trained full time maintenance staff. Others, such as K-12 school playgrounds, some aesthetic plantings at commercial centers, and traffic medians, may lack full time resources and attention and are more apt to be inefficient.

Potential water savings for this category of landscape irrigation (CII Mixed Use Meters) will not be accounted for in this section. These potential saving are accounted for in the CII section.

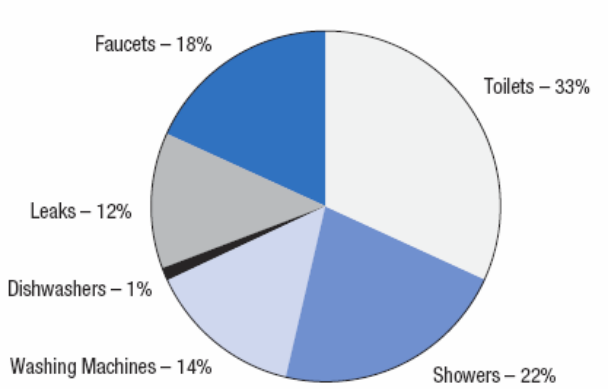
Increased implementation of cost-effective Best Management Practices for all landscapes will assist water suppliers in meeting their 2020 water use targets. These practices include:

- Irrigation audits targeted to high water users. In a recent study (Single Family Home End Use Study, Irvine Ranch 2007) the majority of savings from outdoor use were be found from a small segment (around 15%) of the customers. Set aside all other users and focus on high water using homes.
- Assign and monitor water budgets based on landscape size and local climate. Install dedicated landscape meters at all CII sites.
- Incentivize landscape improvements including “cash for grass” conversions, irrigation system upgrades, sprinkler nozzle replacement and irrigation controller replacements. Target incentive programs at water users with high application rates.
- Education and other public awareness programs aimed at residential water users and landscape professionals.
- Work with local land use agencies to put water efficient landscape ordinances into practice.
- Facilitate training of local landscape, nursery and irrigation personnel in water efficient landscape tools and techniques, including irrigation auditing, and irrigation scheduling and budgeting.
- Promote climate appropriate plant selection; including reducing cool season turfgrass used as amenity groundcovers and where other plant species would be suitable.
- Use of pool covers, auto shut-off spray nozzles, and prohibition of pavement spraying.

A comprehensive approach to reducing landscape water demand requires a portfolio of programs and approaches. Education increases persistence of savings and financial incentives increase the customer base that can act to reduce water use.

Indoor Residential

Indoor water use in the residential sector (both single and multi-family housing) accounts for about 31% of total urban water in California. For the baseline reporting period, using the 2000 population, this equates to 62 GPCD. As a very high benchmark for comparison, an EPA study of retrofit homes (2000) (homes were retrofitted with high efficiency fixtures and appliances) reached an indoor efficiency of 37 GPCD. This demonstrates that although a great deal of water savings has been captured by the retrofit of indoor residential fixtures, significant savings remain to be captured in this sector.



Residential indoor water is delivered through only a small number of fixtures - toilets, clothes washers, showers, faucets, and dishwashers.

Toilets

The American Water Works Association (AWWA) study, *Residential End Uses of Water* (1997) revealed that toilets were the biggest component of indoor water use at that time. Years later, it appears this was still the case. The authors of the *California Single Family Water Use Efficiency Study (Single Family Water Use Study)*, 2011, and *Waste Not, Want Not*, Pacific Institute (2003) show that home toilets account for 20- 32% of indoor water use, an average of 13-19 GPCD.

Code requirements on toilet sales have increased the efficiency of new and replacement toilets from 3.5 and 5 gallons per flush (gpf) to 1.6 gpf in 1992 and 1.29 gpf in 2014.Yet many toilets remain to be converted to efficient models, and indications are that, once installed, not all efficient toilets flush at the intended volume, further reducing efficiencies. The 20 x 2020 Plan estimated that the saturation of toilets with a flush volume of 1.6 gpf (also known as ultra-low flow toilets, or ULFT) in 2005 was 54%. Data in the Single Family Water Use Study suggest that 60% or more of the individual toilets in the study are ULFT or better.

The 20 x 2020 Plan calculates that retrofitting residential toilets, so that 81% are ULFT or High Efficiency Toilets (HET), could be an important part of the strategy for achieving the 20% reduction by 2020. This degree of retrofitting will be supported by AB 715, the state code that requires only high-efficiency toilets and urinals (HETs and HEUs) to be sold or installed after January 1, 2014, as well as SB 407, which requires retrofit upon resale with compliant fixtures in 2017 for residential properties and 2019 for commercial. But water suppliers will need to continue and enhance their toilet retrofit programs.

The 20 x 2020 Plan estimates potential savings from increased toilet efficiencies at roughly 5 GPCD.

Clothes Washers

In 2000 clothes washers accounted for 14-17.5% of indoor residential use, about 9-10.5 GPCD (Pacific Institute 2003 and Aquacraft 2011). According to the Single Family Water Use Study, the average load used about 36 gallons of water per load, whereas the new, efficient models use about 26 gallon per load. Only about 20% of homes were washing at that efficiency, indicating that there is great potential for increasing efficiency, through appliance replacement, in this area.

New water efficiency standards for clothes washers were adopted by the California Energy Commission in 2004.The standard is based on the “water factor” of the clothes washer, which is the number of gallons per cubic foot of drum capacity. Conventional washers have a water factor of about 13.3. In 2007 the maximum

water factor to be allowed was 8.5. By 2010 the standard would have been further reduced to 6.0. Federal approval is still required, as the Federal Energy Policy Act of 1992 allows on the federal government to regulate residential clothes washers, pre-empting state standards, unless a state waiver is approved, California has requested such a waiver and continued to press for federal approval.

The 20 x 2020 Plan calculates that replacing older washers with efficient models, so that 85% are water efficient, will be important to achieving the 20% reduction by 2020. Obtaining authorization for state standards for high efficiency clothes washers will support the saturation goal.

The 20 x 2020 Plan provides this estimate for potential savings from increased efficiencies in clothes washers. First, savings for fixtures and appliances in new construction were estimated assuming that the efficiency code had gone into effect as intended; this code is estimated to produce savings of 2-3 GPCD. Additionally, active rebate programs and natural turnover of old appliances in existing construction will produce another 2-3 GPCD savings by 2020. Total projected savings for clothes washers is 4-6 GPCD.

Leaks

Residential water loss, due to leaks from all sources (dripping faucets, leaking toilets, leaking pipes, swimming pool leaks, etc…), average from about 7 to 10 GPCD (Pacific Institute 2003 and Single Family Water Use Study). Although this number is relatively large, the majority of the water loss is concentrated in a small number of homes. The Single Family Water Use Study showed that while the median loss was only 1.4 GPCD, 14% of the homes were leaking over 17 GPCD. A very small percentage of homes, 7%, were leaking over 34 GPCD and accounted for 44% of the leakage volume.

Since the majority of water lost to leaks is from the top 15% of homes, strategies that target these homes would be the most cost effective for water suppliers. The Single Family Water Use Study points to several methods to detect homes with high rates of leakage, including:

- Develop water budgets – homes with leaks will exceed budgets and pay excess use rates, thus encouraging repair.
- Install smart meters – provides real-time feedback to users, alerting them of a sudden jump in water use that may signify a leak.
- Identify excessive water users (by comparison of water bills with similar properties) and offer water audits to these customers.

The Pacific Institute and Single Family Water Use Study determined the median value of residential leaks was 1.4 -3.9 GPCD. If leaks could be detected and repaired so that the average leak rates are reduced to the median values observed in studies, the savings would be 6-7.5 GPCD. As mentioned above, targeting the highest water users would be most effective as only 15% of homes accounted for the majority of leaks. Even with a targeted strategy, water agencies would need to have a much more aggressive residential leak reduction program than most currently do, and would need to maintain their programs at this high degree to keep up with new leaks as they arise. Assuming that water agencies were able to work with their residential customers so that just under half of this potential leakage could be detected and repaired, the savings would then be 3 GPCD.

City of Sacramento - Case Study
Advanced Metering Infrastructure (AMI)

City of Sacramento installed AMI to 17,600 residencies.

- 1,076 leaks were detected through AMI reports
- 367 million gallons of aggregate annual water loss calculated through AMI reports
- 236 million gallons of water saved, which equates to 12.6 GPCD

AMI can play a major component in helping the City of Sacramento reach the State mandate of 20% per capita reduction by 2020.

Showers

Showers account for about 20-22% of indoor residential use, equivalent to about 11.8-13.5 GPCD. The Aquacraft Study found that nearly 80% of all homes had showerheads operating at 2.5 gpm or less, the flow of an efficient showerhead, with an average shower volume of 18.2 gallons. The flow rate of 2.5 gpm can be achieved by use of a low flow shower head, or by simply not turning the shower on to full volume. Changing behavior, especially in the population at large, is much more difficult than replacing a fixture for water savings.

The 20 x 2020 Plan calculates that the continued retrofitting of inefficient shower heads to a 97% saturation level will be important to achieving the 20% reduction by 2010. Also, because water use in a shower is dependent upon flow rate and shower duration, public education campaigns that include a message to take shorter showers could have a positive impact.

The 20 x 2020 Plan estimates potential water savings that still remain to be captured in shower water use is roughly 1 GPCD.

Faucets

Faucets account for about 19% of indoor use, approximately 11- 12 GPCD. The Single Family Water Use Study shows that homes ran their faucets on average 56 times a day with an average duration of 37 seconds. At least some of this was wasted when the faucet was running but the water was simply going down the drain. Use of faucets to hand-wash dishes while leaving the water run continuously is one of the largest types of faucet uses encountered in the Single Family Water Use Study analysis. The volume wasted by this is affected both by flow rates and run times. The maximum flow rate for new faucets, set by federal standards in 1994, is 2.5 gpm, though some faucets, especially bathroom faucets, can operate as low as .5 gpm. The AWWA study of 1999 estimated there was 50% penetration of 2.2 gpm faucet aerators.

Water agencies should continue to support retrofits of older faucets with low-flow fixtures and aerators. The Single Family Water Use Study notes that inefficiencies in faucets will become more important as other indoor inefficiencies become addressed. With this in mind, water agencies should monitor the development of new devices that can temporarily halt flows or have dual flow modes.

The Single Family Water Use Study assumes only a reduction of 10% in faucet water use. (11.5 GPCD X 10% = 1 GPCD). This equates to a 1 GPCD savings.

Total Projected Savings for Indoor Residential

Adding the savings from each of the fixtures and appliances above, total projected water savings for indoor residential use is 15 GPCD.

Potential Savings for Indoor Residential Water Use (in GPCD)	
Toilets	5 gpcd
Showers	1 gpcd
Leaks	3 gpcd
Faucets	1 gpcd
Clothes Washers	4-6 gpcd
TOTAL	**15 GPCD**

Commercial/Industrial/Institutional (CII)

The eight year average water use for California (California Water Plan 2009) shows that the commercial/industrial/institutional sector uses about 20% of urban water, which equates to 1.76 Million Acre Feet or approximately 48 GPCD

If water used for large landscapes with dedicated meters is added to CII water use, the total CII water use would then be 30% of urban water use. The 30% figure is often quoted for CII water use as a percentage of total urban water use. However, water use for large landscapes with dedicated meters has been addressed above and will not be discussed in this section, nor will projected water savings from these landscapes be included in this section, so as to avoid double counting. The CII landscapes with mixed use meters (indoor and outdoor use on one meter) are included in this section.

The CII sector covers a broad range of water uses, from schoolyard playgrounds and drinking faucets to metal finishers and bottling plants. This presents a challenge when addressing this sector as a whole. The State does not currently have the data necessary to establish the baseline of use in each CII sector and the information needed to estimate statewide savings must await the development of the baselines and metrics.

CII Task Force

In response to the complexity of the CII sector and the lack of data available on CII water use, the SBX 7-7 legislation called for a CII Task Force to address CII water use efficiency, including development of alternative best management practices and metrics for water use in CII sectors. The complete report from this task force can be found http://www.water.ca.gov/xxxxx.

Potential for Savings in CII Water Use

Because of the numerous and varied water uses in this sector, specific discussion on each use will not be included in this chapter. And, in fact, there are limited centralized data concerning how much water is used in the CII sectors. However, certain broad inefficiencies were noted in the CII Task Force report. Also, common water uses within the CII sector have been identified in both the CII Task Force and Pacific Institute's study, *Waste Not Want Not.*. These are restrooms, cooling, landscaping, process, kitchen, and laundry. With the exception of process water use, these end uses are very similar among industries.

- Restrooms. Restrooms usage is one of the high end uses in CII. Inefficiencies in this area are similar to those in the residential sector, such as older toilets with high volume flush rates and high volume faucets.
- Cooling. Water is used for production processes, for cooling heated equipment, and for cooling towers and air conditioning. Inefficiencies include improper adjustments made by system operators, system leaks, and the use of older, inefficient equipment.
- Landscape. Inefficiencies in CII landscape, as with other landscapes, include poorly designed and maintained irrigation systems, excessive watering schedules, and landscape designs that rely on high water using plants, especially cool season turf, where low water using plants could provide the same benefit while using less water use.
- Process. Process water inefficiencies include poorly adjusted equipment, leaks, use of outdated technology and/or equipment that are not water efficient, and use of potable water where recycled or re-used water may be adequate.

Process Water

Process water is water used by industrial water users for producing a product or product content, or water used for research and development. Process water is highly specific to each industrial user.

Process water, within certain parameters, may be excluded from calculations of baselines and targets in order to avoid a disproportionate burden on another customer sector.
From DWR Process Water Regulation

- Kitchen. The majority of the water used in the kitchens is for pre-rinsing, washing dishes and pots, making ice, food preparation, and equipment cleaning. Inefficiencies in kitchen water use include usage of old machineries, high volume spray values, and cooking behaviors and techniques.
- Laundry. Water savings can be achieved through use of more efficient washers.

Water Agency Actions

Each water agency will face a unique blend of CII customers and will need to tailor the implementation of their CII water conservation program to fit local needs and opportunities. However, certain actions will assist water agencies in increasing CII water use efficiency to meet 2020 targets. These include: identifying the highest users of CII water within the agency and offering or otherwise supporting water use surveys for these customers, continued and more aggressive conversions of mixed use meters to dedicated landscape meters, continued retrofit of older toilets to ULFT and HET.

CII Task Force Recommendations (Draft Report)

The CII Task Force makes the following recommendations for CII end users:

- Adjust equipment and fix leaks. Make adjustments and repairs to existing equipment and processes so that it operates more efficiently.
- Modify equipment or install water saving devices and controls. Add devices, automated systems, or equipment to existing water using equipment and processes.
- Replacement with more efficient equipment. Replacing older inefficient water using equipment and fixtures with water saving types of equipment is one of the most recognized ways to reduce water use. As better technology becomes available CII businesses may decide to upgrade their water using equipment, fixtures, and machines when they reach their useful life as a cost effective measure. Older equipment by their design uses more water, energy, chemical, and wastewater than newly designed equipment.
- Water reuse/recycling. Many case examples of water recycling can be found in the CII Task Force report and show the potential for using this non-potable water source. A thorough discussion of this is found in the Recycled Water RMS, Chapter X of the California Water Plan.
- Switch to a waterless process. A number of examples of replacing water using equipment with equipment that does not use water can be found in the BMPs of the CII Task Force report.

Projected CII Savings

Because of the lack of sufficient water use data for the CII sector, and the fact that water conservation potential varies greatly among technologies, industries, and regions, determining a value for projected savings is challenging.

However, the SBX 7-7 legislation and the CUWCC MOU both point to a savings in the CII sector of 10% from the baseline. In order to maintain consistency with the legislation and the MOU, DWR will also use the value of 10% to project CII water savings.

In order not to double count the potential savings from large landscapes with dedicated meters, which are included in the Landscape Irrigation section, these savings will not be included in this section.

Potential Savings in CII Sector (AF)
1.76 MAF x 10% = 176,000 AF

Potential Savings in CII Sector (GPCD)
176,000 AF = 4.8GPCD

California Prisons Reduced Water Usage by 21 Percent

California Department of Corrections and Rehabilitation (CDCR) achieved a 21 percent annual reduction in water usage, a total of 2.4 billion gallons of water.

CDCR enacted the following measures:

- Flush meters were installed nearly one-third of all adult institutions. The flush meters aided in a 27 percent average annual water savings, compared to 17 percent without flush meters.
- Report monthly water consumption to CDCR headquarters
- Practice low-or-no-cost water conservation methods

California Department of Corrections and Rehabilitation, April 3, 2009

Water Loss Control

Detecting and repairing leaks is a main component of water loss control. Leaks are caused by inadequate corrosion protection, old or poorly constructed pipelines, poorly maintained valves, and mechanical damages. To have effective leakage management, water utilities need to search for hidden leaks, and optimize the operation of their distribution infrastructure. Repairs of leaking water pipes in a supply system can greatly reduce water losses.

Inefficiencies in Distribution Systems

Authors of the Southern California Edison report (2006) estimated a statewide real loss volume of 10% of total water volume supplied. This estimate is based on two methods. The first method was based on literature reviews that estimated a ten percent of the volume supplied in California as a commonly quoted threshold for acceptable real losses in the state. The total volume of real losses in the state was calculated at 0.87MAF (17.5 GPCD).

The second method analyzed water audit data sets from 17 water agencies throughout California according to their real loss performance indicators (PI). PIs are evaluated on their Infrastructure Leakage Index (ILI), volume of real losses per connection per day, and volume of real losses as a percentage of total water supplied. ILI is the most reliable PI. Due to insufficient data, extrapolating average ILI performance indicators were not possible, and real losses per service connection per day were used instead. The estimated statewide real loss was calculated at 0.95 MAF (19 GPCD) from the service connection method, compared to 0.87 MAF (17.5 GPCD) from the ten percent threshold method.

Although the two methods are different, the results were very similar. This provides confidence in extrapolating averages from the data set to estimate the statewide loss volumes.

The first method of calculating a ten percent water loss was used as a more conservative estimate.

Actions

Water auditing is the first step in being aware of how much water is being used, and to seek ways to minimize water use by implementing conservation measures. Low levels of water loss reporting are typical among water utilities. Water utilities that do not perform water audits are most likely to be unaware of the level of real losses in their networks, making it unlikely for them to implement best management practices to curb their real loss volumes.

Major innovations in water loss control methods and technologies have developed since the early 1990s.

American Water Works Association (AWWA) updated their M36 publication, *Water Audits and Loss Control Programs* (2009) to reflect the advancements in water auditing methodologies. From 1997-2000, AWWA was involved in the Water Loss Task Force along with the International Water Association (IWA). The Water Loss Task Force studied various water audit methods from the United States and around the world. Best management practice methodologies were developed from the studies. Including in the methodologies are a set of rational terms and definitions, and an array of performance indicators.

The new manual incorporates the IWA/AWWA water audit methodologies and performance indicators, which provides comprehensive guidance on water auditing, and overviews the best loss control techniques. The manual goes over clear step-by-step instructions on how to gather data to conduct a water audit, to identify and control water losses, to understand the occurrence and impacts of leakage, and how to plan and sustain a water loss control program. A strong water loss control program can benefit the user by optimizing revenue recovery, optimizing operation efficiencies, and improve system integrity.

AWWA updated their water auditing software to calculate performance indicators and key statistics for the users. The performance indicators allow water agencies to make performance comparisons with other agencies, and to trend their own performance over time. The software tool calculates the costs of real and apparent losses, giving agencies a sense of their system cost effectiveness. This will help water agencies obtain an indication of the financial impact of their inefficiencies, making a means to promote water conservation to drive down losses. The software not only tracks water consumption and losses but also encourages water utilities with a means to effectively control their financial losses.

AWWA's auditing method is now a required procedure in the BMPs for the CUWCC. It is BMP 1.2 Water Loss Control. Water agencies are expected to complete their standard water audit and balances through the software. AWWA offers free water auditing software tool on their website (http://www.awwa.org).

An emerging technology for detecting leaks of end users is Advance Metering Infrastructure (AMI). AMI monitors water usage in real time, sampling hourly to every 15 minute. Because of the frequent monitoring and collection of water use data, a constant flow (leak) can be detected quickly and efficiently.

Repairing leaky pipes can be expensive and practically difficult for agencies to fix. Trenchless pipe repair is an emerging technology that requires no trenching or digging and can be done in much less time without large excavations, saving money, time, and labor. The damaged pipe is lined with a new cured-in-place-pipe that seals all cracks, splits, and faulty joints. Trenchless pipe repair is a cost effective and efficient alternative in pipe repair.

Projected Savings

From an analysis of a water audit performed on the San Francisco Public Utilities Commission, the authors of the report observed that an estimate of forty percent of the water loss is economically recoverable. That amounts to 0.35 MAF or 7 GPCD worth of water savings.

The estimated water demand reduction from water loss control is .35 Million Acre Feet or 7 GPCD. This is 10% of total urban water use (estimated water loss) multiplied by 40% (cost effective loss recovery).

From the 20x2020 plan, the report estimated a statewide potential water loss savings of 0.3 MAF or 6 GPCD with a target of 40 gallons/connection/day. CUWCC's BMP3 aims to reduce non-revenue water to ten percent of production. Other countries have shown that it is possible that these goals can be exceeded. Most of United Kingdom and Europe operate at or below 40 gallons/connection/day. The report suggested that if such goals were pursued in California, statewide water savings of 0.3 MAF (6 GPCD) can be achieved.

Recycled Water Use

(placeholder – data being analyzed)

Combined Demand Reductions

Combining the estimated demand reductions from each sector, as detailed in the preceding paragraphs, the state of California could theoretically reduce demand for potable water in the year 2020 by 2 Million Acre Feet.

Demand Reduction Sectors	GPCD Reduction	Projected Savings in 2020 (AF)
Large Landscape	3	148,000
CII	4	197,000
Residential Interior	15	739,000
Residential Exterior	16	789,000
Water Loss Control	7	345,000
Recycled Water		

Challenges to Urban Water Use Efficiency

Cost Recovery for Water Suppliers

Water rates can and must be set to enable the supplier to recover its purchase, treatment, and delivery costs as well as the additional costs, such as water conservation programs, programs related to water shortage responses, and replenishing the drought emergency fund.

Changing rate structures requires public support and can be difficult to gain, especially during the economic downturn. But low rates of cost recovery threaten the long term financial stability of a water agency and its ability to maintain infrastructure and programs, such as water conservation.

Poor Operation and Maintenance of Landscape Irrigation Systems

Landscape maintenance generally focuses on plant care and irrigation system maintenance is overlooked, yet this is where the greatest savings can be achieved. Irrigation controllers are set to irrigate during the hottest part of the year and then left at that setting throughout the entire year. Sprinklers are set to turn on during the night and, consequently, property owners rarely, if ever, see their systems operate. Whatever inefficiencies (overspray, runoff, and low-head drainage) might be seen during daylight hours are not seen at night. When a sprinkler head is broken, it is generally repaired with another head that doesn't match others in the system, resulting in systems with several types of heads and poor distribution uniformity. Maintenance contracts frequently do not include provisions for irrigation system maintenance.

Demand Rebound

Many water agencies are reporting in their 2010 UWMPs that they have already met their 2020 water use targets. This is generally accounted for because of water use restrictions in place during the drought of 2009-2011 and the economic downturn during that same period. Both of these would result in lower per capita consumption rates.

When drought restrictions are lifted and when the economy strengthens water consumption can return to previous levels. During drought, a statewide public education plan was conducted encouraging people to conserve water. At the same time, newspapers, radio, and television carried stories on the drought, usually accompanied by an exhortation to conserve water. During a drought, water savings come from a combination of changes to behavior and technology. As an example of behavioral change, customers may take shorter showers, or scale back on lawn watering or car washing. Some customers install water-saving fixtures that they purchase or receive via a giveaway or rebate from the utility. A "rebound effect" is often observed following a drought when customers return to their former patterns of water use. However, a certain amount of savings are more lasting, partly due to the spread of water-efficient technologies, but also due to lasting behavioral changes.

Non-Standardized Reporting of Water Uses

Non-standardized reporting of water loss?
There is a lack of standardization of the current general classification system used by the water industry and water resources managers. Water users are typically classified by urban water utilities by their billing rate structure. This commonly includes residential, multifamily, CII, large landscape, and agricultural. Water utilities do not share common definitions or coding standards when assigning a customer to one of the sectors. For example, establishments such as laundries may be classified as industrial rather than commercial. Multifamily establishments may be classified as residential or commercial. Depending on ownership or legal identity, large landscape customers may be classified as commercial or institutional (e.g., commercial such as a privately owned golf course or institutional such as a city park). These are but a few of the examples which are occurring throughout the state due to poor standardization within water use categories.

Recommendations

Reduce Landscape Irrigation Demand

Approximately 43% of all urban water use is dedicated to landscape irrigation. A vigorous comprehensive program to improve landscape water use efficiency will be essential to ensure that the 2020 goals are met.

- Educational outreach to end users on irrigation system maintenance and water efficient landscape design. These efforts should build upon the momentum of the "Save Our Water" campaign.
- Training programs for landscape professionals on irrigation system installation and maintenance.
- Rebates for upgrades of irrigation equipment and reduction of cool season turf areas.
- Working with landscape architecture curriculum programs to ensure that future landscape architects have the knowledge to design landscapes and irrigation systems that are efficient, as well as more suited to California's climate and conditions

Increase the Use of Recycled Water

Recycled water means water which, as a result of treatment of waste, is suitable for a beneficial use that would not otherwise occur. In the urban sector, recycled water can be used in place of potable water in landscape irrigation, some industrial uses, and groundwater recharge. Government and water agencies should pursue appropriate opportunities for replacing potable water with recycled water. This can be especially effective for use in the CII sector.

Implement Conservation Based Pricing of Wastewater Service
Although roughly 90 percent of California households served by a public water supplier pay for drinking water through a volumetric rate applied to metered water deliveries, about 70 percent of such California households pay for sewer service through a flat non-volumetric charge (*Volumetric Pricing for Sanitary Sewer Service in the State of California*, Chesnutt, 2011). Billing for wastewater with volumetric rates provides an important incentive to customers to conserve water. While fixed charges have the advantage of being simple, they do not distinguish between customers within the same class that produce larger amounts of wastewater and those that produce smaller amounts. Fixed charges also do not provide signals to customers about the potential monetary savings from water use efficiency or on-site treatment and reuse.

Develop Targeted Programs That Aim to Control Leakage
Water loss accounts for approximately 10% of urban water use. Water loss can be controlled and leaks can be repaired both for residential and CII end uses as well as supplier distribution systems. Simple techniques for indoor residential includes checking running toilets, dripping faucets, and other household leaks. Most leaks within a home can be easily fixed without investing in new equipment, and be performed with the knowledge and the guidance of the local water agency. Having an active water auditing program increases awareness of water loss in the distribution system, which can assist in targeting repairs and implementing best management practices.

Investigate the Use of Standardized Water Use Reporting Categories
As stated in the 20 x 2020 Plan, a uniform, streamlined data collection process has multiple advantages: the reporting burden on local agencies would be reduced, data reviews related to state action such as grant disbursement would be expedited, state agencies would have more timely access to water use data, the quality and accuracy of the data would improve, better and more complete data would facilitate better water management; and data management costs would be reduced over time.
At a minimum, use of the following water use sectors throughout DWR and by water suppliers should be investigated:

- Single family residential
- Multi-family residential
- Commercial
- Institutional
- Industrial
- Dedicated irrigation
- System water losses
- Recycled water

References

Aquacraft Water Engineering and Management. “California Single Family Water Use Efficiency Study”. April 2011.

Pacific Institute. “Waste Not, Want Not: The Potential for Urban Water Conservation in California”. November 2003.

AWWA Research Foundation and American Water Works Association. “Residential End Uses of Water (REWUS)”. 1999.

California Urban Water Conservation Council. *BMP 9 Handbook: A Guide to Implementing Commercial Industrial & Institutional Conservation Programs*. “Annual Report 2001”. 2001.

Alliance for Water Efficiency. “Transforming water: Water efficiency as stimulus and long-term investment”. 2008.

Department of Water Resources. “California Water Plan Highlights: Integrated Water Management”. 2009.

California Urban Water Conservation Council. “Memorandum of understanding regarding urban water conservation in California”. September 2011.

California Senate Bill x7-7. “The Water Conservation Act of 2009: U3 Urban Technical Methodologies”. 2009

Assembly Bill 1881. “Model Water Efficient Landscape Ordinance”. September 2009.

California State Water Resourced Control Board. “20x2020 Water Conservation Plan”. February 2010.

California Urban Water Conservation Council. “Splash or Sprinkle? Comparing the water use of swimming pools and irrigated landscapes”.

The Metropolitan Water District of Southern California and The East Bay Municipal Utility District. “Evaluation of California Weather-Based “Smart” Irrigation Controller Programs”. July 2009

California Urban Water Conservation Council. “Water Smart Landscapes for California. AB 2717 Landscape Task Force Findings, Recommendations, & Actions”. December 2005.

Municipal Water District of Orange County and Irvine Ranch Water District. “Residential Runoff Reduction Study”. July 2004.

Seattle Public Utilities and The United States Environmental Protection Agency. “Seattle Home Water Conservation Study: The impacts of high efficiency plumbing fixture retrofits in single-family homes”. December 2000.

California Urban Water Conservation Council. Commercial Industrial, Institutional Task Force. 2012.

Southern California Edison report. "Secondary research for water leak detection program and water system loss control study". December 2009.

American Water Works Association. *Water Audits and Loss Control Programs M36* Third Edition. 2009.

National Drinking Water Clearinghouse. "Tech Brief: Leak Detection and Water Loss Control". May 2001.

California Landscape Contractors Association. "Urban CII landscape water use efficiency in California". October 2003.

Chesnutt,T., Volumetric Pricing for Sanitary Sewer Service in the State of California, 2011.

Department of Water Resources, Commercial, Institutional, and Industrial Task Force Best Management Practices Report to the Legislature (DRAFT), March 2012

Hanak, E. and Davis, M: Lawns and Water Demand in California, 2006: Public Policy Institute of California

Hunt, T; Lessick, D.; Berg, J.; Wiedman, J.; Ash, T., Pagano, D., Marian, M.; Bamezai, A.: Residential Weather-Based Irrigation Scheduling: Evidence from the Irvine "ET Controller" Study, 2001.