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Urban Water Conservation and Efficiency Potential in California

Improving urban water-use efficiency is a key solution to California's short-term and long-term water challenges: from drought to unsustainable groundwater use to growing tensions over limited supplies. Reducing unnecessary water withdrawals leaves more water in reservoirs and aquifers for future use and has tangible benefits to fish and other wildlife in our rivers and estuaries. In addition, improving water-use efficiency and reducing waste can save energy, lower water and wastewater treatment costs, and eliminate the need for costly new infrastructure.

Californians across the state are replacing their lawns with beautiful, low water-use, environmentally-friendly gardens.
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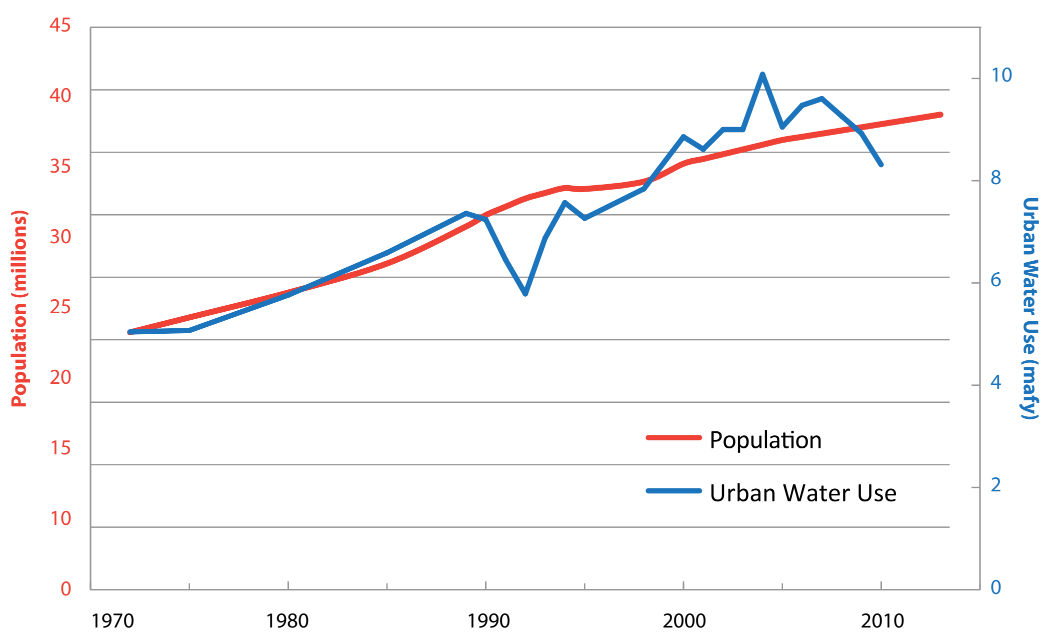
Between 2001 and 2010, California's urban water use averaged 9.1 million acre-feet per year, accounting for about one-fifth of the state's developed water use (DWR 2014). Based on our analysis, we found that businesses and industry can improve their water-use efficiency by 30 to 60 percent by adopting proven water-efficient technologies and practices. Residents can improve their home water efficiency by 40 to 60 percent by repairing leaks, installing the most efficient appliances and fixtures, and by replacing lawns and other water-intensive landscaping with plants requiring less water. In addition, water utilities can expand their efforts to identify and cut leaks and losses in underground pipes and other components of their distribution systems. Together, these measures could reduce urban water use by 2.9 million to 5.2 million acre-feet per year. All of this could be accomplished through more widespread adoption of technology and practices that are readily available and in use in California and around the world.

URBAN WATER USE IN CALIFORNIA

According to the most recent estimates from the California Department of Water Resources (DWR), water use in cities and suburbs accounts for one-fifth of water withdrawals in most years. Between 2001 and 2010, urban water use ranged from 8.3 million to 9.6 million acre-feet per year, and averaged 9.1 million acre-feet per year (DWR 2014). Of the water delivered to urban areas each year, most is used in and around our homes, with residential water use accounting for 64 percent of total urban use. Together, institutions (such as schools, prisons, and hospitals) and commercial businesses (such as hotels, restaurants, and office buildings) account for about 23 percent of California's urban water use. Another 6 percent is used by industry to manufacture a wide range of products, from chemicals and electronics to food and beverages. About 2 percent of water withdrawals for urban use are lost in conveyance, through seepage or evaporation from canals, another 2 percent is used for energy production, and another 3 percent is used to replenish groundwater aquifers (DWR 2014). The majority of the state's urban water use is in the South Coast hydrologic region, home to over half of the state's population (Figure 2). The second highest user is the 9-county San Francisco Bay region, home to over 6 million people.

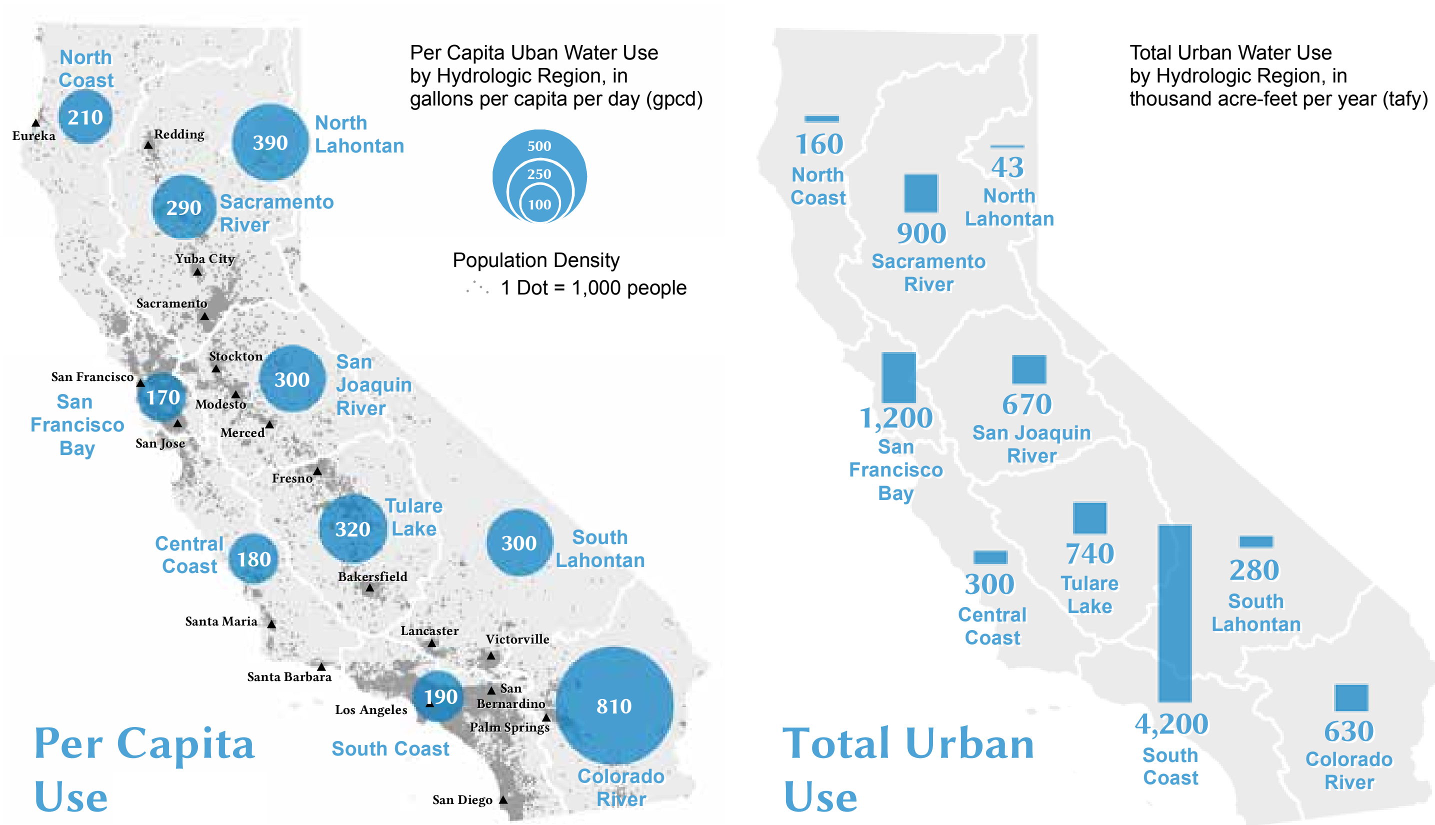
About half of California's urban water use, equivalent to 4.2 million acre-feet per year, is outdoors, largely for watering landscapes, but also for such uses as washing cars or sidewalks, and filling pools or spas. About 70 percent of outdoor use is residential, representing both single- and multi-family homes. Commercial businesses and institutions account for the remaining 30 percent of outdoor water use. The highest rates of outdoor use are in the hot, dry areas of the state and in communities where water is inexpensive. In these areas, outdoor water use can account for up to 80 percent of the total (Hanak and Davis 2006).

Figure 1. California's population and urban water use from 1970 to 2010



Source: Urban water use estimates from DWR spreadsheet Statewide Water Balance (1998-2010) (DWR 2014). Population estimates from California Department of Finance spreadsheet E-7. California Population Estimates (DOF 2013).

Figure 2. Urban per capita water use (in gallons per capita per day) and total water use (in thousand acre-feet per year) by hydrologic region, averaged for the years 2001–2010



Source: DWR Water Use Balances for Planning Areas, 1998–2010 (DWR 2014) and US Census Bureau (2010 population by Census Tract).

According to DWR estimates, on a statewide basis, urban water use has grown roughly in proportion to population since 1970 (Figure 1). Per-capita urban use averaged 220 gallons per capita per day (gpcd) in the 1980s, declined to 200 gpcd in the 1990s, and rose to 230 gpcd in the first decade of the 2000s. While a number of urban areas have mounted aggressive water conservation campaigns and lowered per-capita use, this has been offset by rapid population growth occurring in hot, dry inland areas with higher outdoor water use. California's urban water use showed a steady decline in the last three years for which data is available, in the years 2008, 2009, and 2010. This decline can be explained by a combination of the economic slowdown and drought restrictions in place at the time, and it remains to be seen whether, on a statewide basis, urban use has continued to decline since 2010 or whether water use has "rebounded" as the economy improved and drought restrictions were lifted beginning around 2011.

The intensity of water use varies by region. Between 2001 and 2010, per capita water use for all urban uses averaged 230 gpcd, but varied widely around the state, ranging from 170 gpcd in the San Francisco Bay area to over 300 gpcd or more in some hot, dry inland areas of Southern California (Figure 2).[1] The rate of per-capita use is lower in the coastal regions than in the mountain counties of the Lahontan region, or in the inland valley regions. However, the coastal regions have much larger populations, and thus higher total water use.

QUANTIFYING THE URBAN EFFICIENCY POTENTIAL

What is the technical potential for improving the efficiency of water use in urban California? In 2003, the Pacific Institute conducted the first comprehensive assessment of the statewide urban water efficiency potential (Gleick et al. 2003), and found that technologies available at the time could reduce urban water use by one-third at lower cost than developing new supplies and with fewer social and environmental impacts. Today, some of the potential identified in 2003 has been captured, although newer, more efficient technologies and practices have also been introduced into the marketplace. For example, today's Energy Star clothes washers use only 15 gallons of water per load, a significant savings over standard machines and even those manufactured 10 years ago (Energy Star 2013).

To inform ongoing discussions in California about the drought and longstanding challenges facing the water sector, we have updated the 2003 estimates of the urban water conservation and efficiency potential using new data from state agencies to model the effect of increased deployment of water-efficient technologies. We based our estimates on water use and demographic data averaged over the period 2001 – 2010, the most recent time period for which reliable information is available. Our focus here is on technological solutions for using water more efficiently, rather than on behavioral changes, such as shorter showers. However, decades of experience show that educational campaigns and economic incentives can also influence people's behavior and reduce waste. We did not examine the potential water savings in the areas of conveyance, energy production, and groundwater recharge, which account for an average 8 percent of withdrawals for urban water use in California.

Indoor

For this analysis, we examined the potential to reduce indoor and outdoor water use in urban areas in California. For indoor use, we estimated how much water could be saved by retrofitting homes with the latest models of water-efficient appliances and fixtures. We estimated the efficiency potential using two different methods. For the first method, we focused on individual end uses of water and estimated how much water would be saved if every household in California were upgraded to more efficient fixtures. To do this, we used estimates of the current "market penetration" of various types of appliances and fixtures in California homes, for example, the average flow volume of toilets in homes today. We also used information on average use, such as the number of times an average person flushes the toilet. This type of information is highly variable, but averages can help us to model water use and potential savings. We drew upon information from several recent surveys and studies, including the *California Single-Family Water Use Efficiency Study* (DeOreo et al. 2011), which reports detailed information on water use in more than 700 homes. Additional information on household water use came from a journal article that summarized statistical studies of the showering and bathing behaviors of Americans (Wilkes, Mason, and Hern 2005).

Staying with our toilet example, data indicate that an average Californian flushes 4.8 times per day, and that the average flush volume is 2.8 gallons per flush. Upgrading an old, inefficient toilet to a 1.28-gallon-per-flush model would save 7.3 gallons per person per day. Multiplying this by the average population over the study period (36 million people) gives us a potential savings of 260 million gallons per day, or 0.29 million acre-feet per year.[2] We performed similar calculations for all the major end uses of water where a conserving technology is available—clothes washers, showers, bath and kitchen faucets, and dishwashers. In each case, we estimated the savings by upgrading to the latest widely-available water-efficient model with an Energy Star or EPA Water Sense label. We also calculated the effect of eliminating water loss from leaky pipes and fixtures; while most residents are unaware of leaks, studies show that they are present in the majority of homes (Mayer et al. 1999; DeOreo et al. 2011). We found a total potential statewide indoor water savings of 33 gpcd, or 1.3 million acre-feet per year.

We used a second method to estimate residential indoor water savings potential, an approach based on a "water budget" for a typical home using water-efficient appliances and fixtures. Table 1 shows our theoretical per capita water budget for an "average" California household that uses widely-available water-efficient appliances and fixtures, such as Water Sense-labeled toilets and showerheads, and an Energy Star clothes washer. We estimate than an average California resident living in a highly-efficient home would use about 32 gallons per day indoors. We calculated the potential savings by comparing this with official estimates of water use in each hydrologic region (DWR 2014). For example, residential indoor use in the Central Coast Hydrologic Region averaged 55 gpcd. This means that the average Central Coast

Table 1. Water budget for one person using efficient appliances and fixtures

End Use	Assumptions	Gallons per person per day
Leaks	Reduced to zero	0
Toilets	4.8 flushes per day @ 1.28 gallons per flush	6.1
Clothes washer	2.3 loads per week @ 14.4 gallons per load	4.7
Shower	4.7 showers per week for 8.7 minutes each with conserving showerhead rated at 2.0 gpm and throttle factor of 72% for actual flow rate of 1.44 gpm	8.4
Bath	2.24 baths per week @ 18 gallons each	5.8
Faucets	10.1 minutes per day at an average flow rate of 0.64 gpm	6.5
Dishwasher	0.85 times per week @ 3.5 gallons per load	0.4
Total	**Efficient Household Water Budget**	**32**

Note: Average duration and frequency of usage were derived from the *California Single Family Water Use Efficiency Study* (DeOreo et al. 2011) and a 2005 article in the journal *Risk Analysis* whose authors summarized statistical studies of the showering and bathing behavior of Americans (Wilkes, Mason, and Hern 2005).

household, by lowering indoor water use to 32 gpcd, would save 20 gallons per person per day. Using the water-budget based method, we found average statewide indoor water savings potential of 40 gpcd, or 1.6 million acre-feet per year.

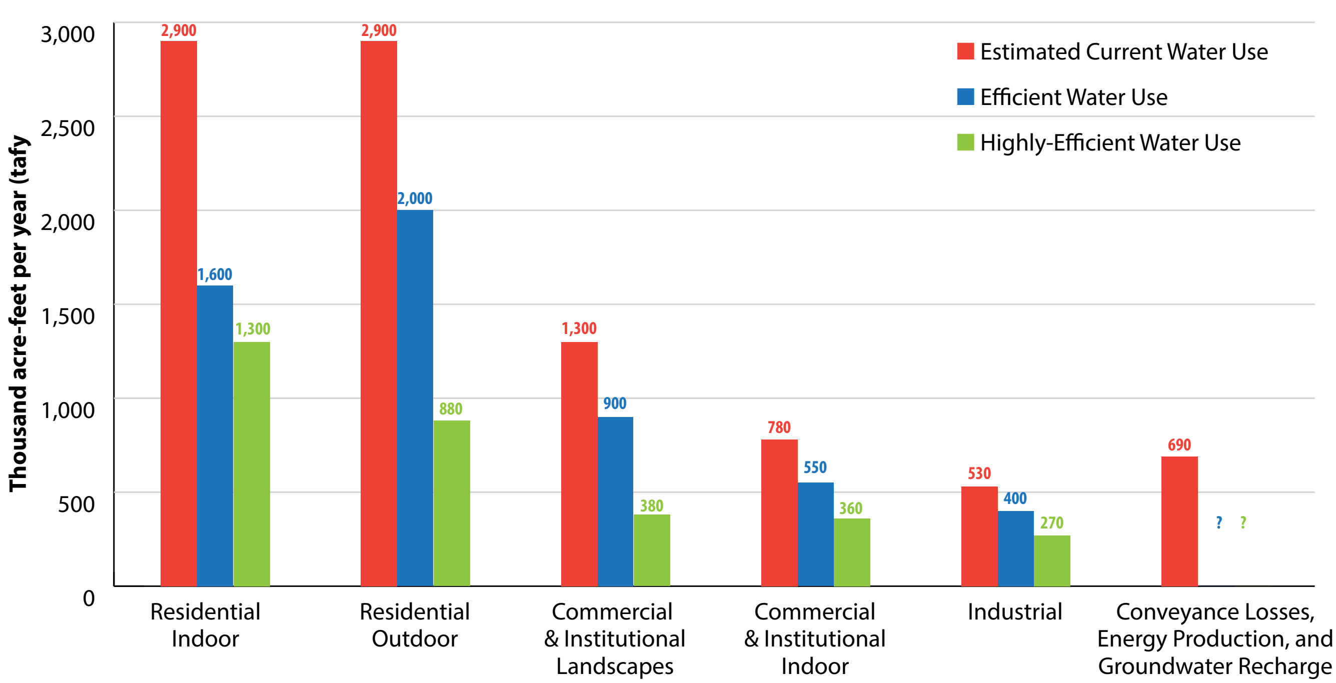
Each of these methods has advantages and disadvantages. The first method does not consider regional variation in water use, and so does not take into account the significant progress that has already been made in improving water efficiency in some regions. The second, water-budget-based approach looks only at typical water uses and does not take into account some of the other ways that people use water at home, such as water softeners or water treatment systems that increase water use, medical devices, or a hobby or home business. However, each of these methods gives us a theoretical efficiency potential. While we do not expect 100 percent saturation of these solutions in the real world, these calculations highlight the total savings possible through the adoption of more efficient appliances and fixtures.

Significant indoor water savings are also available in the commercial, industrial, and institutional sectors. Limited data are available on water use and the potential efficiency savings for these sectors. The most recent quantitative assessment of commercial and industrial water conservation and efficiency potential in California was done by the Pacific Institute in 2003 (Gleick et al. 2003), and the authors' estimates have been adopted by state water planners. Using the estimates from this report, along with updated data on water use, we estimated that commercial indoor water efficiency could be improved by 30 to 50 percent, and industrial efficiency could be improved by 25 to 50 percent.

Outdoor

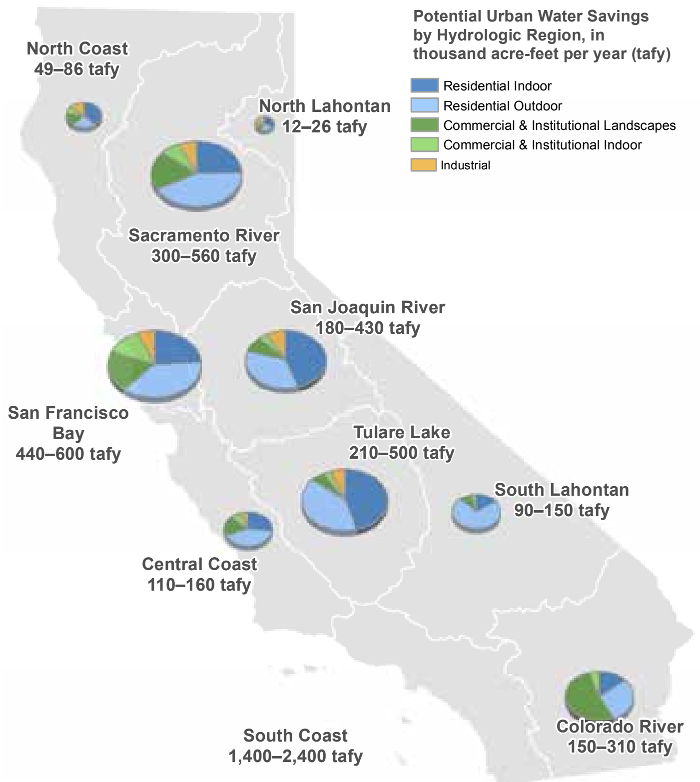
To estimate the potential to reduce outdoor water use, we used the landscape water budget method, where plant species are classified by their water needs and assigned a "water-use factor." The water-use factor is the ratio of the plant's water needs to that of a well-watered grass crop, or "reference evapotranspiration" and varies with location, weather, and other factors (Costello et al. 2000). High water-demand plants, such as cool-season grass or vegetable gardens, have water-use factors of 1 or more, while low water-use plants may have factors as low as 0.1 and require little or no supplemental irrigation. Recent studies have found that residential landscapes in California have an average water use factor of around 1.0, as many homeowners have lawns, and medium water-use trees, shrubs, and perennials (DeOreo et al. 2011, 161). For this analysis, we calculated the potential

Figure 3. California's urban water conservation potential by sector



Note: We did not evaluate water savings in the areas of conveyance, energy production, and groundwater recharge, which account for 8 percent of withdrawals for urban water use in California.

Figure 4. Potential urban water savings by hydrologic region, in thousands of acre-feet per year (tafy)



water savings of converting to water-efficient landscapes with an average water-use factor of 0.7, the maximum level allowed under the state's Model Water Efficient Landscape Ordinance and is required for new large and commercial landscapes in California (A.B. 1881, the Water Conservation in Landscaping Act of 2006). We also modeled the impact of a more extensive landscape conversion alternative, where landscapes are re-planted with low water-use plants with an average water-use factor of 0.3. This level of water use encompasses a broad range of California-native and Mediterranean plants (for example, the garden on page 1). Besides having colorful blooms that attract birds and pollinators, these plants have other benefits, such as ease of maintenance and less need for fertilizers and pesticides. We estimated that moderate landscape conversions could reduce outdoor water use by 30 percent, while more extensive conversions could reduce outdoor use by 70 percent.

System Losses

For every water utility, a certain amount of high-quality water is lost from the system of underground pipes that distributes water to homes and businesses. This is a national problem, with an average of 17 percent of water pumped by utilities in the United States lost to leaks (Baird 2011). A 2009 study found that California water utilities lose an estimated total of 0.87 million acre-feet per year (Water Systems Optimization Inc. 2009), equivalent to about 21 gallons per capita per day. The authors estimated that 40 percent of that lost water, or 0.35 million acre-feet per year, could be recovered economically. Some California utilities are making progress in identifying and reducing water losses. For example, the Los Angeles Department of Water and Power, which provides water to four million people, has implemented a program to conduct water system audits; replace old, inaccurate meters; install fire hydrant shutoffs; and detect and repair distribution system leaks (LADWP 2011). Continued efforts to reduce losses should be a priority for utilities, as investments in finding and repairing these leaks can pay for themselves in terms of reduced costs in just a few years (Dickinson 2005). While there is strong evidence for the water savings associated with utility-scale leak reduction, we have not incorporated these estimates into the totals presented in this paper.

URBAN EFFICIENCY POTENTIAL

Many water utilities have made considerable progress in improving water-use efficiency over the past few decades, holding their total water use at or near constant levels even while population has increased. For example, water use in the city of Long Beach has held steady since 1970, despite the fact that population has grown by 40 percent. In San Francisco, water use has decreased since the 1970s despite population gains. Both cases can be explained by decreasing per-capita water use—San Francisco's water use averaged nearly 140 gpcd in the 1980s, and decreased to 86 gpcd by 2010 (SFPUC 2011, 33). More can be done—as has been shown in many other industrialized countries, where per capita water use is significantly lower than in California.

We estimate that existing technologies and policies can reduce current urban water use in California by 2.9 million to 5.2 million-acre-feet per year. Between 70 and 75 percent of the potential savings, or 2.2 million to 3.6 million acre-feet per year, are in the residential sector, which includes all types of residences, from detached single-family homes to high-rise apartment buildings (Figure 3). The remainder of the savings potential (0.74 million to 1.6 million acre-feet) comes from efforts to improve efficiency among commercial, institutional, and industrial users. The greatest savings potential is in the South Coast region, due to its large population, but significant water savings are available in all 10 of California's hydrologic regions (Figure 4). In the following sections, we provide additional detail on the savings potential for each sector.

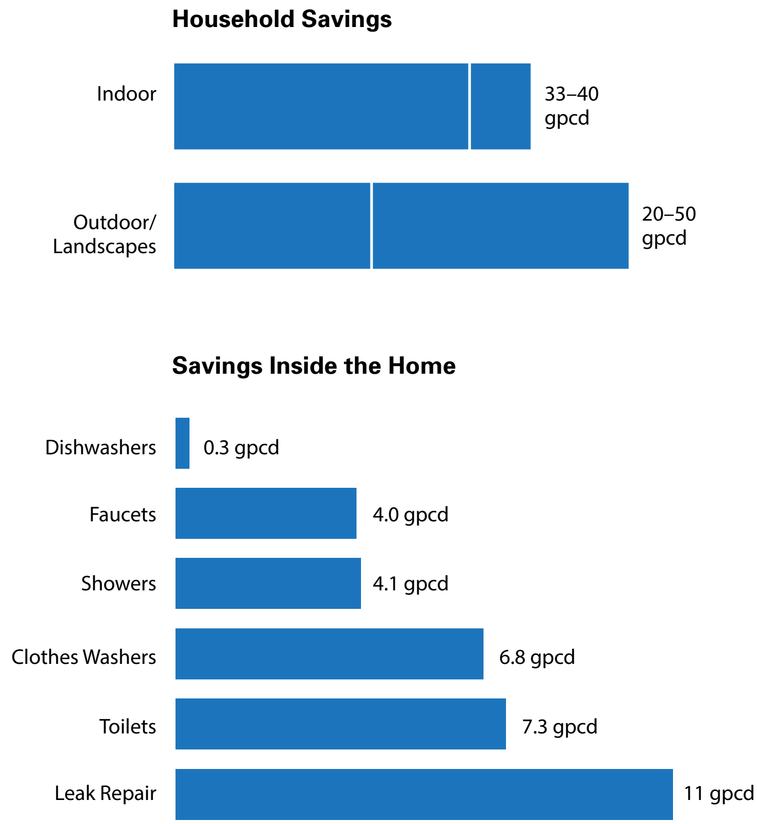
Residential Water Savings

There are many ways to reduce water waste and improve efficiency at home. Over the past several decades, many Californians have lowered their water use by installing efficient showerheads, toilets, and washing machines, or by replacing their lawn with low water-use plants. However, there is still considerable room for improvement. For example, recent in-home measurements indicate that nearly half of California's households still use old, inefficient toilets that waste water with every flush (DeOreo et al. 2011, 137–138). Additionally, many homeowners and commercial developments still have large expanses of lawn, and the result is that outdoor water use accounts for nearly half of urban water use in California.

The residential sector is the largest urban water-use sector, using an average of 5.8 million acre-feet per year, and it offers the largest volume of potential savings. We estimated that widespread adoption of water-efficient appliances and fixtures in California homes, combined with replacement of lawns with low-water landscapes, could reduce total residential water use by 40 to 60 percent, saving 2.2 million to 3.6 million-acre-feet per year. We found that the average Californian could cut home water use by 50 to 90 gpcd (Figure 5). Repairing leaks could reduce home water use by 11 gpcd, while installing efficient toilets and clothes washers could each reduce home water use by about 7 gpcd. Additional savings are available by installing more efficient showerheads, faucets, and dishwashers. But the biggest savings come from reducing outdoor water use. Moderate landscape conversions could lower outdoor water use by 30 percent, and more comprehensive conversions could save 70 percent. Much of the outdoor savings potential is in Central and Southern California, which has a hot, dry climate, and is home to two-thirds of the state's population (Figure 4).

Based on the our calculations above, a Californian living in an efficient home would use 50 to 90 gpcd, down from the current average of 140 gpcd. Is such a dramatic reduction possible in the Golden State? International experience demonstrates that these savings are feasible. Australian households use an average of 54 gpcd (for both indoor and outdoor uses), and residents of the Australian state of Victoria use only 40 gpcd (Australian Bureau of Statistics 2013). Australians have not always been water misers—a few decades ago their water use looked much like California's—but they have lowered their consumption dramatically over the past decade in response to their unprecedented Millennium Drought by adopting new water-efficient technologies and water-saving habits (Heberger 2011). For example, dual-flush toilets are now found in nine out of ten Australian homes.

Figure 5. Residential water conservation potential in California, in gallons per capita per day (gpcd)



Note: The white line for household savings represents the low end of the range.

COMMERCIAL, INDUSTRIAL, AND INSTITUTIONAL WATER SAVINGS

About a quarter of all California's urban water use is in the commercial and institutional sectors, and about 6 percent is used for industry. There are many ways that these sectors can save water, reflecting the diversity of ways in which water is used. Some of these measures mirror residential water conservation efforts, such as installing efficient toilets and urinals, while others are customized to meet a particular industry's needs. For example, restaurants have lowered water and energy bills by installing water-efficient pre-rinse spray valves, ice machines, dishwashers, and food steamers (CII Task Force 2013, Vol III, p. 74–133). One of the biggest areas for potential savings is in the cooling water used in many industrial processes and in large air conditioning systems. Methods are available to cycle water longer in cooling towers by carefully adjusting its chemistry and limiting the amount of "make-up" water needed (Koeller et al. 2007). Using efficiency estimates from previous assessments, along with updated data on water use, we estimated that

Outdoor Conservation Potential

Half of all water used in California's urban areas is for outdoor use. Some of this is used for washing cars or sidewalks, or for filling pools and spas, but the vast majority is for landscape irrigation. Big savings are possible in outdoor water conservation in homes, businesses, and institutions (Table 2). We estimate that moderate landscape conversions could save 1.3 million acre-feet per year, equivalent to a statewide per capita water use of 30 gpcd. More extensive landscape conversion, i.e., converting to all low water-use plants, could save a total of 2.9 million acre-feet per year, reducing per capita water use by 72 gpcd. The largest outdoor savings potential is at residences (0.9 million to 2 million acre-feet per year). An additional 0.4 million to 0.9 million acre-feet per year can be saved by commercial and institutional landscapes. The greatest potential savings are in the South Coast hydrologic region, followed by the San Francisco and Sacramento River hydrologic regions.

Table 2. Urban outdoor water conservation potential by hydrologic region, in thousand acre-feet per year (tafy)

Hydrologic Region	Moderate Conversions	Extensive Conversions
North Coast	15	34
San Francisco	140	330
Central Coast	42	97
South Coast	560	1,300
Sacramento River	150	340
San Joaquin River	81	190
Tulare Lake	100	240
North Lahontan	4	9
South Lahontan	57	130
Colorado River	110	260
California Statewide	**1,300**	**2,900**

commercial water use can be reduced by 30 percent to 50 percent, and industrial use reduced by 25 percent to 50 percent (Gleick et al. 2003), saving an estimated 0.74 to 1.6 million acre-feet per year. Increasing water efficiency means that businesses can continue to provide the same products and services while using less water.

An expert panel recently convened by the state recommended several practices to reduce water use in the commercial, industrial, and institutional sectors (CII Task Force 2013, Vol. II). First, companies should fix leaks and make adjustments or repairs to control water loss. Second, old or inefficient equipment should be retrofitted or, third, replaced. Fourth, industrial water users should investigate the feasibility of treating and reusing water onsite or using recycled municipal wastewater or other non-potable supplies. Fifth, some industries can replace existing equipment with waterless processes, for example, by replacing cooling towers with air-cooling or geothermal cooling systems, or by installing dry vacuum pumps in laboratories and medical facilities (CII Task Force 2013, Vol. II, 69). In many cases, businesses that invest in water efficiency can improve their own bottom line through lower water and energy bills and reduced costs for chemicals and water purification.

CONCLUSIONS

There remains a tremendous untapped potential to increase water-use efficiency at home, in businesses, and in government. In the commercial, institutional, and industrial sectors, prior analysis has demonstrated that efficiency could be increased 30 to 60 percent. This would save an estimated 0.74 million to 1.6 million acre-feet per year. At home, widespread adoption of water-saving appliances and fixtures, along with replacement of lawns with water-efficient landscapes, could reduce total residential water use by 40 to 60 percent, saving 2.2 million to 3.6 million acre-feet per year. Altogether, these efficiency improvements could save 2.9 million to 5.2 million acre-feet per year. Improving water-use efficiency makes our cities more resilient to drought, saves energy and reduces greenhouse gas emissions, lowers the cost of water treatment and new infrastructure, and frees up water to flow in our rivers and estuaries to benefit fish, wildlife, and recreational users.

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Footnotes

1 We have estimated state and regional water use and per capita consumption from data provided by DWR (Land and Water Use Balances 1998-2010). Because water use varies from year to year due to a variety of factors (e.g., climate, economic conditions, and drought restrictions), we averaged water use for the years 2001 to 2010. Because of this, our estimates vary slightly from those in the "20 x 2020" report published by the State Water Resources Control Board in 2010, which used 2005 as its base year. The lack of consistent, reliable, and up-to-date data on flows and water use is a persistent problem for analysts of California water policy.

2 The average population in California over the time period for our analysis 2001-2010 was 36 million, according to Census Bureau data, California's population in April 2013 was 38.3 million.

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