PACIFIC INSTITUTE

# Waste Not, Want Not:
## The Potential for Urban Water Conservation in California

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# About the Pacific Institute

Founded in 1987 and based in Oakland, California, the Pacific Institute for Studies in Development, Environment, and Security is an independent, nonprofit organization that provides research and policy analysis on issues at the intersection of sustainable development, environmental protection, and international security. We strive to improve policy through solid research and consistent dialogue with policymakers and action-oriented groups, both domestic and international. By bringing knowledge to power, we hope to protect our natural world, encourage sustainable development, and improve global security. This report comes out of the Water and Sustainability Program of the Institute. More information about the Institute, staff, directors, funders, and programs can be found at www.pacinst.org and www.worldwater.org.

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# Abbreviations and Acronyms

**AF:** acre-feet

**AF/yr:** acre-feet per year

**AWWARF:** American Water Works Association Research Foundation

**BMPs:** Best Management Practices

**CDOF:** California Department of Finance

**CDWR:** California Department of Water Resources

**CEE:** Consortium for Energy Efficiency

**CUWA:** California Urban Water Agencies

**CUWCC:** California Urban Water Conservation Council

**EBMUD:** East Bay Municipal Utility District

**$ET_o$:** reference evapotranspiration

**gpcd:** gallons per capita per day

**gpcy:** gallons per capita per year

**gpd:** gallons per day

**gpf:** gallons per flush

**gpl:** gallons per load

**gpm:** gallons per minute

**HE:** high efficiency

**kWhr:** kilowatt hours

**kWhr/yr:** kilowatt-hours per year

**LRMC:** long-run marginal cost

**MAF/yr:** million acre-feet per year

**MAF:** million acre-feet

**MCC:** marginal cost of avoidable capacity investment

**MWD:** Metropolitan Water District of Southern California

**REUWS:** Residential End-Use of Water Study (see Mayer et al. 1999)

**rpm:** revolutions per minute

**SRMC:** short-run marginal cost

**TAF:** thousand acre-feet

**THELMA:** The High Efficiency Laundry Metering and Marketing Analysis Project

**UfW:** unaccounted-for water

**ULFT:** ultra-low-flow toilet

**USDOE:** U.S. Department of Energy

**USHUD:** U.S. Department of Housing and Urban Development

**UWMPs:** urban water managements plans

**Best available technology (BAT):** The best proven commercial technology available for reducing water use. This is an objective assessment of potential, independent of cost or social acceptability.

**Best practical technology (BPT):** The best technology available for reducing water use that meets current legislative and societal norms. This definition involves subjective judgments of social acceptability but defines a more realistic estimate of maximum practical technical potential, independent of cost.

**Maximum available savings (MAS):** For a given agency, region, or state, MAS is an estimate of the maximum amount of water than can be saved under full implementation of best available technology (BAT), independent of costs.

**Maximum practical savings (MPS):** For a given agency, region, or state, MPS is an estimate of the maximum amount of water that can be saved under full implementation of best practical technology (BPT), independent of current costs.

**Maximum cost-effective savings (MCES):** For a given agency, region, or state, MCES is the maximum amount of water that can be cost-effectively saved under full implementation of best practical technology (BPT). "Cost-effectiveness" is defined as the point where the marginal cost of the efficiency improvements is less than or equal to the marginal cost of developing new supplies.

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* All appendices are available online at www.pacinst.org/reports/urban_usage/

# Executive Summary

The largest, least expensive, and most environmentally sound source of water to meet California's future needs is the water currently being wasted in every sector of our economy. This report, "Waste Not, Want Not," strongly indicates that California's urban water needs can be met into the foreseeable future by reducing water waste through cost-effective water-saving technologies, revised economic policies, appropriate state and local regulations, and public education.

The potential for conservation and efficiency improvements in California is so large that even when the expected growth in the state's population and economy is taken into account, no new water-supply dams or resevoirs are needed in the coming decades. Furthermore, the state's natural ecological inheritance and beauty do not have to be sacrificed to satisfy our water needs. In fact, through improvements in efficiency and conservation, we can meet California's future water needs while increasing the amount of water returned to the natural environment – thus ensuring that natural systems are protected and underground aquifers recharged. Another benefit: Saving water saves money – for water providers, consumers, and the state as a whole. Last but not least, cutting our use of water brings with it several significant "co-benefits" – from decreased sewage bills and less polluted landscape runoff to a decrease in energy consumption and improvements in air quality.

**Our best estimate is that one-third of California's current urban water use – more than 2.3 million acre-feet (AF) – can be saved with existing technology. At least 85% of this (more than 2 million AF) can be saved at costs below what it would cost to tap into new sources of supply and without the many social, environmental, and economic consequences that any major water project will bring.**

Table ES-1 and Figure ES-1 summarize our estimate of current urban water use in California and the potential to reduce this use cost-effectively. We understand that capturing this wasted water will involve new efforts and face educational, political, and social barriers. Overcoming those barriers will require commitments on the part of government agencies, public interest groups, and many others with vested, often conflicting interests in California's water policy. But we also believe that this approach has fewer barriers and more economic, environmental, and social advantages than any other path before us.

**Table ES-1**
California Urban Water Use in 2000 and the Potential to Improve Efficiency and Conservation (a)

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

(a) Minimum cost-effective conservation is that for which economically relevant data were available and our estimates of the cost of conserved water were less than $600/AF. The figure for indoor uses in the residential sector assumes natural replacement of devices when accelerated replacement would cost more than $600/AF. See Section 5 for details and definitions.
(b) This is a range of estimated outdoor residential water use. Our best estimate is 1,450,000 AF/yr. See Section 3.
(c) This is the range of conservation potential for this sector, based on the best estimate for residential outdoor use.
(d) No independent estimate of unaccounted-for water was made. We adopt here the 10% estimate from the California Department of Water Resources. No separate estimate of the potential to reduce unaccounted-for water was made in this analysis.
(e) Combined commercial, institutional, and industrial cost-effective savings estimated at around 660,000 AF/yr.

## Potential for Urban Conservation: How Much Can We Save?

What is the true potential for water conservation and efficiency improvements in California? Remarkably, no state water organization has ever made a comprehensive effort to find out. Yet this information is vital to decisions about meeting future needs, restoring the health of the San Francisco Bay-Sacramento/San Joaquin Delta, replacing Colorado River water claimed by other states, and setting a whole range of ecological, agricultural, and urban policy priorities. Without information on the potential for water conservation, questions about industrial production, ecosystem restoration, immigration policy, land use, and urban growth will be much harder to answer, or, worse, the answers provided will be wrong.

"Waste Not, Want Not" is an effort to provide a key part of this missing information. In this study, the Pacific Institute quantifies the potential for water conservation and efficiency improvements in California's urban sector, where around 20 percent of the state's water is used to meet commercial, industrial, institutional, and residential needs.

One question that may occur to a skeptical reader is, "Why conserve?" Although it is beyond the scope of this report to examine the threats to California's fresh water in detail, it is important to note that the way we use water today is not sustainable – environmentally or politically.

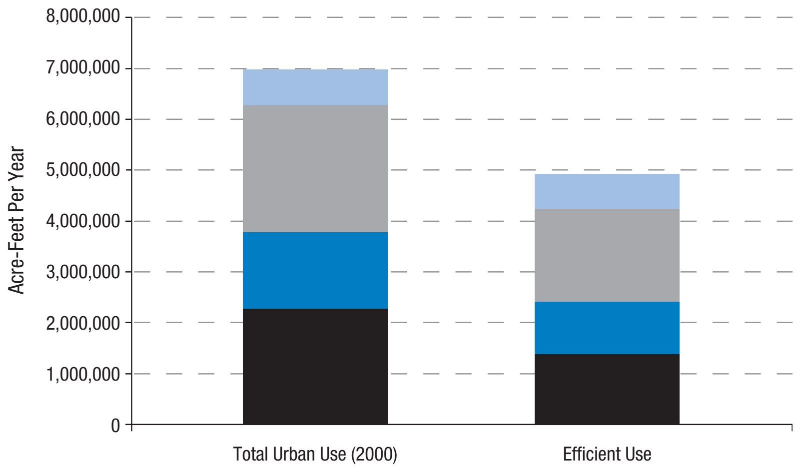



**Figure ES-1**
Summary of California Urban Water Use (2000) and the Potential for Cost-Effective Conservation Improvements

This figure summarizes our estimates of current urban water use by sector and the potential for cost-effective conservation improvements using existing technology. Current use is around 7 million acre-feet per year. Cost-effective savings could cut this to under 5 million acre-feet per year. Note that these savings represent the potential available. Capturing this potential will require a wide range of new and expanded efforts.

Controversies rage over allocation of water among users, the need to reduce the state's use of Colorado River water, overpumping of groundwater, and ecological damages caused by human withdrawals of water. All these factors, combined with concern over growing populations and the threat of climate change, make it essential that the deadlock over California water policy be broken. The best way to do this is through reducing waste in the system, using proper pricing and economics, educating the public, and improving water efficiency and conservation efforts.

We do not argue that the savings potential we identify will all be captured. Capturing wasted water will require better use of available technology, expanding existing conservation programs, developing new approaches and policies, and educating consumers and policymakers. Further technological advances will also help. Some of the needed improvements will be easy; some will be difficult. But there is no doubt that the path to a sustainable water future lies not with more "hard" infrastructure of dams and pipelines but with the soft infrastructure of responsible local water management, smart application of existing technology, active stakeholder participation in decision-making, and the efforts of innovative communities and businesses. We hope that this report is the beginning, not the end, of a real debate over water conservation in California.

## California's Urban Water Use

California uses water to meet a wide variety of needs. By far the greatest amount of water goes to the agricultural sector. Yet urban water use plays a fundamental role in supporting the state's economy and population, satisfying a wide range of residential, industrial, commercial, and institutional demands.

No definitive data on total water used in the urban sector are available, and different sources and methods yield different estimates. Estimates of the fraction used by different sectors or end uses also vary considerably, sometimes within the same report, depending on assumptions about leak rates, indoor versus outdoor uses, regional reporting differences, and other variables. By far the greatest uncertainties are in estimates of outdoor water use, particularly for the residential and institutional sectors.

Overall, we estimate California's urban water use in 2000 to be approximately 7 million acre-feet (MAF), with an uncertainty of at least 10 percent. This estimate is shown in Table ES-1 and Figure ES-1, broken down by sector. This is equivalent to around 185 gallons per capita per day (gpcd) for the nearly 34 million people living in California in 2000. Total indoor and outdoor residential use was roughly 3.75 MAF, with the greatest uncertainty around outdoor landscape use. Commercial and industrial uses in 2000 are estimated to have been 1.9 million AF and approximately 700,000 AF respectively, with governmental and institutional uses included in the commercial estimate. No independent estimate of unaccounted-for water (UfW) was done here; we adopt the California Department of Water Resources estimate for UfW of around 10 percent of all urban use.

### A Word About Agriculture in California

Before we delve any deeper into the details of urban water conservation, it is worth noting that the vast majority of water used in California goes to the agricultural sector, which is not discussed in this report. Current estimates are that more than three-quarters of California's applied water, and an even higher percentage of consumed water, is used for irrigation of food, fodder, and fiber crops.

Water use in many parts of California's agricultural sector is inefficient and wasteful, although efforts are underway to address these problems. No comprehensive conservation and efficiency policy – indeed, no rational water policy – can afford to ignore inefficient agricultural water uses. A detailed assessment of the potential to improve efficiency of agricultural water use is urgently needed. Given the proper information, incentives, technology, and regulatory guidance, great water savings will be possible in California's agricultural sector while maintaining a healthy farm economy. However, the potential for significant savings in the agricultural sector does not eliminate the need for greater efficiency in residential, commercial, industrial, and institutional water use.

## Conservation and Efficiency in the Urban Sector

The savings that urban water conservation measures can provide are real, are practical, and offer enormous untapped potential. Water users have been improving efficiency for many years by replacing old technologies and practices with those that permit us to accomplish the same desired goals with less water – well-known examples include low-flush toilets and water-efficient clothes washers.

Despite this progress, our best estimate is that existing technologies and policies can reduce current urban water use by another 2.3 MAF, where at least 2 MAF of these savings are cost-effective. If current water use in California becomes as efficient as readily available technology permits, total urban use will drop from 7 MAF to around 4.7 MAF – a savings of

33 percent. This will reduce California's urban water use from around 185 gallons per capita per day to around 123 gpcd.

For the purposes of this report, we have divided the different users of water in California into several broad categories: residential, commercial, institutional, and industrial.

## Residential Water Use

The residential sector is the largest urban water use sector, and it offers the largest volume of potential savings compared with other urban sectors. Californians used about 2.3 MAF of water to meet their indoor domestic needs in 2000 and around 1.5 MAF of water for outdoor residential uses. This is equivalent to approximately 100 gallons per capita per day (gpcd). Figure ES-2 and Table ES-2 show our estimate of indoor residential water use by end use for 2000. Table ES-4 shows our outdoor residential water use estimates.

**Table ES-2**
Estimated Current Indoor Residential Water Use in California, by End Use (Year 2000)

| End Use | Current Use (AF/year) | Fraction of Total Indoor Use (%) |
|---|---|---|
| Toilets | 734,000 | 32 |
| Showers | 496,000 | 22 |
| Washing Machines | 330,000 | 14 |
| Dishwashers | 28,000 | 1 |
| Leaks | 285,000 | 12 |
| Faucets | 423,000 | 19 |
| **Total Indoor Residential Use** | **2,296,000** | **100** |

While some water districts evaluate details of local residential water use, there are no comprehensive assessments of statewide end use of water in homes. In order to calculate current residential water use and the potential to reduce that use with conservation technologies and policies, we disaggregated all residential use into detailed end uses, including sanitation, faucet use, dishwashing, clothes washing, leaks, and outdoor landscape and garden demands. For every end use, separate assessments were done to determine how much water was required to deliver the benefits of water use (e.g., clean dishes). This involved evaluating available water-using technologies, current behavior and cultural practices, and likely changes in those factors over time. We then evaluated the potential for technologies and policies to reduce water use without reducing the benefits desired. Finally, we evaluated the cost-effectiveness of conservation technologies and policies whenever feasible. Detailed assumptions are described in Sections 2, 3, and 5; more complete technical appendices are available electronically at http://www.pacinst.org/reports/urban_usage/.

With current technologies and policies, residential water use in 2000 could have been as low as 60 to 65 gpcd without any change in the services actually provided by the water. Table ES-3, ES-4, and Figure ES-3 show total current residential water use in California and the fraction that could be saved with current technologies and policies.

**Figure ES-2**
Estimated Current Indoor Residential Water Use in California (Year 2000)

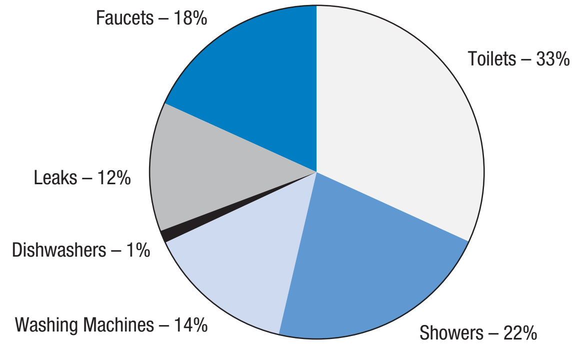
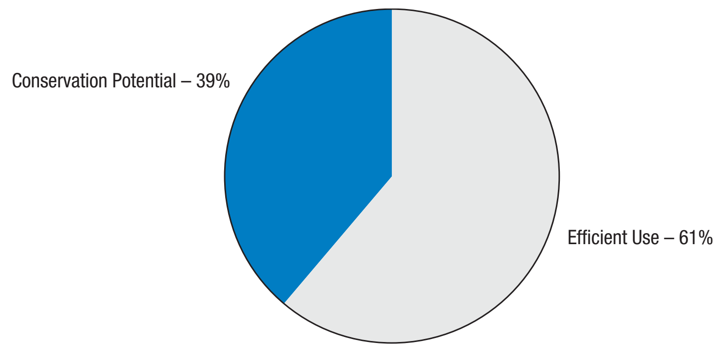



**Figure ES-3**
Current Residential Water Use in California (Indoor and Outdoor) and Conservation Potential (Year 2000)




### *Indoor Residential Water Use*

In 2000, existing conservation measures reduced California's indoor residential water use by more than 700,000 AF/yr from what it would otherwise have been. If used efficiently, this conserved water could meet the indoor residential needs of 17 million people annually.[1] While these savings are significant, savings could more than double if all reasonable potential conservation could be captured.

**Even without improvements in technology, we estimate that indoor residential use could be reduced by approximately 890,000 AF/yr – almost 40 percent – by replacing remaining inefficient toilets, washing machines, showerheads, and dishwashers, and by reducing the level of leaks. All of these savings are cost-effective and have important co-benefits like saving energy and decreasing the amount of waste water created.**

This would have the effect of reducing current indoor residential use, on average, from around 60 gallons per capita per day to around 37 gallons per capita per day. Table ES-3 summarizes our estimate of the potential to further reduce existing indoor residential water use.

1 One acre-foot currently satisfies the annual *indoor* residential needs of approximately 15 people in California. If currently available efficiency technology were used, one acre-foot could meet the indoor residential needs of 25 people. An acre-foot of water would cover one acre to a depth of one foot and equals 326,000 gallons.

| Indoor Residential Water Use (Year 2000) | Best Estimate of Additional Cost-Effective Water Conservation Potential (2000) (AF per year) | Conservation Potential: Percent Reduction Over Current Use (%) | Cost of Conserved Water ($ per AF, natural replacement) (f) |
|---|---|---|---|
| Toilets | 420,000 (a) | 57 | $50 |
| Showers | 120,000 (b) | 24 | -$1,038 |
| Washing Machines | 110,000 (c) | 33 | -$74 |
| Dishwashers | 13,000 | 46 | -$14 |
| Leaks | 230,000 (d) | 80 | < $200 |
| Faucets/Fixed Volume Uses | (e) | (e) | |
| **Total Additional Indoor Savings** | **893,000** | **40** | |

**Table ES-3**
Cost-Effective Water Conservation Potential in the Indoor Residential Sector (2000)

Details are in Section 2.

(a) For toilets, this requires full replacement of inefficient toilets with 1.6 gallon per flush models.
(b) For showers, this requires full replacement of showerheads with 2.5 gallon per minute models (with actual flow rates averaging 1.7 gallons per minute).
(c) For washing machines, these savings would result from the complete replacement of current models with the average (not the best) of the efficient machines currently on the market.
(d) The 80 percent savings estimate comes from assuming that leak rates are reduced to the median value now observed. At the same time, CDWR (2003b) estimates that half of all leaks can be saved for less than $100 per acre-foot and 80% for less than $200 per acre-foot. See Section 2 for more detail.
(e) For faucets and other fixed volume uses such as baths, no additional "technical" savings are assumed in this study.
(f) These costs are all well below the cost of new supply options. Indeed, several have "negative" costs, indicating that they are cost-effective even if the cost of water were zero, because of co-benefits (primarily energy savings associated with the water savings) that come with conservation.

For all indoor uses, additional temporary "savings" can be achieved during droughts by behavioral modifications (e.g., cutting back on the frequency of actions like flushing, showering, washing). We do not consider these to be "conservation" or "efficiency" improvements.

### *Outdoor Residential Water Use*

A substantial amount of water in California is used outside of homes to water lawns and gardens, among other uses. Outdoor water use rises to a maximum during the summer when supplies are most constrained; as a result, residential landscape use plays a large role in driving the need for increases in system capacity and reliability. Furthermore, much of this water is lost to evaporation and transpiration and is thus no longer available for capture and reuse, unlike most indoor use.

While there are great uncertainties about the volume of total outdoor residential water use, our best estimate is that just under 1.5 MAF were used for these purposes in 2000. Table ES-4 shows our estimated range of outdoor residential water use for 2000.

There are a large number of options available to the homeowner or landlord for reducing the amount of water used for landscape purposes. We split our efficiency analysis into four general categories: management practices, hardware improvements, landscape design, and policy options. These options are summarized in Table ES-5 along with estimates of potential savings from each approach. These savings are not always additive, so care should be taken in estimating overall potential.

| Estimate | Water Use (AF per year) |
|---|---|
| Low | 983,000 |
| High | 1,900,000 |
| Average | 1,450,000 |

**Table ES-4**
Estimated Outdoor Residential Water Use (2000)

See Section 3 for details on the range of estimates for current outdoor residential water use in California.

We estimate that cost-effective reductions of at least 32.5% (a savings of 470,000 AF/yr) could be made relatively quickly with improved management practices and available irrigation technology. These improvements have the potential to substantially reduce total and peak water demand in

California. Substantially larger improvements can be achieved through long-term changes in plant selection and garden design.

There are additional benefits to such improvements as well. These include reduced energy and chemical use, fewer mowings, and less waste created. We quantified some of these factor – the ones for which several credible sources of data existed – but did not quantify them all, and urge that more work be done to incorporate and capture these co-benefits.

Given the uncertainties in estimates of current outdoor residential water use in California, more data collection and monitoring and better reporting by urban agencies should be top priorities for water policy-makers and planners. Most agencies know little about the characteristics of their residential landscapes; they do not always have reliable estimates of outdoor water use, let alone landscape acreage, type of plantings, or irrigation methods. Residential customers typically do not have dedicated irrigation meters, so site-specific information can be a challenge to collect. Few water districts have collected data on residential landscapes.[2] Statewide estimates are even less reliable.

**Table ES-5**
Options for the Reduction of Outdoor Garden/Landscape Water Use

| Options | Potential Savings (Percent) |
|---|---|
| **Management** | |
| Turf maintenance (a) | 10 |
| Turf maintenance, irrigation system maintenance, irrigation scheduling | 20 |
| Mulching in ornamental gardens | 20 |
| Soil amendments (compost) | 20 |
| Irrigation scheduling | ~25 |
| Irrigation/soil maintenance | 65 to 75 |
| Allow lawn to go dormant | 90 |
| **Hardware** | |
| Auto rain shut off | 10 |
| Soil moisture sensors; soil probes | 10 to 30 |
| Improve performance (b) | 40 |
| Drip/bubbler irrigation | 50 |
| Gray water (c) | Up to 100 |
| Rain barrel catchment (c) | Up to 100 (in some regions) |
| **Landscape Design** | |
| Landscape design (d) | 19 to 55 |
| Turf reduction (e) | 19 to 35 |
| Choice of plants (f) | 30 to 80 |

Notes: Savings are not necessarily additive. See Section 3 for details.
(a) Includes thatching, aerating, over-seeding, and top-dressing.
(b) Includes repair, removal, or adjustment of in-ground system components.
(c) This option is used to reduce the volume of potable water used; it does not affect the total volume of water used.
(d) Based on minimizing turf area and perimeter.
(e) Non-turf areas are not necessarily comprised of low-water-use plants.
(f) Savings based on $ET_0$ range of 0.2 to 1.0 and a current $ET_0$ of 1.0.

### Commercial, Institutional, and Industrial (CII) Water Use

California's commercial, institutional, and industrial (CII) sectors use approximately 2.5 MAF of water annually, or about one-third of all urban water use. Previous studies of specific regions and industries have indicated that the potential for water conservation in this sector is high. But none of these studies attempted to aggregate potential water savings in the CII sector at the state level. This report uses data surveys and sec-

2 A handful of agencies, such as the EBMUD and IRWD, have made special efforts in this area. Their experience has been valuable for researchers and practitioners.

toral water studies to present, for the first time in California, a statewide assessment of the potential savings in the CII sector from conservation and improved water-use efficiency.

Within the CII sector, water use varies among individual users in both quantity and purpose. Because of these differences in use, conservation potential varies from one industry to the next, and we had to examine each industry independently. Due to resource and data constraints, we examined industries that account for about 70 percent of total CII water use. Table ES-6 shows the industries examined in detail and their estimated water use in 2000. More general conclusions were made about the remaining sectoral end uses.

**Table ES-6**
Best Estimate of 2000 Water Use in California's CII Sectors (thousand acre-feet (TAF))

| Commercial Sector | (TAF) | Industrial Sector | (TAF) |
|---|---|---|---|
| Schools | 251 | Dairy Processing | 17 |
| Hotels | 30 | Meat Processing | 15 |
| Restaurants | 163 | Fruit and Vegetable Processing | 70 |
| Retail | 153 | Beverage Processing | 57 |
| Offices | 339 | Refining | 84 |
| Hospitals | 37 | High Tech | 75 |
| Golf Courses | 229 | Paper | 22 |
| Laundries | 30 | Textiles | 29 |
| | | Fabricated Metals | 20 |
| Other Commercial | 621 | Other Industrial | 276 |
| **Total Commercial (a)** | **1,852** | **Total Industrial** | **665** |

(a) Commercial water use, as reported here, includes both commercial and institutional uses.

"Other" commercial and industrial uses reported in this table include a wide range of water uses, but insufficient information on detailed end uses limits the ability to make specific conservation estimates. For these uses, proportional savings were assumed.

When estimating water use in the CII sectors, we used two independent approaches and crosschecked our findings against other published estimates. The first approach involved compiling, reviewing, comparing, and analyzing data gathered from CII water users around the state in various surveys. From these surveys, we calculated water-use coefficients (in gallons of water each employee used per day). These coefficients were then combined with statewide employment data to estimate total water use for each industry. In the second approach, we used water-delivery data by sector, as reported by water agencies across the state. For more details, see Section 4.

### The Potential for CII Water Conservation and Efficiency Improvements

Although water conservation potential varies greatly among technologies, industries, and regions, the potential for savings is high. Improving the efficiency of water use in the CII sectors can be accomplished with a broad range of technologies and actions that won't affect production.

Since the total amount of water that can be saved in the CII sectors varies tremendously by industry and end use, our estimates of best practical savings also vary by industries. To address these differences, we report potential savings as "best" (what we judge to be the most accurate estimate based on source of the data, age of the data, and sample size), "low" (lowest plausible estimate available), and "high" (highest plausible estimate available).

The greatest percentage of water savings could be realized in traditional heavy industries, such as petroleum refining, which could potentially save nearly three-quarters of its total current water use (in this case by replacement of large volumes of cooling and process water with recycled and reclaimed water). Other industries that could save a large percentage of their total water use include paper and pulp (40 percent – through process improvements), commercial laundries (50 percent – mostly using more efficient commercial washers), and schools (44 percent – mostly through toilet and landscape improvements). Overall, we estimate that the range of potential savings is between 710,000 AF/yr and 1.3 MAF/yr over current use. Our best estimate of practical savings in the CII sector is about 975,000 AF, or 39 percent of total current annual water use (see Tables ES-7 and ES-8).

**Table ES-7**
Estimated Potential Savings in California's Commercial and Institutional Sector for 2000 (TAF/yr)

Note: The commercial sector includes California's institutional water use (government buildings, schools, and universities).

| Commercial | Potential Savings (TAF) | | |
|---|---|---|---|
| | Low | High | Best |
| Schools | 92 | 124 | 116 |
| Hotels | 9 | 11 | 10 |
| Restaurants | 44 | 51 | 48 |
| Retail Stores | 41 | 67 | 56 |
| Office Buildings | 101 | 154 | 133 |
| Hospitals | 11 | 17 | 15 |
| Golf Courses | 56 | 212 | 82 |
| Industrial Laundries | 11 | 18 | 15 |
| Other Industries | 185 | 330 | 239 |
| **Total Commercial** | **551** | **984** | **714** |

**Table ES-8**
Estimated Potential Savings in California's Industrial Sector for 2000 (TAF/yr)

| Industrial | Potential Savings (TAF) | | |
|---|---|---|---|
| | Low | High | Best |
| Dairy Processing | 2 | 7 | 5 |
| Meat Processing | 2 | 5 | 4 |
| Fruit and Vegetable Processing | 7 | 25 | 18 |
| Beverages | 6 | 10 | 9 |
| Petroleum Refining | 39 | 78 | 62 |
| High Tech | 19 | 37 | 29 |
| Paper and Pulp | 3 | 10 | 7 |
| Textiles | 9 | 13 | 11 |
| Fabricated Metals | 5 | 9 | 7 |
| Other Industries | 66 | 138 | 108 |
| **Total Industrial** | **158** | **331** | **260** |

Several data constraints ultimately affect any final estimate of conservation potential in the CII sectors. These constraints were encountered when calculating current water use by specific end uses, penetration rates of efficient technologies, and potential water savings. The primary limitation is lack of data. At the most basic level, reliable end-use data were unavailable for a few industries in the industrial sector, such as textiles. Without this basic information, estimates of the amount of water these industries used for specific tasks must be determined from other sources, adding uncertainty. The penetration rates of some efficient technologies were also unavailable. We discuss data limitations in greater depth in Section 4 and the detailed Appendices (which are available online at http://www.pacinst.org/reports/urban_usage/).

Finally, we evaluated the cost-effectiveness of CII water use whenever feasible. The evaluation was done on a measure-by-measure basis, with some measures (e.g., toilet retrofits) conserving water in many CII sectors. Data were not available with which to assess cost-effectiveness of all measures, however, so our results are labeled as the "minimum cost-effective" conservation levels. We found that at least 657,000 AF of CII water used in California at present could be conserved cost-effectively. More CII conservation may be cost-effective. Most of the measures for which we could not develop estimates have already been adopted by at least some businesses or institutions; suggesting that they are in fact cost-effective.

## A Few Key Points: Cost-Effectiveness Analysis

Saving water saves money. Section 5 presents our assessment of the cost-effectiveness of efficiency technologies and conservation options. Economists use cost-effectiveness analysis to compare the unit cost of alternatives (such as dollars spent to obtain, treat, and deliver an acre-foot of water from a particular source). Since each water-conservation measure is an alternative to new or expanded physical water supply, measures are considered cost-effective when their unit cost – what we call "the cost of conserved water" – is less than the unit cost of the cheapest alternative for new or expanded water supply.

**We conclude that in California, it is much cheaper to conserve water and encourage efficiency than to build new water supplies or even, in some cases, expand existing ones.**

Many credible studies and sources indicate that the marginal cost of new or expanded water supply in most, if not all, of California is greater than most of our estimates of the cost of conserved water. Indeed, because of the non-water benefits of conservation, in some cases consumers or water agencies will find it cost-effective to implement a number of the options described here even if water were free.

The costs of conserved water we estimate in this report are deliberately biased toward the higher end of the cost range to make our analysis more conservative. We also found that one need not include many favorable, but difficult-to-quantify, cost factors for the analysis to show that the water-conservation measures under consideration are cost-effective. Thus we include only the reasonably quantifiable and financially tangible "co-benefits" of water conservation. These are benefits that automatically come along with the intended objective. For example, low-flow showerheads reduce water-heating bills and sewage costs, and improved irrigation scheduling reduces fertilizer use. What our research shows is that even a conservative approach to co-benefits makes the case for water conservation much stronger than less complete assessments that exclude these benefits.

All five indoor residential conservation measures evaluated – toilets, washing machines, showerheads, leak detection and reduction, and dishwashers – are cost-effective under natural replacement. The outdoor measures that we evaluated – improved irrigation scheduling, operation, and maintenance, including some replacement of irrigation technology – are also cost-effective. We did not evaluate changes in landscape type (e.g., replacing turf with low-water use native plants) because this could change the benefit received by the owner of the landscape, which in turn has financial or value implications beyond the scope of this report. We note, however, that these changes could well be cost-effective, given recent evidence from pilot projects, detailed case studies, and large-scale landscape programs (see Section 5 for a description of our methodology).

A far wider set of conservation options was evaluated in the CII sector, with a variety of results. Examples of cost-effective options are replacement of all commercial toilets with low-flow models as the new fixtures are needed, accelerated replacement with ultra-low-flow toilets in establishments where toilets are flushed more than 15 times per day, and using low-flow showerheads in all urban sectors. Other examples include recirculating water used by x-ray machines and sterilizing equipment in hospitals, a wide variety of "good housekeeping" and leak-detection options in all establishments, water-efficient dishwashers and pre-rinse nozzles in restaurants, efficient washing machines and recycling systems in laundromats, acid recovery and textile dye-water recycling in the textile industry, a wide variety of microfiltration systems in the food industry, and use of recycled/reclaimed water in refineries, among others.

Although much work has been put into ensuring that our methodologies are clear and consistent, care should be taken in reading and using the numbers in Section 5. While the basic approach taken to calculate cost-effectiveness among the different urban sectors is the same, some important details differ among the indoor residential, outdoor residential, and commercial and industrial analyses. For every sector, see the detailed assumptions described in the body of the report. Additional detail is provided online at http://www.pacinst.org/reports/urban_usage/.

## Lessons and Recommendations

### General Conclusions

*California is using water unsustainably.*

The pressures of a growing population and economy, combined with traditional approaches to water supply and management, have led to the unsustainable use of California's freshwater resources. The state must change its ways to avoid water shortages, ecological collapse, and economic disaster.

*Improved efficiency and increased conservation are the cheapest, easiest, and least destructive ways to meet California's future water needs.*

This report strongly indicates that California can save 30% of its current urban water use with cost-effective water-saving solutions. Indeed, fully implementing existing conservation technologies in the urban sector can eliminate the need for new urban water supplies for the next three decades.

*Existing technologies for improving urban conservation and water-use efficiency have enormous untapped potential.*

Many technologies are available for using water more efficiently, in every urban sector. These include low-flow toilets, faucets, and showerheads; efficient residential and commercial washing machines and dishwashers; drip and precision irrigation sprinklers; commercial and industrial recycling systems; and many more.

*Smart water policies to capture conservation savings are available at all levels of government and society.*

Examples of the smart water policies that will help capture the conservation and efficiency potential include proper pricing of water to encourage waste reduction, financial incentives for low-flow appliances, proper design of subsidy and rebate programs, new state and national efficiency standards for appliances, education and information outreach, water metering programs, and more aggressive local efforts to promote conservation. These are described in more detail below and in the full report.

*There are barriers to capturing all conservation potential, but these barriers can be overcome.*

Becoming more efficient requires both easy and difficult actions. But experience has shown that the barriers to more efficient water use are often overestimated and can be overcome by intelligent planning efforts that collect the right information, identify real conservation potential, and then work with stakeholders to implement policies and programs in a fair and transparent fashion.

## The Power of Technology

*Existing technologies are available to greatly reduce urban water use without reducing the goods and services we desire.*

This report focused on existing, commercially tested, and readily available water-efficiency technologies like low-flow toilets and better water use in landscapes. We found a vast number of options that enable us to reduce urban water use without harming our quality of life.

*New technologies are constantly evolving.*

Between the times we began and finished this report, new technologies and improvements in old technologies have continued to appear on the market. Computer-controlled “smart” sprinklers can greatly reduce overwatering. Dual-flush toilets that improve upon current technology are now available in the United States and are standard in other countries. Waterless urinals are being installed in government and commercial buildings in California. New efficient nozzles for washing dishes in restaurants are being installed more widely. Efficient washing machines are appearing faster and their prices are dropping more rapidly than expected. This trend of continuing improvements in water use efficiency technology is likely to continue and will make saving water even easier and cheaper.

## The Power of Proper Economics

*The power of proper pricing of water is underestimated.*

When water is not properly priced, it is frequently wasted. Inexpensive water only appears inexpensive. It often carries high or hidden costs for water users and the environment. In all urban uses, pricing water at appropriate levels encourages conservation and efficiency actions and investments. All water use and wastewater discharges should be charged at rates (and with rate structures) that encourage efficiency – but governments do have a duty to ensure that basic human needs for water are met regardless of one's ability to pay.

*Economic innovation and financing mechanisms lead to cost-effective water conservation.*

Many conservation technologies are cost-effective for customers, but are not perceived as cost-effective. Innovative economic tools and financing mechanisms can help customers make smarter water-use decisions.

## The Power of Smart Regulation

*Smart regulation is more effective than no regulation.*

There is a critical role for federal, state, and local standards and rules in moving toward more efficient water use in all sectors. For example, the federal water-efficiency standards have been enormously effective at helping the nation keep total water use well below the levels that would otherwise have resulted from continued inefficient water use. They have also been economically attractive, saving far more money than they cost.

*Appliance standards are powerful conservation tools that also help educate consumers.*

Experience has repeatedly shown that appliance efficiency standards are powerful tools for reducing waste. The water-efficiency standards of the National Energy Policy Act have been tremendously successful at cost-effectively reducing wasteful use of water in U.S. toilets and showerheads. New standards should be pursued for washing machines, dishwashers, and some commercial and industrial water-using fixtures, but such standards should be flexible enough to permit advances in technology to continue to lead to improvements in water productivity.

## The Power of Information

*Ignorance is not bliss: Data and information are keys to successful conservation.*

As highlighted in different sections of the report, lack of information (or failure to disseminate that information) hinders effective action. Although we calculate the most accurate water use and conservation potential we can with the information available, increasing the accuracy of future estimates is necessary. This will depend on water users, suppliers, and managers at all levels taking specific steps to increase the reliability, quality, and quantity of available data on water use and water conservation options.

*Some specific data needs should be a top priority.*

Collect and report more water-use data in standard formats, consistently and regularly. Data on landscape use and self-supplied water are particularly poor. Details on end uses of water are limited. And experience with conservation efforts to date is poorly documented.

*Meter and measure all water uses.*

When water use is not metered, it is wasted. With very few exceptions, water uses should be monitored and measured so that actual use can be evaluated and compared to the benefits that water provides. Unfortunately, several sizeable cities in California, including Sacramento, still do not have water meters.

*Appliance labeling is a powerful educational tool.*

The success of the Energy Star labeling program highlights the power of information. A "Water Star" label for water-using appliances should be implemented, showing total water use per year (or some comparable measure). Such labeling permits consumers to make more informed choices about their actions and purchases.

*Standardize water-use terms.*

Confusion over terms such as water use, consumption, withdrawal, new water, real water, conservation, productivity, efficiency, and so on can hinder policy and analysis. Some efforts should be made to standardize terms related to water use and conservation.

*Educate decision-makers about conservation opportunities.*

Homeowners, individuals, and industries sometimes choose less-efficient technologies because they are operating with incomplete information. Many homeowners do not know that the performance of the new ultra-low-flow toilets is as good as, or better than, older, inefficient models and that such toilets will save a considerable amount of money for the homeowner. Discussions with a specific dishwasher manufacturer, for example, revealed that sales of their inefficient dishwasher models far exceed similarly designed efficient models because initial costs of the efficient models are about ten percent higher.

*Give agencies and industries an opportunity to share success stories.*

Water-conservation programs are already successfully reducing water use. Sharing information on these success stories in industry forums, user groups, or conferences can help promote more widespread efforts.

*California's state and local water agencies should work more closely with industry associations and national agencies on data collection.*

When industry associations and national agencies collect water use and conservation data, they often collect these data in the state of California and then combine them with data from other states to calculate a national estimate. If state agencies could obtain this California-specific data in a consistent format, this information could be used for future research.

*Reconcile data reported from individual water agencies, industry associations, and various other agencies.*

A significant amount of data reported by one agency may conflict with what other agencies are reporting. State and local agencies need to reconcile these differences and work with national and industry associations.

## The Power of Smart and Integrated Water Management

*Be aware of the water implications of non-water policies.*

Water agencies should also encourage the implementation of new policies and technologies that are not intended to achieve reductions in water use but do so anyway. In hospitals, for example, water-ring vacuum pumps were historically installed because flammable gases were used as anesthetics. Once the flammable gases were discontinued, hospitals slowly shifted to oil-based pumps, incidentally saving water. Similarly, digital x-ray film processors are gaining market share for their superior ability to process, transmit, and manipulate x-ray images, yet these systems also use little or no water.

*Promote reclaimed and recycled water as a secure source for water supply.*

While this report does not discuss the overall potential for using reclaimed or recycled water as a source of new supply, that potential is real and likely quite significant for California's urban sector. A comprehensive water program will address the availability and potential use of this water source. Examples already exist: The desire for a guaranteed water supply during drought conditions has driven some refineries to switch to reclaimed water for their cooling needs. Even if water is not a major cost component, an interruption of water supply can cause shutdowns in many industries and result in lost income. Promoting reclaimed water as a secure supply may encourage some industries to invest in the necessary infrastructure for using this water.

*Smart management practices should be encouraged at water districts or within specific industries.*

Often, water districts or specific industries will introduce conservation measures, but differences in management approaches can prevent the full implementation of these measures. In the CII sector, for example, failing to budget worker time for implementing water conservation technologies contributes to poor implementation rates and may even increase water use.

# 1

# Introduction to California Water Use and Conservation

Water conservation measures are real, are practical, and offer enormous untapped potential. In fact, the largest and least expensive source of water to meet California's future needs is the water currently being wasted in every sector of the economy. The potential for conservation and improved efficiency is so large that no new dams or reservoirs will be needed for the foreseeable future, even with expected growth in population and the state's economy. Moreover, capturing this water will be cheaper and more environmentally beneficial than any other alternative available.

What is the potential for water conservation and efficiency improvements in California? Remarkably, no state water organization has ever made a comprehensive effort to find out. Yet this information is vital to decisions about meeting future needs, restoring the health of the San Francisco Bay-Sacramento/San Joaquin Delta, replacing Colorado River water claimed by other states, and setting a whole range of ecological, agricultural, and urban policy priorities. Without information on the potential for water conservation, questions about industrial production, ecosystem restoration, immigration policy, land use, and urban growth will be much harder to answer, or, worse, the answers provided will be wrong.

This report is an effort to provide part of the missing information. The Pacific Institute quantifies the potential for water conservation and efficiency improvements in California's urban sector, where around 7 MAF of water are used to satisfy commercial, industrial, institutional, and residential needs.

**Our best estimate is that one-third of California's current urban water use – more than 2.3 million acre-feet (AF) – could be saved with existing technology. At least 85% of this (more than 2 million AF) can be saved at costs below what it would cost to tap into new sources of supply, if politically and environmentally acceptable new supplies could be found.**

Our research strongly indicates that most, if not all, of California water needs in the coming years can be met by smart and thoughtful use of existing technology, revised economic and pricing policies, appropriate state and local regulations, and public education. Furthermore, the state's natural ecological inheritance and beauty do not have to be sacrificed to meet water needs for future economic development.

Capturing this wasted water will require expanding existing conservation and efficiency programs, developing new programs and policies, and educating consumers and our policymakers. Further technological advances will also help. Some of the needed improvements will be easy; some will be difficult. But there is no doubt that the path to a sustainable water future lies not with more hard infrastructure of dams and pipelines but with the soft infrastructure of local water management, smart small-scale technology, active community participation in decision-making, and efforts of innovative businesses.

## Traditional Water Planning

The water problem, according to conventional wisdom, is how to increase water supplies to meet some projection of future demand. The solution to this problem, according to the same conventional wisdom, is to build infrastructure – dams, aqueducts, and pipelines – to capture water in wet seasons for use in dry seasons and to move water to dry areas from wet areas. Although these big projects have brought many benefits, the environmental and social consequences of this approach have become increasingly intolerable, even as the demand for water supposedly grows. Failing to meet this projected "demand" will, it is usually claimed, lead to economic catastrophe, massive unemployment, industrial flight, and agricultural ruin.

But projections of water use are increasingly recognized to be arbitrary and unreliable. Future use of water has usually been assumed to be a direct function of population size, economic wealth, and per capita water use per unit of wealth. As these factors grow, traditional estimates of future water use grow with them. In recent years, however, it has become increasingly apparent that these traditional projections are usually wrong – often wildly wrong. Figure 1-1 shows actual water withdrawals globally together with projections of future water use made over the past forty years. With very few exceptions, forecasts of future water use have greatly exceeded actual water withdrawals. Only within the past few years have new projections begun to incorporate new thinking and approaches.

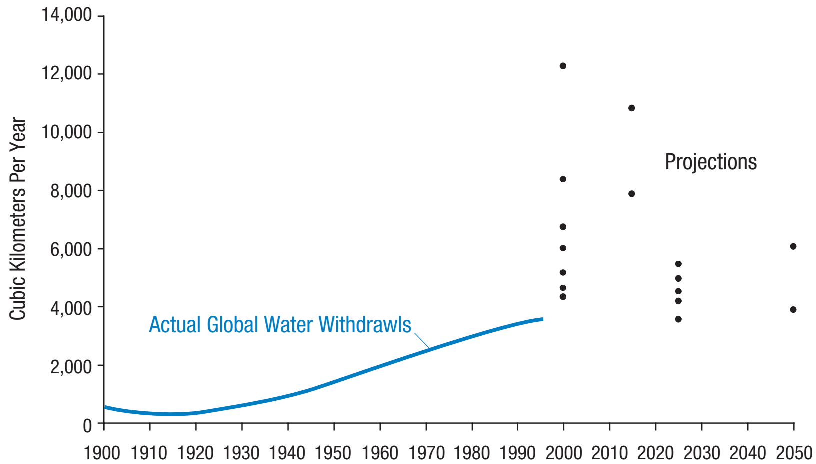



**Figure 1-1**
Global Water Projections and Actual Withdrawals

Projections of future water withdrawals have regularly been substantially higher than actual withdrawals because of inappropriate assumptions about future demand.

- Black dots represent various projections made from 1967 to 1998.

Beginning in the late 1960s and early 1970s, the ecological and political costs of building large-scale water infrastructure became more apparent and the environmental movement began to challenge proposals for new dams. More recently, the economic costs of the traditional water path have become unacceptably high, as government pork-barrel spending and water subsidies have come under increasing scrutiny. The disintegration of this old approach is now making water planners re-examine fundamental assumptions. But what can replace this path? In order to talk intelligently about future water requirements, some basic questions must be asked and answered: Who is going to require water? For what purpose or goal is water needed? What kind of water? How much water? Without an understanding of the tasks that must be performed, designing a rational water system isn't possible. Strange as it may seem, water managers rarely provide comprehensive answers to these questions.

## Who is going to require water?

Who is going to require water? This question is typically addressed in a rudimentary way by identifying traditional constituents such as urban and agricultural users. Urban users are often broken into residential, industrial, commercial, and institutional users. But a detailed analysis of the diverse kinds of human users of water is rarely provided. Even more rare is any inclusion of explicit environmental or ecological water users in estimates of total water demand.

## For what purposes is water required?

This question gets immediately to the heart of the issue of conservation and demand management. Water use of any kind makes sense solely in the context of the goods and services provided by that use. What is desired is not to use a certain amount of water, but to achieve certain goals: to remove wastes, produce goods and services, grow food, generate energy, provide recreation, and so on. Without understanding what we want to do, it is impossible to evaluate the water needed to accomplish our goals.

Proponents of endless growth of water use argue that we need new water to meet future needs. But what needs? Without real estimates of needs, water will continue to be taken from sensitive ecosystems without limits and expensive infrastructure will be built unnecessarily.

### What kind of water is necessary to meet specific goals?

Different water demands can be met with waters of differing quality. In the United States, water delivered to a home is treated to the highest drinking water standards in order to maintain human health free of water-related diseases. Only a tiny fraction of domestic water use, however, is used for drinking.

Similarly, the same high-quality potable water is delivered to commercial, industrial, and institutional water users for toilet flushing, watering landscapes, washing cars, cooling power plants, and many other uses that do not require potable water. These factors are rarely considered in traditional water planning. Future water demand in urban areas is assumed implicitly to require potable water, which exaggerates the amount of water actually needed and inflates the overall cost of providing it.

### How much water is actually needed to meet any given goal?

There are problems with the data on how much water we use. The common measure of how much water we withdraw for a task does not tell us how much water is actually delivered to the point of use. The amount of water used to provide goods or services tells nothing about how much water is actually required to produce those things. And the amount of water actually required to do a particular task or provide a particular service tells us nothing about whether the thing we did was worth doing.

Research and data are available telling us how much water is used to flush a toilet, or produce a computer chip, or grow cotton in California's Central Valley, but very little research has been done to tell us the *minimum* amount of water required to flush human wastes down a toilet, or to produce a chip, or to grow a crop of cotton.

Getting rid of human wastes in toilets can take 6 gallons of water, or 3.5 gallons, or 1.6 gallons per flush, or even no water at all depending on the toilet. Growing an acre of cotton can take 5 AF of water per year, or 3, or even 1.5 depending on the climate, soil, irrigation technology, and efforts of the farmer. By thinking about specific tasks to be accomplished, more attention can be given in water-scarce regions to the minimum amount of water required to satisfy a goal. And society has yet to seriously consider whether using water to dispose of human wastes is appropriate at all, or whether a computer chip can be made without water, or whether it makes sense to grow a crop of cotton in California. All of these factors affect the amount of water society uses.

## Water and Well-Being

Many traditional water planners still cling to the incorrect idea that using less water somehow means a loss of prosperity. Yet the link between water use and GNP in the United States, and California, has now been broken, and economic well-being is rising while water use is holding steady or even falling. Figure 1-2 shows water withdrawals in the U.S. from 1900 to the present, compared to the nation's gross national product in current dollars. From 1900 to 1980, these two curves rose in lockstep – increases in national wealth were matched by similar increases in water withdrawals. This relationship ended around 1980, with continued rapid increases in national wealth but a leveling off of total water withdrawals. Similarly, Figure 1-3 shows California's "economic productivity of water use," measured (in dollars per gallon) as the gross state product divided by total state water use. As this curve shows, the state has been getting more dollars of economic growth per unit of water for more than three decades, as conservation and efficiency have improved and as the economy has shifted away from water-intensive industries.

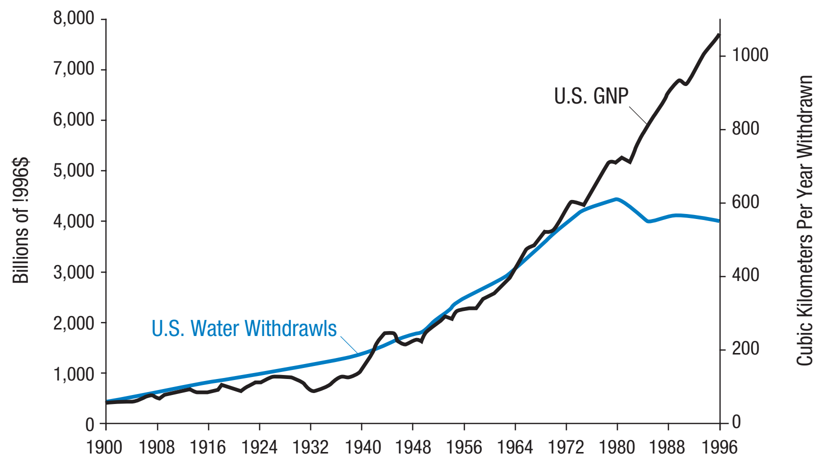



**Figure 1-2**
U.S. GNP and Water Withdrawals

Total U.S. water withdrawals peaked in the late 1970s and have now leveled off, and even declined, as water-use efficiency has improved and the structure of the U.S. economy has changed.

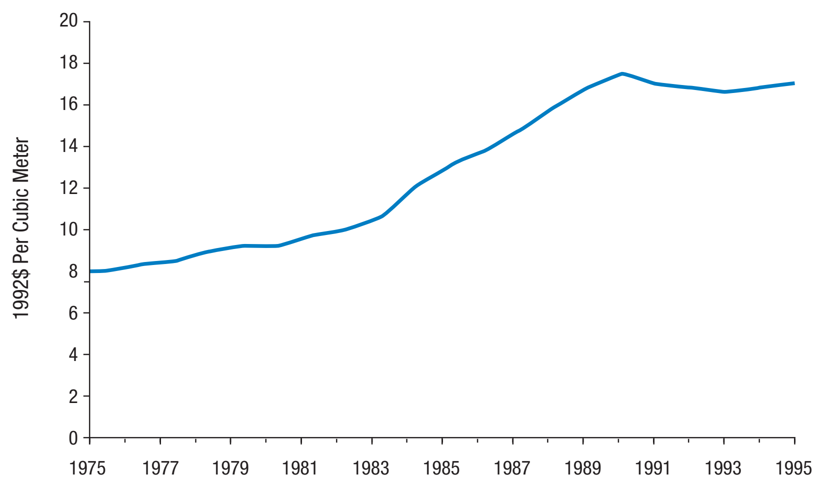



**Figure 1-3**
California's "Economic Productivity of Water"

This figure measures California's economic productivity per unit of water used, in 1992$ per cubic meter of water. California has more than doubled economic output per unit water since the mid-1970s.

If it were true that larger populations and increasing economic growth led inexorably to higher and higher water use, then there would be no point in re-evaluating water policies and institutions. But trend is not destiny. We've already seen that there are coherent alternatives – the combination of approaches often called water conservation, efficiency, and demand management.

## The Debate over California's Water

California has a long history of rancorous and contentious water debates. The sheer size of the state, the number and diversity of people, and the complexity of our natural climate and hydrology have led to the development of an expensive, sophisticated, and controversial water system to address the needs of competing interests and stakeholders. While California's population may increase by 25 percent in the next 20 years (CDOF 2002), financial, environmental, political, and social factors will likely prevent any significant expansion of California's water supply.

Traditionally, western states satisfied increasing water demands through centralized decision-making and large infrastructure investments in dams, pipelines, and treatment plants. Much of this infrastructure was built at the expense of taxpayers from around the nation. But the most cost-effective water sources were developed decades ago, leaving only expensive, environmentally sensitive, and politically controversial sites available for future development. At the same time, California's water supply is likely to shrink due to a reduction in diversions from the Colorado River[1], the return of water to natural ecosystems, and efforts to eliminate unsustainable groundwater overdraft.

During the 20th century, California water policy revolved around the simple belief that regular additions to supply were the only viable options for meeting anticipated increases in demand. This belief led to the first pipelines to bring water to California towns and cities, followed by ambitious aqueducts and big reservoirs to capture and store water far from where the water was needed, culminating in the vision – now a reality – of the massive state and federal water projects that dominate today's landscape.

This classical approach to water policy, imitated around the world, led to enormous benefits to the state and its people. It permitted California to grow into the dominant economic power that it is today, with vibrant and dynamic industrial and agricultural sectors, and allowed the growth of large population centers where local water resources were inadequate. But this approach also came with high costs – costs largely unrecognized or ignored by those who created and implemented that vision. Those costs included the degradation and destruction of a significant part of California's ecological heritage, the growing mistrust of local communities toward state and federal water planners, and ultimate gridlock of water policy during the closing years of the 20th century.

As we move into the 21st century, these costs can no longer be ignored. The old reliance on narrow definitions of supply can no longer be used to meet new needs. The failure of California's traditional water-planning process is slowly leading to new discussions, new ideas, and new

1 Due to high flows and unused water rights on the Colorado River in recent years, California has consistently had access to approximately 20 percent more water than its legal entitlement of 4.4 million acre-feet. A highly contentious process is underway now to reduce California's use of Colorado River water.

participants. In the past decade, progress has been made in building bridges among competing water interests and in expanding directions for discussing and resolving disputes. In time, we hope that these efforts will lead to new ways of thinking and new ways of meeting California's diverse water needs in a sustainable and equitable manner. But the process of developing an alternative approach has not yet been completed.

One of the major new factors in California's long water debate is the first real discussion about how water is actually used and the potential for using the state's limited water resources more efficiently. The water community is slowly coming to the realization that our current use of water is highly inefficient and wasteful. Rethinking our needs for water and how we meet those needs could go a long way toward reducing the pressure on the state's fixed water supply. Various terms have been used to describe this concept: conservation, water-use efficiency, demand management, water productivity, best management practices, and so on. Despite some subtle or not-so-subtle differences among these terms, they all refer to policies, technologies, and approaches that permit society to meet specific goals with less water.

## Defining Water "Conservation" and "Efficiency"

The concept of conservation and improved management of water use goes back many decades. In 1950, the President's Water Resources Policy Commission published "A Water Policy for the American People," which noted:

> We can no longer be wasteful and careless in our attitude towards our water resources. Not only in the West, where the crucial value of water has long been recognized, but in every part of the country, *we must manage and conserve water* if we are to make the best use of it for future development. (italics added)

What does conservation mean? There are many different and sometimes contradictory definitions of conservation. Baumann et al. (1980) defined water conservation using a benefit-cost approach: "the socially beneficial reduction of water use or water loss." In this context, water conservation involves trade-offs between the benefits and costs of water-management options. The advantage of this definition is that it focuses on comprehensive demand-management strategies with a goal of increasing overall wellbeing, not curtailing water use. In the public eye, conservation sometimes seems to mean deprivation – simply cutting back use of a resource, even if that means cutting back the goods and services produced by using that resource. More recently, academics and water professionals have made a major effort to ensure that the term "water conservation" refers to reducing water use by improving the efficiency of various uses of water, *without decreasing services.*

Another term – "technical efficiency" – is sometimes used to refer to the ratio of output to inputs, such as dollars per gallon of water used. Improving technical efficiency can be accomplished by either increasing output or reducing water inputs. While this term can be useful, if offers little guidance as to how much reduction in water use is enough (Dziegielewski 1999). For some end uses, maximum technical efficiency for water could be infinite by cutting the water requirement to zero. For example, dry composting toilets or waterless urinals require minimal or even no water.

The concept of efficiency is also useful when put into the context of investment decisions. "Economic efficiency" offers insight into the level of conservation reached when the incremental cost of reducing demand is the same as the incremental cost of augmenting supply. Using this criterion, water utilities or individuals would invest in water conservation programs until the conserved water is as expensive as new supplies, taking into account all the costs and benefits of water conservation and supply augmentation, including environmental and other external factors.

For the purposes of this analysis, we use several different terms; the most common, **conservation**, describes any action or technology that increases the productivity of water use. Collectively, we refer to these actions and technologies as conservation measures, demand management, or improving water productivity. We examine two broad types of conservation measures: **improving water-use efficiency** and, to a lesser degree, substituting reclaimed water for some end uses.[2] Improving water-use efficiency includes behavioral and managerial improvements, such as adjusting a watering schedule, and technological improvements. Technological improvements usually involve replacing water-using equipment with equipment that serves the same purpose with less water. Thus **improving water-use efficiency** means reducing the amount of water needed for any goal while still accomplishing that goal. We exclude from our analysis any options that limit the production of goods and services through deprivation or cutbacks in production.

Many technologies and policies are available for reducing water use. In this context, the **theoretical maximum water-use efficiency** occurs when society actually uses the minimum amount of water necessary to do something. In reality, however, this theoretical maximum efficiency is rarely, if ever, achieved or even computed because the technology isn't available or commercialized, the economic cost is too high, or societal or cultural preferences rule out particular approaches. We have adopted the following additional terms and definitions to guide our analysis.

**Best available technology (BAT):** The best proven commercial technology available for reducing water use. A good example is the composting toilet, capable of meeting all disposal needs without the use of water. These toilets are proven and commercially available. BAT is useful for quantifying a maximum savings technically available. This is an objective assessment of potential, independent of cost or social acceptability. Thus, the BAT for toilets uses no water.

**Best practical technology (BPT):** The best technology available for reducing water use that meets current legislative and societal norms. This definition involves subjective judgments of social acceptability but defines a more realistic estimate of maximum practical technical potential, independent of cost. Our assumption of the BPT for toilets in the United States is the ultra-low-flow toilet (ULFTs) meeting existing national standards of 1.6 gallons per flush.[3]

2 The potential for substituting reclaimed water for a wide range of water needs is large in California and elsewhere. This report does not directly address this potential in the residential sector, though some estimates are provided in Sections 4 and 5 of the potential for this approach in specific industrial and commercial end uses.

3 We note here, and elsewhere, that "dual-flush" toilets, which use less water than the current US standard of 1.6 gallons per flush (gpf), are the norm in Australia and Japan. We fully expect them to become more common in the U.S. over time, but for the purposes of this study, we use 1.6 gpf as the BPT.

**Maximum available savings (MAS):** For a given agency, region, or state, MAS is an estimate of the maximum amount of water than can be saved under full implementation of best available technology (BAT), independent of costs.

**Maximum practical savings (MPS):** For a given agency, region, or state, MPS is an estimate of the maximum amount of water that can be saved under full implementation of best practical technology (BPT), independent of current costs.

**Maximum cost-effective savings (MCES):** For a given agency, region, or state, we define the MCES as the maximum amount of water that can be cost-effectively saved under full implementation of best practical technology (BPT). "Cost-effectiveness" is defined as the point where the marginal cost (and benefits) of the efficiency improvements is less than or equal to the marginal cost of developing new supplies

## Where Are We Today? Current Urban Water Use in California

Like many western states (and indeed, water-short nations), California faces a growing population but a fixed and limited water supply. Much of the state's population lives in urban centers along the coast and, increasingly, in the Central Valley. In 2003, the California Department of Finance estimated California's total population to be 35.6 million people (CDOF 2003). While the state's population may increase by more than 30 percent in the next 20 years (State of California 2001), financial, environmental, political, and social factors will likely prevent any significant expansion of California's water supply.

Urban water is used for residential, commercial, and industrial purposes; outdoor landscaping; and other miscellaneous uses. The best official estimates of total urban water use in the early and mid-1990s ranged from 7 to almost 9 MAF/year (CDWR 1994a, CDWR 1994b, CDWR 1998), but significant uncertainties accompany these numbers. Estimates of the fraction used by different sectors or end uses vary considerably, sometimes within the same report, depending on assumptions about leaks, indoor versus outdoor uses, regional reporting differences, and other variables. By far the greatest uncertainties are in estimates of outdoor water use, particularly for the residential and institutional sectors.

For this report, the Pacific Institute revised all statewide urban water use estimates for 2000 using an end-use approach. Overall, we estimate urban water use in California in 2000 to be approximately 7 MAF, with an uncertainty of at least 10 percent. This estimate is shown in Table 1-1 and Figure ES-1. Total residential use is around 3.75 MAF. Commercial and industrial uses are estimated to be just under 1.9 MAF and 700,000 AF, respectively, with governmental and institutional uses included in the commercial estimate. No independent estimate of unaccounted-for water (UfW) was done here; we adopt the Department of Water Resources estimate for UfW of 10 percent of all urban use (CDWR 1994b).

**Table 1-1**
California Urban Water Use in 2000

(a) We provide a range here given the uncertainties in the data.
(b) Calculated using the average of this range is 1,450,000 AF.
(c) No independent estimate of unaccounted-for water was made in this report. We adopt the 10 percent estimate from the California Department of Water Resources.
(d) Rounded.

| California Urban Water Use by Sector | 2000 Water Use (AF per year) | Percent of Total Urban Use (%) |
|---|---|---|
| Residential Indoor | 2,300,000 | 33 |
| Residential Outdoor | 983,000 to 1,900,000 (a) | 21 (b) |
| Commercial/Institutional | 1,850,000 | 27 |
| Industrial | 665,000 | 10 |
| Unaccounted-for Water (c) | 695,000 | 10 |
| **Total** | **6,960,000 (+/- 10%)** | **100 (d)** |

We estimate indoor residential water use in 2000 was approximately 2.3 MAF. Table 1-2 shows our estimate of total indoor residential water use in 2000 by end use. Approximately a third of all indoor residential water goes to flush toilets. Other major uses are showers/baths, washing machines, and leaks. We estimate that leaks (which vary widely from house to house) average as much as 12 percent of total indoor water use.

Our estimate of outdoor residential water use is calculated in Section 3 as a range. Great uncertainties accompany any estimate of current outdoor water use, since this use is not measured directly. Instead, we used several different approaches to evaluate outdoor use, including the difference between summer and winter water usage, end-use estimates based on landscape area, plant types, climatic factors and representative lot sizes, and other methods, as described in Section 3. We calculate outdoor residential water use falls in the range of one million to 1.9 MAF annually in 2000, with an average of 1.45 MAF. Using this average, outdoor residential use is approximately 39 percent of total residential use.

**Table 1-2**
Estimated Indoor Residential Water Use in California (Year 2000)

See Section 2 for details.

| Indoor End Use | Current Use (AF per year) | Fraction of Total Indoor Use (%) |
|---|---|---|
| Toilets | 734,000 | 32 |
| Showers | 496,000 | 22 |
| Washing Machines | 330,000 | 14 |
| Dishwashers | 28,000 | 1 |
| Leaks | 285,000 | 12 |
| Faucets | 423,000 | 19 |
| **Total Indoor Residential Use (AF/yr)** | **2,296,000** | **100** |

Commercial (including institutional) and industrial water-use estimates are developed in Section 4 and shown in Table 1-3, with detail by end-use sectors. Commercial water uses reported here include governmental and institutional end uses totaling around 1.85 MAF in 2000. We estimate industrial water use was around 665,000 AF in 2000.

| Commercial (a) | Water Use (AF/yr) | Industrial | Water Use (AF/yr) |
|---|---|---|---|
| Schools | 251,000 | Dairy Processing | 17,000 |
| Hotels | 30,000 | Meat Processing | 15,000 |
| Restaurants | 163,000 | Fruit and Vegetable Processing | 70,000 |
| Retail | 150,000 | Beverage Processing | 57,000 |
| Offices | 339,000 | Refining | 84,000 |
| Hospitals | 37,000 | High Technology | 75,000 |
| Golf Courses | 342,000 | Paper | 22,000 |
| Laundries | 30,000 | Textiles | 31,000 |
| Fabricated Metals | 20,000 | Other Industrial (b) | 274,000 |
| Other Commercial (b) | 508,000 | | |
| **Total Commercial** | **1,850,000** | **Total Industrial** | **665,000** |

**Table 1-3**
Estimated Commercial and Industrial Water Use in California (Year 2000)

(a) Commercial water use, as reported herein, includes both commercial and institutional uses.
(b) "Other" commercial and industrial uses are included in this study but not differentiated by end use because of data limitations.

## A Word About Agricultural Water Use

The vast majority of water used in California goes to the agricultural sector – an important part of our water "economy" not discussed in this report. Current estimates are that three-quarters of California's applied water, and an even higher percentage of consumed water, is used for irrigation of food and fiber crops. Overall, the California Department of Water Resources estimated agricultural applied water use in the 1990s to be around 30 MAF/year.

Water use in many parts of California's agricultural sector is inefficient and wasteful, although some efforts are underway to address these problems. No comprehensive conservation and efficiency policy – indeed, no rational water policy – can afford to ignore inefficient agricultural water uses. If just 10 percent of this water can be saved with efficiency and conservation efforts – which we consider a highly conservative estimate given the available data and direct experience with on-farm efficiency programs in California and elsewhere – around 3 MAF of water would become available for alternative farming needs, ecosystem restoration, urban water use, or some combination (Owens-Viani et al. 1999, Vickers 2001).

Obviously, a better, detailed assessment of the potential to improve efficiency of agricultural water use is urgently needed. The Pacific Institute expects to develop a separate analysis of this potential if funding and time permit. Some unusual barriers make any such analysis difficult, however. In particular, the low prices paid for agricultural water send a message to farmers that efforts to improve efficiency are not worth pursuing. Institutional barriers such as outdated water laws, water rights constraints, and even tradition and culture also hinder farmers from making smart use of water that might otherwise be saved. Severe data gaps limit the ability to analyze waste in several sectors and regions. Experience shows, however, that when agricultural conservation and efficiency programs are tried, water has been saved, crop yields have been increased, and economic returns to farmers have improved. Ultimately, we believe that most farmers are innovative and ingenious. Given the proper information, incentives, technology, and regulatory guidance, great water savings will be possible in California's agricultural sector.

## Economics of Water Savings

Economics must play a fundamental role in helping to evaluate the relative merits of various water policy options and in implementing solutions to water problems. Each water conservation measure is an alternative to new or expanded physical water supply. We evaluate the cost-effectiveness of a range of water conservation options in Section 5.

It is important to note limitations of economic analyses. Many economic data are uncertain. Water prices and rate structures vary over a wide range of values and designs. Humans respond to prices, but total water use is also determined by non-financial factors such as culture, preference, and tradition. And the costs of water-efficiency options change with time.

In order to address these uncertainties, we make our assumptions and citations explicit. When data are ambiguous we conservatively estimate the costs of efficiency options by leaving out some of the difficult-to-quantify benefits. We note the uncertainties and inadequacies of the analysis. Finally, we have solicited extensive review and feedback on our approach. These steps help to ensure that, within the limited accuracy of any such analysis, they are likely to be as reliable as possible.

Utility managers are beginning to realize that interest, escalation, and delays associated with large capital-intensive water projects that lead to even slight forecasting errors can cause enormous increases in costs. It is an inherent characteristic of small-scale water-efficiency efforts that their lead times are substantially shorter than those of conventional big systems. Whether in development, distribution, installation, or repair, small and technically simple systems such as high-efficiency toilets, showerheads, or washing machines are faster than designing, permitting, financing, and constructing large-scale reservoirs. As Lovins (1977) noted for the energy industry, the industrial dynamics of this approach are very different, the technical risks are smaller, and the dollars risked far fewer.

One of the reasons that efficiency approaches are difficult for traditional water agencies to adopt is that they shift the burden from engineering logistics to social ones. Traditional water agencies are often comprised of highly trained engineering experts who know how to design and build large structures that can serve a million people. But these same experts are unfamiliar with methods for designing and implementing conservation programs that reach a million individual customers.

The results of our analysis strongly indicate that the economic benefits of improving statewide water-use efficiency are substantial and compelling. We do not attempt to determine the specific regional or sectoral cost-effective potential, since this depends on the water rates of individual agencies and on the specific options available to them, but it is important to note that in California, the popularity of conservation technologies should only increase in the future as competition for water grows, prices increase, and technology improves.

Our results also suggest that the benefits we have quantified **understate** the total benefits of these kinds of programs – perhaps substantially.

Below we list several kinds of benefits that we have not attempted to quantify, but that could have enormous additional advantages.

- Reductions in residential water use will lead directly to reductions in wastewater costs, both for treating wastewater as well as for building expensive new treatment facilities.
- Reductions in water use will lead to lower average peak water system loads – the most expensive kind of water to provide.
- Reductions in water use will lead to lower average peak energy demands – the most expensive kind of energy to provide.
- Reductions in water use and subsequently in wastewater generation will lead to reductions in environmental damages from water withdrawals or wastewater discharges in sensitive regions.
- Investments in water-use efficiency leave money in local communities and create local jobs. Investments in distant new supply options usually take money from local communities and create distant jobs.

## Data and Information Gaps

The "true" potential for water conservation technologies and programs will always be uncertain, because of wide variations in regional water use, prices, efficiency technologies, and many other factors. As a result, the estimates provided here should be used with caution and an understanding that they are only as good as the assumptions and methods used to develop them. We have tried to be conservative in our estimates and explicit in describing our assumptions, and believe that the potential for cost-effective improvements in water use statewide most likely exceeds the numbers reported here. But we urge that these kinds of estimates be done on local and regional levels as well, where uncertainties and data problems may be more readily resolved.

The availability of good data is a major constraint to comprehensive assessment of conservation potential. Data problems limit the ability of all researchers interested in water conservation and efficiency to evaluate potential savings and current success of conservation programs. We point out these data limitations throughout the report. But even when data were available, they often contained limitations that further affected the reliability of our estimates. Some data on efficiency programs were reported at the national level, which may be atypical. And when California-specific data were available, several factors often limited their usefulness.

Large uncertainties still remain about the potential for urban water conservation and improvements in water-use efficiency in California. The magnitude of this potential depends on how water is used, prices for both water and conservation technologies, rate designs and structures, existing and developing technology, public opinion and preferences, and policies pursued by water agencies and managers.

Many of the uncertainties associated with current estimates are the result of data gaps and flaws that, we believe, can be reduced with modest investments in data collection and analysis. Until better information is gathered, however, large investments in new water-supply systems should be delayed, since the best evidence suggests that they are economically and environmental unjustifiable when compared with conservation and efficiency improvements. In order to make intelligent decisions about water policy, gaps in the data urgently need to be filled, including the following examples (among many others):

- Residential landscape area is highly uncertain.
- Residential and commercial landscape water use is poorly understood or measured.
- Distribution of residential water-using appliances, by type and use, is not well known.
- Economic costs of conservation options are sensitive to actual costs, lifetimes of conservation technologies, interest rates, and many other factors. Estimates of costs should be developed on a regional and utility basis.
- The water balance of major regions has not been adequately done.
- Rates of industrial water reuse are poorly reported.
- The implications for water quality of conservation options have not been explored analytically.
- There is a lack of comprehensive multi-family water-use studies.
- Many benefits of water conservation are inadequately studied, poorly understood, or unquantified. These benefits include ecosystem improvements, reductions in wastewater treatment volumes, reduced need for investment for new facilities, and reductions in greenhouse gas emissions from changes in energy use.

## Matching Water Need with Water Quality

Often ignored in water efficiency debates is the issue of water "quality," by which we mean the "type" of water to be used to meet a given demand, as opposed to the traditional definition that evaluates the presence or absence of various forms of pollutants. Different water demands can be met with waters of differing quality. Traditionally in the United States, water delivered to a home is potable – treated to the highest drinking water standards in order to maintain human health free of water-related diseases. Only a tiny fraction of domestic water use, however, is used for drinking. Similarly, because municipal water systems are rarely plumbed for multiple uses, the same high-quality potable water is typically delivered to commercial, industrial, and institutional water users for toilet flushing, watering landscapes, washing cars, and even large-scale industrial cooling.

Future water demand in urban areas is all assumed implicitly to require potable water, which exaggerates the amount of water actually needed and the overall cost of providing it. If water agencies were able to better match the quality of the water available with the quality of the water needed to meet specific purposes, system reliability could be greatly increased and the risks of shortages reduced. We do not address this issue here, but note that rational water policy in regions of water scarcity should pay more attention to quality of water *needs*.

## "Real" Water, "Paper" Water, "New" Water

Confusing information has been published in the past few years about the benefits of "saving water" and the kinds of water that efficiency improvements produce. Some of this information has been extremely valuable in identifying where and when conservation is most beneficial for other users or the environment. Some of it, however, has been misleading and used to misrepresent the potential for efficiency improvements. Among the terms used to describe the "kinds" of water that might be saved are "real" water, "paper" water, "applied" water, and "new" water. In this section we describe some of these terms and the assumptions behind them.

A fundamental assumption underlying water-use projections in the California Water Plan (Bulletin 160-98) and adopted in the CALFED draft EIR/EIS is that most efficiency savings do not produce any real benefit to water supply. Their approach assumes that in a region with limited water resources and 100 percent downstream reuse, any reductions in non-consumptive uses of water do not produce "new" water, because any water saved is already committed for use by a downstream user. This distinction has long been understood in agricultural water analysis, and under limited circumstances it is very useful. Among other things, this distinction can help identify where improvements in water-use efficiency may be most appropriate and valuable (Keller and Keller 1995, Seckler 1996, Molden 1997).

This concept, however, also has a fundamental flaw, particularly when a distinction is made between consumptive and non-consumptive uses of water.[4] In a region with **fixed demands**, only reductions in consumptive uses produce "new" or "real" water that can be reallocated to other users in that basin or traded outside of a basin. This line of reasoning, when applied to certain calculations of agricultural water use, is justifiable.

Problems arise when this approach is applied to inland urban water use in a situation of **growing demand**. In such a situation, not all improvements in water-use efficiency lead to "new" water being created, but they all lead to real reductions in assumed future demands in a region. Hence they displace or eliminate equal amounts of expected demand for new supply. This is independent of whether that region returns water to a saline sink or downstream user. Every single gallon of water currently used to satisfy a need that can be met with less water is a gallon that could instead be used to meet another need. Every gallon that can be saved through water-use efficiency improvements is a gallon that can be left in a river for the environment. In a region of growing population or water demand, this means that every single gallon saved can be reallo-

4 A consumptive use of water prevents that water from being reused within a basin, such as through evaporative loss, contamination, or discharge to a salt sink such as the ocean.

cated to other future users, delaying or even eliminating the need to identify and deliver new water supplies.

Water-use efficiency improvements that reduce non-consumptive uses have other significant benefits that are real, but rarely quantified; for example, they reduce contamination of water, they increase the amount of water that can be left in a river or stream for ecological purposes, and they reduce wastewater discharges that must be treated at considerable expense. Additional benefits include energy savings from not having to heat, pump, or treat water; reduced costs of distribution system capacity; and savings in capital expenditures because of deferred or downsized new water-supply projects (Dziegielewski 1999).

The failure to properly categorize and apply urban water-efficiency improvements in California has led to a significant overestimate of future urban demand for water – we have previously calculated that overestimate to exceed one million acre-feet alone by 2020 (Gleick and Haasz 1998). As this report shows, we now believe it to be even larger.

## Recycled Water

The California Water Code defines recycled water as water that "as a result of treatment of waste, is suitable for a direct beneficial use or controlled use that would not otherwise occur." Recycled water must be considered an important part of smart water policy for California, in combination with conservation and efficiency. It is already playing an important role in water supply for many communities and end uses. California is currently recycling approximately 500,000 AF/year of water for various purposes and has the potential to recycle at least 1.5 MAF by 2030 (CDWR 2003a). While recycled water is not classically considered water conservation and efficiency, it does represent a new "source" of supply that could supplant the need to find other water resources for future needs.

## Where Do We Go from Here? Steps to a More Efficient World

Three steps are required to move toward a more water-efficient world: The first is identifying the potential for improving water-use efficiency and allocation. The second is identifying the institutional, economic, and technological barriers that impede these improvements. The third is implementing appropriate economic, educational, and regulatory policies needed to remove the barriers and capture the available savings.

While all of these steps require some discussion, the third one tends to cause the most consternation. Present water policymakers tend to portray conservation and efficiency as "uneconomic," argue that it will lead to an unacceptable change in lifestyle, or assume that it is unable to compete without restrictive regulatory requirements or wholly new technology. Yet when such approaches are proposed they are rejected as government intrusion in the market or social engineering. At the same time, traditional water developments are backed by powerful constituencies that have benefited from vast government subsidies, weak environmental laws, and past federal largess.

Rational discussion requires that all of these factors be considered and analyzed. While changing outdated water policies will not be easy, failing to change them will be worse.

### Economic Approaches

Economic techniques for reducing water use rely upon monetary incentives such as rebates and tax credits, as well as disincentives such as higher prices, fines, and penalty rate structures. The goal of both kinds of approaches is to provide accurate information to users about the value of water and the total costs of acquiring and using water. Setting the proper prices for water helps to ensure that goods and services are allocated to higher valued uses. In the past, subventions in the form of federal and state grants for construction projects, long-term contracts for water that don't reflect the full cost of water provision, and other subsidies have hidden many of the actual costs of water supply. At the same time, more and more evidence is accruing to show that economic tools can be very powerful approaches to encouraging efficient use of resources.

### Technical Approaches

Water demand is partly a function of technology and the structures built to manage demand. Structural approaches for reducing demand include altering existing systems to permit better control over water demand, such as through retrofitting of equipment, reducing leaks, metering, and recycling. Water efficiency can also be improved through advances in water-use technology and changing the physical nature of a system, such as by replacing grass with lower-water-using plants or recycling water used to clean semiconductors during chip manufacturing.

### Regulatory and Management Policies

Regulatory approaches include policies taken by governments to encourage water conservation, such as funding of public education programs, adoption of appliance efficiency standards, and proper design and application of building codes. Management options include modifying existing water-use activities to control demand. These can include efforts to reduce leaks, improve operational efficiencies, and shift personnel from supply planning to demand management.

### Institutional and Educational

There is a wide range of institutional approaches to encouraging water-use efficiency improvements, including some of the technical, regulatory, and economic approaches described above. Others include educational efforts to inform water users about the potential for water-use efficiency improvements, the options available for users, and costs and benefits of different approaches.

Successful water-use efficiency programs inevitably include combinations of government regulations, economic incentives, and technological changes. Considerable experience in every sector of the economy suggests that the most effective water-use efficiency programs include combinations of all of these approaches (Gleick et al. 1995, Owens-Viani et al. 1999).

### Better Information

The lack of good information hinders efforts to improve water use. Labeling and metering are particularly valuable tools because they provide information critical for understanding water use, setting proper prices, and managing water demand. Evidence from places as diverse as Canada, Washington, New York, Nevada, Colorado, and California has been available for decades that monitoring water use, typically through metering, has the effect of reducing water demand by 15 to 45 percent over unmetered levels (Flack 1981, Liedal 2002, USHUD 1984, Coons 1995, Bishop 1995, New York City 1997, Mitchell 2003). This is actually a pricing effect, as consumers see directly the economic impacts of their water use.

Frankly, while it has long been a source of amazement and amusement to many that water use in several California cities is not monitored and measured, it should now be a source of embarrassment to California water managers. It is unacceptable that in the 21st century, in a state in which water supply and demand are such important and controversial issues, that any urban water use remains unmetered. This is throwing away water and information – something we can ill afford to do.

## Conclusions

The large-scale adoption of water-efficiency measures in California has the potential to greatly reduce pressure on our scarce and precious water resources. Yet the potential for conservation improvements remains largely untapped. Few urban water suppliers can report detailed systemwide demand reductions as a result of conservation programs, though more and more cities and municipalities are getting serious about conservation.

Vickers (1999) describes the results from the Massachusetts Water Resources Authority, serving the Boston area, and the city of Albuquerque, New Mexico, which have reported major reductions (25 percent and 18 percent, respectively) as a result of aggressive conservation efforts. New York City has instituted some effective end-use efficiency programs. Owens-Viani et al. (1999) describes the activities of various California agencies that have achieved substantial water savings and reductions in wastewater volumes allowing them to avoid the time, expense, and controversy of new supply projects.

Even in California, however, which has long been aware of the need for improving water-use efficiency, most urban water conservation programs consist of a set of "best management practices" (BMPs) that are entirely voluntary, not comprehensive, incompletely implemented, and inadequately monitored. While they are an important step in the right direction, even full implementation of them will leave substantial amounts of cost-effective, technically achievable improvements untouched.

We estimate that approximately 2.3 MAF of water can be saved in California's urban sector based on current use and currently available, proven technologies. We estimate that at least 2 MAF of that amount is cost-effective to conserve – that is, meeting needs through conservation investments is less costly than meeting those same needs by building new supply projects. However, there can be no single estimate of the true potential for water-use efficiency improvements. Each water-use efficiency option comes with a different set of assumptions, physical structures, and costs. These characteristics will determine which components are most cost-effective, which are applicable in different regions or for different users, and, ultimately, how much future demands for water in California can be reduced or modified. We hope that this analysis is the beginning, not the end, of a real debate over water conservation in California.

# 2

# Indoor Residential Water Use and Conservation Potential

Water is used in homes for flushing toilets, washing clothes and dishes, bathing and showering, and satisfying a variety of other uses. In 2000, we estimate that Californians used about 2.3 MAF of water to meet indoor domestic needs. Water users have been improving efficiency for many years, by replacing old water-using technologies with those that permit us to accomplish the same desired goals with less water. We estimate that without these efforts, current indoor residential water use in California would have been closer to 3 MAF per year in 2000 – around 30 percent more than is currently being used. But we are far from capturing all potential savings.

**We estimate that indoor residential use could be reduced by approximately another 40 percent by replacing remaining inefficient toilets, washing machines, showerheads, and dishwashers, and by reducing the level of leaks, even without improvements in technology.**

The residential sector is the largest urban water use sector, and it offers the largest volume of potential savings compared with other urban sectors. This section describes specific indoor residential end uses and estimates the potential for improving efficiency of those uses with existing technologies.

For the purposes of analyzing the potential for improving the efficiency of indoor residential uses, we compiled a comprehensive set of data on end uses and built up overall estimates using population data, housing distribution, studies on water-use behavior, and end-use technology profiles. Using this information, we estimate that total indoor residential water use in California totaled approximately 2.3 million acre-feet (MAF) in 2000 (see Table 2-1). More water is used to flush toilets than for any other indoor use. The remainder of water used in California homes goes to meeting landscape and garden (and other outdoor) needs; these are addressed in Section 3.

**Table 2-1**
Estimated Current Indoor Residential Water Use in California (Year 2000)

| End Use | Current Use (AF/yr) | Fraction of Total Indoor Use (%) |
|---|---|---|
| Toilets | 734,000 | 32 |
| Showers | 496,000 | 22 |
| Washing Machines | 330,000 | 14 |
| Dishwashers | 28,000 | 1 |
| Leaks | 285,000 | 12 |
| Faucets | 423,000 | 19 |
| **Total Indoor Residential Use** | **2,296,000** | **100** |

## Existing Indoor Residential Conservation Efforts and Approaches

Efforts to reduce the wasteful use of water in California have been underway for many years. Indeed, water conservation efforts have already made a big difference in improving the reliability of California's water resources, both by reducing demand and freeing up new supply, reducing pressures to take any more water from the state's overtapped river, lakes, and aquifers. Beginning in the early 1980s, Californians have participated in a range of programs to replace inefficient toilets, showerheads, and faucets; to audit heavy water users looking for leaks; and to reduce water use in gardens and other outdoor landscapes. We estimate that over 700,000 acre-feet per year (AF/yr) of indoor savings have already been captured through a combination of smart regulation, improved technology, and educational programs. If used efficiently, this is enough water to meet the entire indoor residential needs of 17 million people each year.[1]

Among the first devices that agencies will chose for conservation programs are showerheads and toilets, because they have a short payback period and are relatively uncomplicated to manage and install. In contrast, we estimate that there has been little significant penetration of higher-efficiency dishwashers (a relatively newly available technology) or reductions in leak rates (because of limited leak detection and prevention programs and inadequate data). In between these two extremes is the growing use of high-efficiency washing machines – these did not begin to appear in significant numbers until the late 1990s, but are now increasingly available and popular. For example, in 1999, an estimated 10,000 rebates were issued for high-efficiency washers in California (based on reporting data from the California Urban Water Conservation Council (CUWCC)); in 2002 more than 24,000 rebates were awarded, and a total of 64,000 rebates have been awarded in the four years since 1999 (Dickinson, personal communications, 2003).

Figure 2-1 shows the indoor water savings that have already been achieved through current efforts and programs to replace inefficient toilets and showerheads. The top line is our estimate of what indoor residential water use in California would have been with no improvements in efficiency since 1980. The bottom line is our estimate of current indoor residential water use. As noted, we estimate that current use is around 750,000 AF/yr below what it would have been without existing conservation efforts.

1 One acre-foot currently satisfies the indoor residential needs of approximately 15 people in California. If currently available efficiency technology were used, one acre-foot could meet the indoor residential needs of 25 people. An acre-foot of water would cover one acre to a depth of one foot and equals 326,000 gallons.

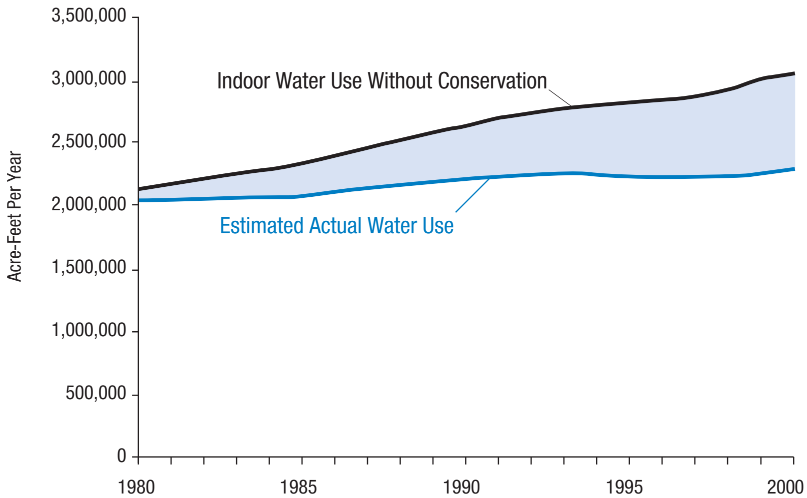



**Figure 2-1**
Total Indoor Residential Water Use with and Without Current Conservation Efforts (1980-2000)

Far more can be done to improve water efficiency, even with existing technology. The amount of water we estimate could be saved through comprehensive adoption of efficient technology and practices is presented in Figure 2-2. Table 2-2 summarizes the potential savings over current use for 2000 by specific end use. Although toilets have already had the single largest effect on indoor residential demand reduction, they still hold the greatest potential for savings. Leak reduction is also a worthwhile target for agencies' efforts. Reducing leaks usually requires adjustment of existing fixtures rather than complete replacement, which reduces overall costs. The savings potential of showers and washing machines is also relatively high, while that of dishwashers is modest. We estimate that full implementation of current conservation potential would cut current use by another 890,000 acre-feet – approximately a further 40 percent reduction. This would have the effect of reducing current indoor residential use, on average, from around 60 gallons per person per day (excluding some uses not evaluated here) to around 37 gallons per person per day.

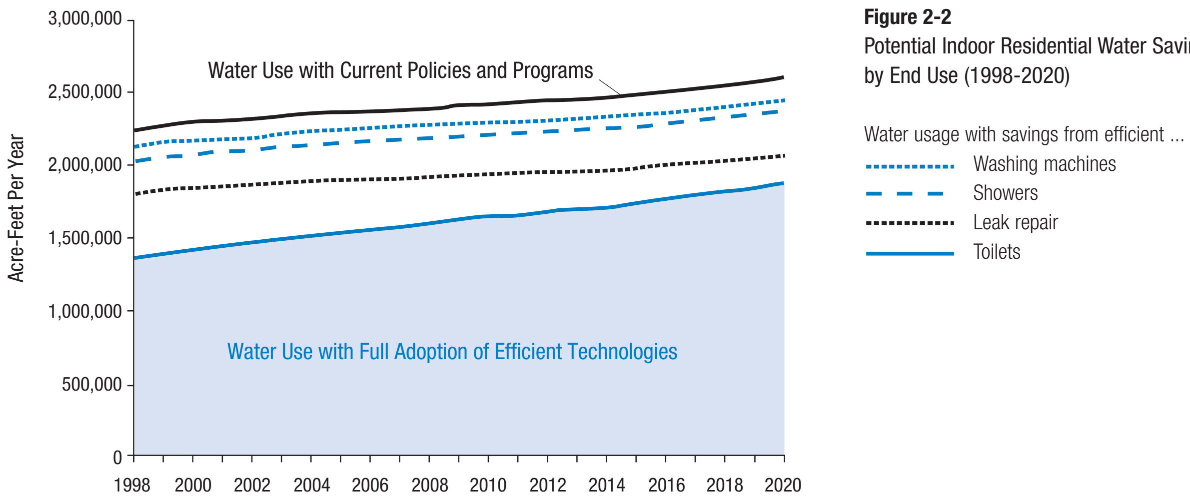



**Figure 2-2**
Potential Indoor Residential Water Savings by End Use (1998-2020)

**Table 2-2**
Indoor Residential Conservation Potential for 2000

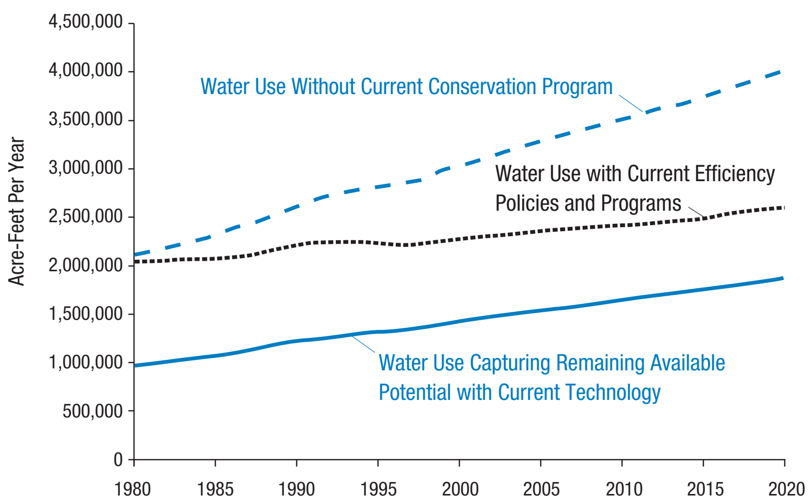
| Indoor Residential Water Use (Year 2000) | Best Estimate of Additional Cost-Effective Water Conservation Potential (2000) (AF/yr) | Conservation Potential: Percent Reduction Over Current Use |
|---|---|---|
| Toilets | 420,000 (a) | 57 |
| Showers | 120,000 (b) | 24 |
| Washing Machines | 110,000 (c) | 33 |
| Dishwashers | 13,000 | 46 |
| Leaks | 230,000 (d) | 80 |
| Faucets/Fixed Volume Uses | (e) | (e) |
| **Total Additional Indoor Savings** | **893,000** | **40** |

(a) For toilets, this requires full replacement of inefficient toilets with 1.6 gallon per flush models.
(b) For showers, this requires full replacement of showerheads with 2.5 gallon per minute models (with actual flow rates averaging 1.7 gallons per minute).
(c) For washing machines, these savings would result from the complete replacement of current models with the average (not the best) of the efficient machines currently on the market.
(d) The 80 percent savings estimate comes from assuming that leak rates are reduced to the median value now observed. At the same time, CDWR (2003b) estimates that half of all leaks can be saved for less than $100 per acre-foot and 80% for less than $200 per acre-foot. See Section 2 for more detail.
(e) For faucets and other fixed volume uses such as baths, no additional "technical" savings are assumed.

For all indoor uses, additional temporary "savings" can be achieved during droughts by behavioral modifications (e.g., cutting back on frequency of actions like flushing, showering, washing). We do not consider these to be "conservation" or "efficiency" improvements.

Figure 2-3 summarizes both the water savings that have been achieved between 1980 and the present and a projection of future potential indoor residential savings with both existing programs and all cost-effective savings to 2020, as a measure of the potential that remains. The top line is a projection of use if no conservation activities had been initiated in the state (i.e., using pre-1980 conditions). The middle line is our "current use" projection (i.e., assuming the current mix of efficient and inefficient uses). The bottom line is our estimate of the further reduction in indoor residential water demand that is possible with all cost-effective savings using existing technology (for more detailed calculations, see the Appendices at http://www.pacinst.org/reports/urban_usage/).

**Figure 2-3**
Indoor Water Use 1980-2020: The Effect of Conservation Policies




The following analysis is based on successful conservation and research programs, research on technologies for reducing water use, and an examination of current water-use patterns in California. The availability of reliable data on water use varies widely from sector to sector. For example, the information on water use and potential savings from toilets is fairly comprehensive and significantly more reliable and accessible than information on landscape water use. Some significant gaps in our understanding of water use remain, however, and we urge state and local water agencies to collect more information on use patterns and the penetration of water-use technologies and to make that information widely available. Without good information we cannot make good decisions.

## Indoor Residential Water Conservation: Methods and Assumptions

The first step in evaluating the savings potential of water-conservation options is to establish a reliable baseline of current water-use patterns. There are a number of different options for defining the baseline: water use by region, sector, household, individual, or specific use. Typically the baseline is reported as water-delivery data (by water agencies and CDWR), but we chose to build the baseline by end use. Looking at end uses allows us to evaluate the effect of improvements in end-use technology and management on water demand while maintaining the purpose for which the water is required.

The end uses examined for the indoor residential sector are sanitation (flush toilets), bathing (showers and baths), washing dishes and clothes, faucet use, and water lost to leaks. Our analysis of outdoor water uses (Section 3) evaluates improvements in water use in gardens and landscapes through technological changes, management efforts, and alternative landscape designs. Water use is variously measured on a per capita (per person), per use, or per household basis. Population and housing data for 1980-1998 and projections into the future were obtained from the California Department of Finance (CDOF). Statewide savings were based on savings from individual end uses summed across regions and populations.

Information on the penetration of water fixtures came partly from the U.S. Census Bureau's American housing survey (U.S. Census Bureau 1995), which includes a breakdown of what kinds of fixtures and appliances people have in their homes. Additional background came from detailed data from California water agencies, individual water districts around the state, and specific end-use surveys. The frequency and intensity of end-use events were obtained from focused end-use studies, including those conducted by AWWARF and reported by Mayer et al. (1999); (the "Residential End Use of Water" study is hereafter referred to as the REUW study).[2]

We applied these empirical values to the entire residential population but made adjustments for differences in certain kinds of domestic uses, regional variations, and certain categories of users. For example, we estimate there is little difference in per capita shower duration or toilet use between single-family and multi-family residents, but there were significant differences in penetration rates of appliances.

Figure 2-4a-c shows indoor water consumption by end use according to three different estimates: the general REUW (Mayer et al. 1999) study,

2 The REUW study is by far the most comprehensive set of surveys of residential indoor water use to date. The study included a survey of 100 representative single-family residences in 12 North American cities. For two summer and two winter weeks, the timing and flow rates of all water-using events were recorded with meter readings every 10 seconds. Over 120 million data points were recorded, and algorithms were developed to identify specific water uses. Using these results, the authors were able to determine how much water was being used by each end use. Surveys determined whether the fixtures were water-conserving or not. Total water use was also converted to per capita values in order to evaluate individual water-use patterns.

California's Bulletin 160-93 (CDWR 1994a), and our current analysis. The differences among the results reflect differences in measurement approach and reporting. For example, DWR does not include leaks, but apportions lost water among different end uses for 1990. The REUW study is based on specific measurements from a subset of single-family housing, while our estimates for 2000 are based on overall end-use estimates for California.

**Figure 2-4a**

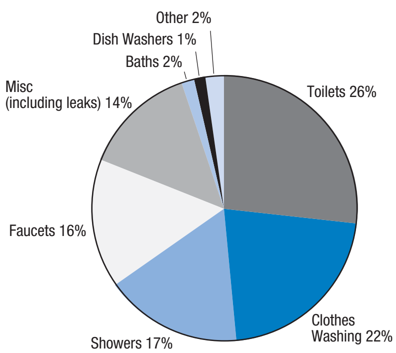



**Figure 2-4b**

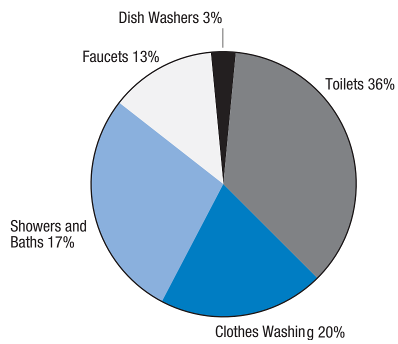



**Figure 2-4c**

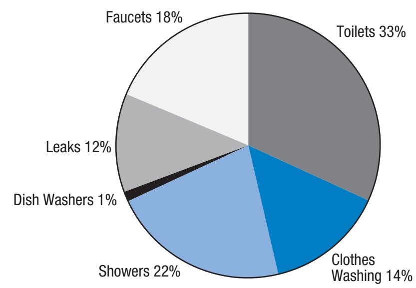



**Figure 2-4a**
Household End Use of Water (Indoor)
(Mayer et al. 1999)

**Figure 2-4b**
Household End Use of Water (Indoor)
(CDWR 1994a)

**Figure 2-4c**
Household End Use of Water (Indoor)
(current estimate for 2000)

The water demand of each indoor residential end use was modeled separately; assumptions and results are described below.

## Toilets

Flushing toilets is the largest single use of water inside the home. Estimates for toilet use range from 28 percent to almost 40 percent of total indoor use.[3] We estimate that 32 percent of current indoor residential water use goes to toilets. For this reason, improving the water efficiency of toilets has long been a high priority. Technical innovations in this field have made it possible to reduce the water used by toilets from 6 gallons per flush (gpf) to under 2 gpf. To tap this potential, federal and state water-efficiency laws now standardize flush volumes at a maximum of 1.6 gpf for all new toilets. Even more efficient toilets are now becoming available, but we do not include them in our assessment.

For our analysis, three types of toilets were considered: non-conserving, conserving, and ultra-low-flow, flushing at 6, 3.5, and 1.6 gallons, respectively. Prior to the late 1970s, all toilets typically used 6 gpf. Effective January 1, 1978, California state law required that toilets not exceed a flush volume of 3.5 gallons. Allowing for an initial lag, we selected 1980 as the year these toilets began to penetrate the residential sector market. In 1992, the National Energy Policy Act reduced the maximum flushing volume of new toilets sold in the United States to 1.6 gallons per flush, effective January 1994. Toilets meeting this standard are often referred to as ultra-low-flow toilets (ULFTs).

The REUW study (Mayer et al. 1999) found that ULFTs were flushed at a slightly higher frequency than non-ULF toilets. The data show that

3 The lower estimates come from studies that include leaks in estimates of total indoor use.

ULFT toilets were flushed slightly more than five times per person per day, while residents of non-ULF homes flushed about 4.9 times per day.[4] Some recent data suggest that the latest ULFTs have the same flushing frequency as non-ULFTs, but we adopted the more conservative frequency estimates into the analysis. Population was used as the standard measure, thus eliminating differences associated with toilet use in single-family and multi-family units.

Toilets do not always flush at their nominal values. Significant differences result from internal refill settings and flush mechanisms. For example, pre-1980 models, designed to use between 6 and 7 gpf, have sometimes been found to use between 4.5 to 5.0 gpf (CUWCC 1992). Low-flow toilets have a nominal flush volume of 1.6 gpf, but field studies show that some early versions used as much as 2 gpf or even more if the water lines or flappers were not correctly adjusted (CTSI 1998). We used nominal flush volumes in this analysis because new studies show the consistency and dependability of 1.6 gpf models have been greatly improved over the earliest units (Leibold 1998, Nelson and Weber 1998, MWD 1998, Koeller, personal communication, 2002). We expect that future ULFT models are more likely to consistently flush at 1.6 gpf, or even less as more efficient models become available and as performance issues are resolved by market forces (Osann and Young 1998).

There has been some concern about flapper (the device closing the flush valve) failure eroding the savings from efficient toilets. While a toilet generally has a useful life of around 25 years, the flapper may fail earlier (MWD 1998, Koeller, personal communication, 2002), especially those subject to the corrosive effect of bowl cleaners, the leading cause of flapper decay. While no performance standards mandate better flappers, market forces and plumbing standards are already eliminating such decay in performance.

To determine how much total water is being used to flush toilets, we calculated the distribution of toilets statewide by flushing volume. Three pieces of information were necessary to answer this question:

- the proportion of the population living in new housing
- the natural replacement rate for toilets, and
- the number of toilets actively retrofit by utility programs.

*The proportion of the population living in new housing*

Since all post-1980 housing requires lower flow toilets by law, the population living in new housing was assumed to be using the more efficient model toilets. Yearly housing estimates, available from the DoF, provided a figure for the number of new houses each year. All houses built after 1980 are assumed to have 3.5 gpf toilets, and all homes built after January 1994 are assumed to have 1.6 gpf models. New housing construction estimates are multiplied by the average number of people per household, resulting in yearly estimates for the population living in new houses.

4 Results were similar in a Seattle study, which found that average flushes per capita were 5.17 and 5.53 with non-ULFT and ULFT models, respectively (Mayer et al. 2000). The REUW study sample size was larger, and we use those numbers here.

### *The natural replacement rate for toilets*

The natural replacement rate refers to the replacement of equipment due to age and wear. The replacement rate used in our model was four percent per year as proposed by the ULFT subcommittee of the CUWCC (CUWCC 1992), equivalent to a 25-year life for toilets.

### *The number of toilets actively retrofit by utility programs*

Water agencies and utilities have long recognized the water-saving potential and economic benefits of ULFT installation. For many agencies, their conservation programs began with accelerating ULFT replacement because the savings captured are large, easy to quantify, and cost-effective to implement. Replacement programs of Southern California agencies have been especially active.

Statewide estimates of utility retrofits do not exist, though data are available for specific water agencies and other sources. In order to develop statewide estimates, information from several sources was compiled, including:

- California Urban Water Conservation Council annual reports. These reports provide estimates of retrofits as reported by their member agencies. However, only signatories of the CUWCC memorandum of understanding (MOU) are required to submit reports, and even they do not always fulfill this requirement. In 1995-96, 52 percent of member agencies submitted reports; in 1996-97, 63 percent of agencies submitted reports, covering only about half the total state population. Even when submitted, the reports are not necessarily accurate. The 1997 BMP Performance Evaluation for the California Urban Water Agencies (CUWA) by Mitchell and Illingworth surveyed eleven large water providers and gathered specific data for each on the number of toilet replacements by year. Although many of the state's large providers were surveyed, there were a number of omissions. Since these figures were reported by agency, it was easier to find and fill in the omissions in this document than it was with the CUWCC reports.

- Direct contact with water providers. Direct contact allowed some of the data gaps in the other reports to be filled and more up-to-date information to be used.

We estimate that about 2.3 million toilets have been retrofit through agency conservation programs through 1998, very close to the estimate of the CUWCC of 2.2 million toilets retrofit statewide (Dickinson, personal communication, 2002). Using data from specific agency studies, including some with precise data on fixture counts for both single- and multi-family accounts, we estimate that there are about 0.76 toilets per person statewide (CTSI 1998, Nelson 1998).[5]

The distribution of toilets statewide was determined by calculating the number of 3.5 and 1.6 gpf toilets that had been installed since 1980, accounting for all new homes, active retrofit programs, and natural

5 CTSI found that, on average, there are 2.1 toilets in single-family homes, 1.4 in multi-family. This is equivalent to 0.77 toilets/person in single-family homes, 0.7 toilets per person in multi-family homes.

replacement. We estimated the total population using low-flow toilets in any given year (Plf) using the following equation:

$$P_{lf} = \Sigma P_{nr} + \Sigma P_{nh} + \Sigma P_{ar}$$

**Equation 2-1**
Number of People Using Low-Flow Toilets

where:

- P is the population for a given year
- $P_{nr}$ is the population using toilets that have already been retrofit as a result of the normal replacement cycle (see equation below)
- $P_{nh}$ is the population in new housing, and
- $P_{ar}$ is the population using toilets retrofit by active programs.

For a given year, the number of people using toilets that have been replaced as a result of the normal toilet replacement cycle is calculated by applying the replacement rate to the population that had not had their toilets replaced by either active or passive programs, and who were not living in a newer home built with efficient model toilets.

$$P_{nr\,\mathit{(current\ year)}} = (P - \Sigma P_{nr\,\mathit{(previous\ years)}} - \Sigma P_{nh} - \Sigma P_{ar}) * TR$$

**Equation 2-2**
Number of People Using Low-Flow Toilets Installed Due to Natural Replacement

where TR is the natural turnover rate.

These calculations were done annually and statewide, providing a population distribution by flush volume. Multiplying the population in each category by flush volume and frequency generates total water use by year for residential toilets. For the separate estimate of maximum practical savings, 1.6 gpf was used as the flush volume for the entire state's population. While newer, more efficient toilets are now coming on the market in many countries – including dual-flush toilets that use a different volume of water for liquid and solid waste, and even no-water options – we have not calculated their potential for California.

For the projection of savings likely to be reached by 2020, we used population projections from the Department of Finance in order to estimate the number of people likely to be living in new housing. Official projections do not differentiate by housing type, so we calculated the proportion of the state population in new housing for 1980-1998 (1.4 percent) and applied that to official 2020 population projections. No estimate was made of toilets installed due to future retrofit programs.

Our calculations to 2000 assume that toilets have a life span of 25 years and therefore we conservatively estimate that only 6 gpf toilets are retrofit through agency programs and natural replacement. It does happen that some old toilets that would likely be replaced as part of the natural replacement cycle are replaced through agency programs. These are called free riders. This assumption has no effect on our estimates of potential savings from full implementation of ULFTs. It is, however, relevant to designing policies to capture effective savings and could slightly change savings estimates for any given year.

When projecting to 2020, we accounted for the natural turnover of 3.5 gpf toilets that began in 2006 as well as the ongoing turnover of 6 gpf units. This turnover was accounted for by subtracting the sum of the retrofits over the preceding 25 years. For example, for the year 2006 we subtracted from the population of that year those people whose toilets had been retrofit between 1981 and 2005. The population using toilets that had been retrofit in 1980 was once again subject to the natural replacement rate. We then applied the four percent turnover rate to both the populations using 6 and 3.5 gpf toilets in order to determine the population using ULFTs and to establish an estimate for water use.

### *ULFT Results: Much Progress Made, Many More Gallons to Save*

The availability of more efficient toilets has already had a noticeable impact on the volume of water used by homes statewide. We estimate current water used by residential toilets statewide is around 730,000 acre-feet per year (in 2000), substantially below the 1.145 million acre-feet that would have been used without the installation of any low-flow toilets. Yet if all the remaining inefficient toilets were replace statewide, current use would be less than 320,000 acre-feet – a potential further reduction of nearly 60 percent over current use. Table 2-3 summarizes our estimate of how many 1.6 gpf, 3.5 gpf, and 6 gpf toilets remain in California in 2003 and in 2020 under continued natural replacement. Table 2-4 summarizes our findings for year 2000 toilet water use under different efficiency assumptions.

**Table 2-3**
Distribution of Toilets in California

| Year | 6 gal/flush | 3.5 gal/flush | 1.6 gal/flush |
|---|---|---|---|
| 2003 | 7.3 million | 13 million | 7.3 million |
| 2020 | 3.7 million | 6.7 million | 24 million |

Assuming continued natural replacement to 2020, most toilets will be 1.6 gallon per flush ULFTs, but substantial numbers of inefficient toilets will remain in place.

Figure 2-5 shows the savings achieved to date as a result of the national efficiency standards and utility conservation programs that promote low-flow toilet installation and projections to 2020 using continued natural replacement. These savings are represented by the difference between the top line, which denotes water use without the California and Federal standards (i.e., assuming everyone was still using 6 gpf toilets), and the middle line, which graphs our estimates of current use. The difference between these two lines is the 412,000 AF (in 2000) that we estimate ULFTs are currently saving every year (see Appendix A, Table A-2, at http://www.pacinst.org/reports/urban_usage/). The amount of water now used to meet the sanitation needs of 34 million people is less water than the state used for this purpose in 1980 to meet the needs of only 24 million people.

By 2020, we estimate that total water used for toilets will drop another 125,000 acre-feet per year below year 2000 levels just through natural replacement, even with a 30 percent increase in population. Yet under this business-as-usual scenario, about 10 percent of the state's population will still be using inefficient toilets in 2020. Thus, we project that without greater efforts, water used for sanitation in 2020 will be around 200,000 acre-feet higher than it needs to be, even with current technology, and nearly 325,000 acre-feet lower than current (year 2000) use. The bottom line in Figure 2-5 represents maximum available savings, when all toilets in the state meet the current standards. The difference between the line representing current use and the line representing maximum practical savings is the savings potential beyond natural replacement. Moreover, these savings are cost-effective for consumers, even if water prices do not rise from current levels. The economics of these replacements are discussed later in this study.

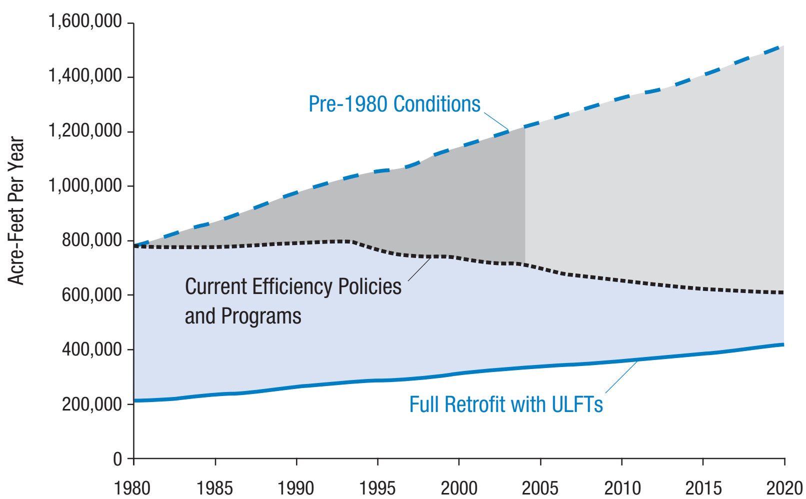



**Figure 2-5**
Water Use for Toilet Flushing (1980 to 2020)

Savings achieved to date
Savings achieved by efficient toilets
Additional potential savings

This graph shows how much water California homes would use for flushing toilets assuming all toilets are inefficient 6 gpf (pre-1980) types; the current mix of inefficient and efficient toilets; and all toilets are efficient 1.6 gpf models. Water use is projected through 2020 assuming continued natural replacement of inefficient toilets.

### *Emerging Technology Can Further Increase Efficiency*

As noted earlier, full replacement with current ULFT technology does not represent the maximum technical savings. The current standard in the United States requires toilets that flush at 1.6 gallons, but more efficient technology has already been tested and installed extensively in other countries. The Save Water and Energy Education Program (SWEEP) in Oregon tested one example, the Caroma Caravelle 305, imported from Australia where dual-flush toilets are the norm. Dual-flush toilets have a two-button mechanism; one button is designated for liquid waste and flushes at about 0.9 gallons; the one for solid waste flushes at the standard 1.6 gallons. SWEEP found that the toilets performed well and that the liquid-flush mode was used about 65 percent of the time. Based on their sample, this design offers an additional 2,000- to 2,500-gallon savings per home per year over the standard 1.6-gallon toilet (Sullivan et al. 2001). While these types of toilets are fairly common in other countries, they have yet to penetrate the North American market.

**Table 2-4**
Summary of Estimated Water Use in California Residential Toilets: With No Efficiency Improvements, Current Use, and Maximum Practical Savings (for 2000).

Note: "Maximum practical savings" is represented by 1.6 gallon per flush (gpf) models, "no efficiency" is represented by 6 gpf models, and "current use" represents the current mix of efficient and inefficient models.

| Fixture | Water Use, No Efficiency Improvements (AF/yr) | Water Use, Estimated Current Use (AF/yr) | Water Use, Maximum Practical Savings (AF/yr) | Additional % Savings, Over 2000 Use (%) |
|---|---|---|---|---|
| Toilets | 1,146,000 | 734,000 | 313,000 | 57 % |

## Showers and Baths

Water used for showers and baths is typically the second- or third-largest category of indoor residential water use. We estimate for California that showers use 22 percent of all indoor home water. Federal legislation has already played a role in tapping the potential savings from showers and baths. The National Energy Policy Act of 1992 mandates that new faucets not exceed a flow rate of 2.5 gpm. Prior to that, the standard flow rate had been 5 gpm.

Originally we intended to use the same analysis method for showerhead water use as we did for toilets – estimating the turnover and retrofit rates in order to get an idea of the statewide distribution of showerheads. Numerous studies have looked at the rate of installation and retention of distributed showerheads. However, the rebate and installation programs sponsored by the utilities were generally monitored less carefully than were ULFT retrofits, making it difficult to determine the number of showerheads distributed and the fraction actually installed.

We assume that no savings are possible from improving fixture efficiency when it comes to baths, which are a fixed volume use, though temporary savings can be achieved during droughts by reducing the frequency of baths. This type of behavioral change is not evaluated here and represents a buffer for water agencies during periodic shortages. Studies show that changing showerheads to low-flow units reduces average shower water use. The REUW study, for example, reports that households having all low-flow showerheads use on average about nine percent less water than households without these fixtures.

An additional problem with estimating shower water use is that showers are often "throttled" below their maximum rated flows (Warwick and Hickman 1994, Mayer et al. 1999). In order to set preferred water temperatures, the cold and/or hot water faucets are often not set at their maximum potential flow. An early study by Brown and Caldwell estimated this "throttle factor" to be 66 percent. In other words, actual faucet flow averaged two-thirds of the maximum rated flow (USHUD 1984). Showerhead flow rates also vary widely depending on the specific model, water pressure, and condition of the fitting. This makes it difficult to distinguish between saturation of low-flow showerheads and showers that are throttled below their maximum capacity.

Vickers (2001) provides information on nominal and actual showerhead flow rates (Table 2-5). We incorporate the "throttle factor" by estimating the mix of showerheads by rated flow and using actual flow to calculate use. We make the following assumptions in determining showerhead water use:

- All pre-1980 showerheads flow at 5.0 gpm.
- Showerheads have a natural replacement rate of eight percent per year.
- From 1980 to 1994 5.0 gpm showerheads are replaced with 3.5 gpm models.
- After 1994 replacement showerheads are assumed to be 2.5 gpm models.
- Shower frequency is 0.67 showers per person per day (Mayer et al. 1999, 2000).
- Shower duration is 6.8 and 8.5 minutes for non-low-flow and low-flow models, respectively (Mayer et al. 1999).[6]

**Table 2-5**
Estimated Water Use by Showerheads

| Years Manufactured or Installed | Rated Flow (gpm) | Assumed Actual Flow (gpm) |
|---|---|---|
| 1994-present | 2.5 | 1.7 |
| 1980-1994 | 2.75 | 1.8 |
| | 3.0 | 2.0 |
| | 4.0 | 2.7 |
| Pre-1980 | 5.0-8.0 | 4.3 |

Source: modified from Vickers (2001).

### *Water Savings of Efficient Showerheads*

Replacing a 5.0 gpm showerhead with a 2.5 gpm model will save about 17 gallons per shower, or over 4,000 gallons per person per year (gpcy). Replacing a 3.5 gpm with a 2.5 gpm model will save about 8.5 gallons per shower, or about 2,000 gpcy. We do not estimate water savings of baths, considered here a fixed volume use.

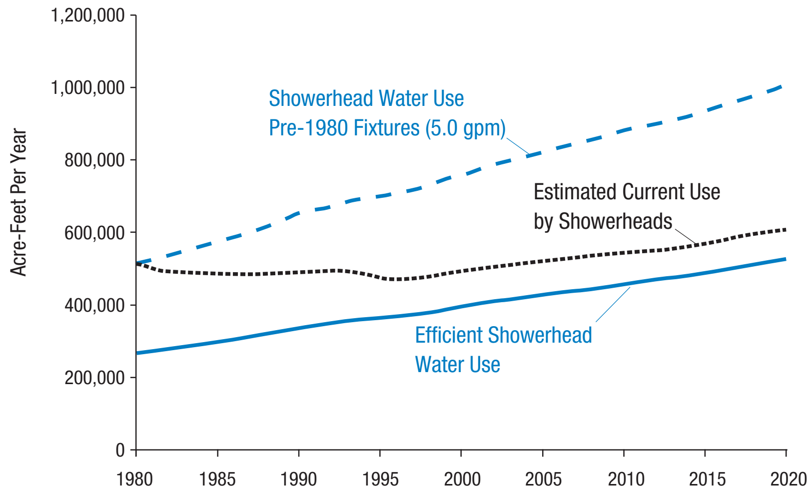
If no showerheads in California had been replaced with more efficient models, we estimate that water used for residential showers would be around 760,000 acre-feet per year (in 2000). Past conservation programs have managed to reduce this demand to around 496,000 AF/yr (in 2000), a reduction of 35 percent and a savings of around 264,000 AF/yr (see the Appendices, http://www.pacinst.org/reports/urban_usage/).

Figure 2-6 shows the water used for showers in the state at different flow rates. According to our calculations, if all showerheads today were high-efficiency models, they would save an additional 120,000 AF/yr, cutting demand for showers to around 376,000 AF/yr – a reduction of 24 percent over current use. Full installation of the current generation of efficient showerheads by 2020 would save more than 110,000 AF/yr beyond our expected 2020 levels of use. Even with growing populations, full use of efficient showerheads would permit water used for showers to remain at the 2000 level in 2020 – approximately 495,000 AF/yr.

6 There has been disagreement as to whether the showerhead flow has an impact on the duration of showers. Skeel and Hill (1998) found that when 3.1 gpm showerheads were replaced with 1.9 gpm models, shower duration dropped from an average of 91 to 68 minutes per unit per week, suggesting an increase in awareness and concern over water use. On the other hand, the REUW analysis found that shower duration can increase when lower flow units were installed: non-low-flow (2.5 gpm or higher) and low-flow shower duration averaged 6.5 and 8.3 minutes per shower, respectively. We use the more conservative REUW study data here.

**Figure 2-6**
Water Used by Showers (1980 to 2020)

This graph shows how much water California homes would use for showers assuming different showerhead flow rates. Water use is projected through 2020 assuming continued natural replacement of inefficient showerheads.




### *Energy Savings of Efficient Showerheads*

Switching to a low-flow showerhead also saves substantial amounts of energy by reducing the amount of water that requires heating. Shower water temperature is heated about 45° F from 60° to 105° F on average (Meier et al. 1983). Average annual water savings from replacing inefficient showerheads are around 4,000 gallons per year. To convert the water savings to energy savings we used Equation 2-3, calculating that the amount of energy required to warm up the saved water is about 19 therms (we assumed the efficiency for gas water heating is 80 percent). For energy use estimates from 1980 to 2020 see the Appendices (http://www.pacinst.org/reports/urban_usage/). These energy savings are an important part of the analysis of the cost-effectiveness of replacing inefficient showerheads.

**Equation 2-3**
Energy savings from Low-Flow Showerheads

### Annual Energy Savings

= [(4033 gallons/yr * .00378 m3/gallon * 1000 kg/m3 * 1000 g/kg * 25° C * 4.2 J/g° C * 1 kWhr/3.6 * 10^6 J * .03414 therms/kWhr)]/0.8

= 19 therms/yr

## Washing Machines

Residential washing machines currently use around 330,000 AF/yr in California, and significant savings can be achieved with new machines. Efficient machines can save a typical household up to 7,000-9,000 gallons of water a year (Bill Jacoby, personal communication, 2002; CEE 2003), cutting per capita indoor use by 6 to 9 percent (Mayer et al. 1999), and these savings are accompanied by a wide range of secondary advantages.

The vast majority of residential washing machines in the U.S. are top-loading machines that immerse the clothes in water and spin around a

7 For typical usage, 80-90 percent of the energy use attributed to clothes is used to heat water. The partial filling of the tub means less total water is required, less hot water, and less water-heating energy (DOE 1990 in http://www.ci.seattle.wa.us/util/recons/papers/p_sh1.HTM).

vertical axis. Horizontal-axis designs use a tumbling action where the washer tub is only partially filled with water, requiring far less water, energy, and detergent.[7] Horizontal-axis washing machines, long popular in Europe where they have captured over 90 percent of the market, have only recently been introduced to the United States.

In the past few years, increasing attention has been paid to the potential for efficient washing machines to reduce water and energy use. Rising pressure on water and energy resources nationwide has prompted detailed field and laboratory surveys evaluating savings from the use of more efficient washing machines (Consortium for Energy Efficiency 1995, USDOE 1996, THELMA 1998). The High Efficiency Laundry Metering and Marketing Analysis project (THELMA) consisted of both lab and field analysis of machines currently available on the market. Separately, the Department of Energy and the Oak Ridge National Laboratory conducted a five-month field study in Bern, Kansas involving 103 machines and over 20,000 loads of laundry. Both studies yielded similar results: water savings of about 15 gallons per load.[8] Water savings from efficient machines are generally estimated to be between 40 and 50 percent (Hill et al. 1998, Pugh and Tomlinson 1999). This potential has encouraged many utilities nationwide to incorporate washing machine programs into their conservation programs.

**Table 2-6**
CEE Washing Machine Specifications

| Level | MEF | WF |
|---|---|---|
| **Baseline*** | **0.817** | **13.3** |
| Tier 1 | 1.26 | 11.0 |
| Tier 2 | 1.42 | 9.5 |
| Tier 3 | 1.60 | 8.5 |
| Tier 4A | 1.80 | 7.5 |
| Tier 4B | 1.80 | 5.5 |

MEF=Modified Energy Factor, a combination of Energy Factor and Remaining Moisture Content. MEF measures energy consumption of the total laundry cycle (washing and drying). It indicates how many cubic feet of laundry can be washed and dried with one kWh of electricity; the higher the number, the greater the efficiency.

WF=Water Factor, the number of gallons required per cubic foot of laundry. A lower number indicates more efficient water use.

*Baseline MEF is the Federal minimum standard, which is scheduled to increase to 1.04 in 2004 and 1.26 in 2007. Baseline WF is an average for washers sold in 1994, as supplied to DOE by the Association of Home Appliance Manufacturers (AHAM).

Source: http://www.ceeformt.org/resid/seha/sehaspec.php3#rwsh2

In 1993 the Consortium for Energy Efficiency (CEE) launched a high-efficiency clothes washer initiative to accelerate the manufacture and sales of high-efficiency machines, recognizing the value of these machines in terms of reduced pollution, wastewater, energy, and water use. The CEE's high-efficiency specifications include both energy and water factors (Table 2-6). In January 2001 the DOE worked with the CEE, manufacturers, and energy conservation advocates to establish national energy-efficiency standards for residential clothes washers, effective 2007. Despite requests from several water agencies (including the San Diego County Water Authority, Santa Barbara, and the Santa Clara Valley Water District) to add a water-efficiency requirement, the new standards have not been explicitly linked to water use.

There has been more legislative success in California, which became the only state to adopt water-efficiency standards for washing machines with the passage of AB 1561, signed into law in the fall of 2002. The bill, which is supposed to take effect in 2007, requires newly manufactured home washers not to exceed a water factor of 9.5 (equivalent to current commercial standards). Currently, some washers rated as energy efficient have a water factor of 11.0, while the average washing machine sold in the mid-1990s has a water factor of 13.3.

8 The two studies used a similar experimental design; the Bern study, however, examined only one efficient washing machine model, while the THELMA study used three different H-axis models.

In a previous Pacific Institute study, the hydrologic impacts of replacing clothes washers were examined (Steding et al. 1996). From weighted average tub volume, a water factor (gallons per cubic foot of tub volume per load) and water consumption per load were calculated for the different models (Table 2-7).[9] This allowed for adjustment for the slightly lower tub volume in some of the horizontal-axis machines. The maximum savings per washer load is about 20 gallons for a machine filled to maximum capacity. As noted earlier, field-testing results are somewhat lower, averaging about 15 gallons per load (Pugh and Tomlinson 1999).

**Table 2-7**
Water Use for Vertical and Horizontal-Axis Washing Machines

| Technology | Gallons Per Load | Water Factor | Source |
|---|---|---|---|
| Average machine in use (1995) | 44 | 16.5 | Kesselring and Gillman 1997 |
| Average machine in use (1995) | 37.5 | 14.3 | CEE 1995, USDOE 1996 |
| Average machine shipped (1995) | 35.8 | 13.3 | CEE 1995, USDOE 1996 |
| Current generation efficient washers | 24.2 | 9.1 | CEE 1995, Kesselring and Gillman 1997 |

To quantify statewide savings potential and cost-effectiveness, we compiled a comprehensive list of machines and evaluated machines that offered comparable performance for a comparable price.[10] We compared the water use of average-sized loads rather than water use at maximum capacity because, with an average frequency of one load per day, studies suggest that most households are not filling their machines to capacity and that washer loads weigh about seven pounds (lbs), while capacity averages about 20 lbs (Chin, personal communication, 2002). We used this average in our analysis, a value similar to that used in standard test procedures.

We divided our list of washing machines into efficient and non-efficient models and compared water use in similarly priced efficient and non-efficient machines. On average, a medium-sized load requires 36.4 gallons in an inefficient machine and 26 gallons in an efficient machine. These savings are more conservative than some of the other estimates being applied; Seattle City Light uses 12 gpl in their analysis (Chin, personal communication, 2002), and the SWEEP study found average savings to be between 14.1 and 15.2 gpl (Sullivan et al. 2001). For maximum available savings we assumed that new machines averaged 24.2 gallons per load. We used the average for existing machines (36.1 gpl) to estimate current conditions.

Information on the penetration of washing machines and frequency of use came from the 1995 American Housing Survey (U.S. Census Bureau 1995), which found that 73 percent of households in the U.S. have washing machines. A separate set of surveys for California cities reveals a range of washing machine penetration of between 69 and 86 percent (Table 2-8). Studies also indicate that the fraction of homes with washing machines has been increasing in recent years. We adopt the more conservative penetration rate of 73 percent and calculate that there are just fewer than 9 million washing machines in the state today with about 2 million more in use by 2020.[11] We use a frequency value of 0.96 loads per

9 The water factor was calculated by dividing the weighted average water consumption per load by the tub volume of the washer. The weighted average water consumption was calculated by assuming the maximum fill to be used 72 percent of the time and the minimum fill 28 percent of the time as per Department of Energy load usage factors. For more information, see the Pacific Institute study (Steding et al. 1996).

10 Hill et al. (1998) finds that consumer choice of washing machine is primarily governed by cost.

11 To estimate the number of households in 2020, we used population forecasts from the CDOF and assumed the same number of persons per household as in 1999.

household per day, determined by averaging the results of three different studies (Koomey et al. 1995, USEPA 2002, Mayer et al. 1999). In terms of the penetration rates of HE machines, we used Energy Star estimates: 20 percent of new machines in CA are HE with a lifetime of 12 years. We also incorporated the legislation that requires that beginning in 2007 all new machines will be HE. From these assumptions we estimated the amount of water used by washing machines and the potential savings from conversion to efficient machines (for detailed calculations, see the Appendices, http://www.pacinst.org/reports/urban_usage/).

### *Summary of Assumptions for Washing Machine Analysis*

- The penetration of efficient washing machines prior to 1998 is negligible.
- Machine lifetime is 12 years.
- Twenty percent of new machines now sold in California are HE until the new standards take effect.
- Frequency of use is 0.96 loads/household/day. The average tub size is 2.65 cubic feet and the load at that tub size is about 7 pounds.
- The persistence of savings from high-efficiency machines has not yet been analyzed. We assume the savings remain consistent through time.
- We ignore behavioral changes associated with clothes washing. Some users tended to fill the front-loading machines to less than full capacity (A&N 1999), while others fill their washers to maximum capacity, reducing the overall numbers of loads.
- The proportion of households with washing machines (73 percent) will not change by 2020.

**Table 2-8**
Households with Washing Machines (U.S. and Regional Data)

| | Total Households | Households with Washing Machines | Fraction with Washing Machines |
|---|---|---|---|
| United States 1995 (total) | 109,457,000 | 79,403,000 | .73 |
| United States 1995 (occupied) | 94,000,000 | | .86 |
| Anaheim, CA 1994 | 851,500 | 591,600 | .69 |
| San Jose, CA 1993 | 534,700 | 391,200 | .73 |
| San Bernadino, Riverside, CA 1994 | 932,900 | 747,200 | .80 |
| San Diego, CA 1994 | 898,800 | 606,700 | .68 |
| Marin Municipal Water District, CA 1994 (single-family) | 49,414 | 44,966 | .91 |
| City of Santa Barbara, CA 1994 | 16,488 | 14,179 | .86 |
| City of Tucson, AZ 1994 | 139,311 | 119,807 | .86 |

Sources: American Housing Survey 1995, Table 1A-4; American Housing Survey 1995, regional reports; Association of Home Appliance Manufacturers 1993; Tucson Water 1995; City of Santa Barbara 1996; Marin Municipal Water District 1994.

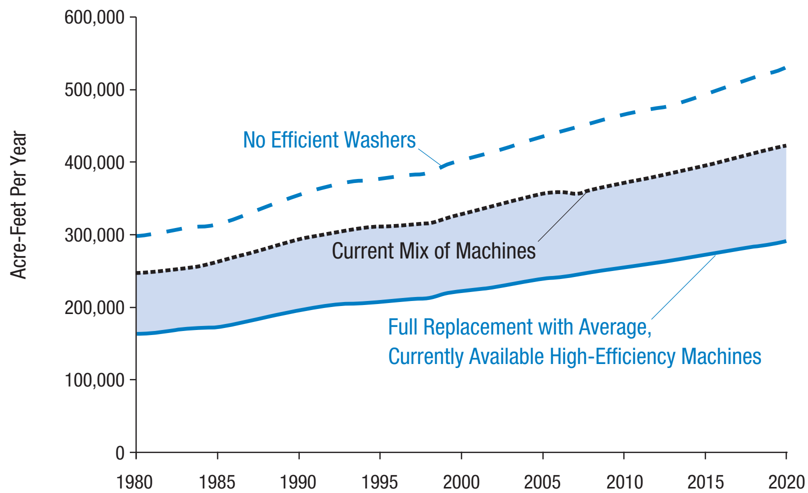
### *Water Savings of Efficient Clothes Washers*

Figure 2-7 shows water use by washing machines from 1980 to 2020, including the effect of the new efficiency standards in 2007. In 2000, residential clothes washers in California used about 330,000 AF, a reduction of around 70,000 AF over estimated use if no efficient machines were in use. We estimate that if all current residential washing machines in California were as efficient as the average of the efficient models currently on the market, water use in California homes would be reduced by another 110,000 AF annually – a 30 percent reduction. By 2020, we estimate that residential clothes washers will be using about 420,000 AF annually as efficient models naturally replace old machines. More aggressive programs leading to full replacement with efficient models can reduce 2020 use to less than 290,000 AF/yr, below even the level used today despite a 30 percent increase in projected population.

**Figure 2-7**
Water Use by Washing Machines (1980 to 2020)

Potential savings: 132 TAF

Indoor residential water use by washing machines is shown assuming the current mix of machines and assuming all machines are as efficient as the average of a set of more efficient machines currently on the market and cost-competitive with inefficient machines.




### *Energy Savings of Efficient Clothes Washers*

Nationwide, energy savings have been a main motivation for promoting efficient washing machines. Studies show that these machines can reduce energy use for washing clothes by between 50 and 65 percent (Environmental Building News 2000).

Washing machines use energy in two ways: to operate the motor and controls of the washer itself, and to heat the water used for washing. If clothes are washed in hot or warm water, using less water means using less energy. On average, 75 percent of washing machine energy goes to heating water (Tomlinson and Rizy 1998, Bill McNary, personal communication, 2000). In addition to reducing water use, some of the efficient models cut energy use for heating water by precisely regulating incoming water temperature (Environmental Building News 2000). Most new models offer flexible control over wash and rinse temperatures and load size. Efficient machines are also better at water extraction, which consequently reduces the energy requirements of clothes dryers, a further benefit not included here. Water extraction is improved because the efficient models have significantly faster spin speeds than traditional top loaders. Instead of 400 to 500 revolutions per minute (rpm) typical of standard machines, the efficient machines spin at 1,000 rpm or even faster.

The efficiency of a clothes washer is measured by the energy factor, which is defined as the cubic feet of washing capacity per kilowatt-hour of electricity. In the past decade, the energy efficiency of standard top-loading washers has doubled. The minimum allowed energy factor rating for standard capacity clothes washers is 1.18; some models exceed this rating by more than three-fold. The DOE has an extensive list of washer models that qualify for the Energy Star® rating (see sidebar for information on the Energy Star® program. For the list of washer models see http://www.energystar.gov/products/clotheswashers/calculator.phtml).

Our estimates of energy savings for washing machines are based on DOE's Energy Guide ratings (http://www.energystar.gov/products/clotheswashers/index.html). According to the ratings, and based on the assumption of 0.96 loads/household/day and 10.4 gpl savings, efficient machines yield an average savings of about 400 kWhr/yr (16.8 therms/yr). We assumed that natural gas rather than electricity is used for water heating and converted the savings to therms by dividing the kWhr by 0.8 (natural gas heater efficiency) and 29.3 (number of kWhr in a therm). For energy savings estimates from 1980 to 2020 see the Appendices, http://www.pacinst.org/reports/urban_usage/.

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### Dishwashers

Dishwashers account for less than two percent of total residential water use (Mayer et al. 1999). Nonetheless, we offer here an evaluation of the potential water savings from efficient dishwashers. From an economic point of view, the energy savings of efficient dishwashers may prove to be a more important factor in determining their value.

Approximately 54 percent of U.S. housing units are equipped with dishwashers (U.S. Census Bureau 1995). We used this value as our penetration rate and assumed that the proportion of housing units with dishwashers does not change over time. A similar penetration rate was found by the East Bay Municipal Utility District (EBMUD) in northern California in their baseline study (CTSI 1998). We estimate that in 2000 there were approximately 6.3 million households in the state with dishwashers, being used at a rate of 0.4 loads per household per day (Mayer et al. 1999).

The amount of water used by dishwashers was determined two different ways: using the REUW study and using information from manufacturers (see results in Appendix A, Table A-5, http://www.pacinst.org/reports/urban_usage/). In the REUW analysis, the authors measured the fill volume for dishwashers, the distribution of these fill volumes in the sample (Table 2-9), and the number of cycles per load (4.96). We integrated the distribution of fill volumes over the number of dishwashers in the state and multiplied it by the number of cycles per load (Equation 2-4) to get total volume of water used by dishwashers.

**Equation 2-4**
Water Use by Dishwashers

$$\text{Total water use} = N_{dw} * V * P * N_c$$

where:

- $N_{dw}$ is the total number of dishwashers
- V is the average cycle fill volume (the midpoint was used for the fill cycle range)
- P is the percent of dishwashers with that cycle volume, and
- $N_c$ is the number of cycles.

For example, 5.82 percent of all dishwashers use 0.5 to 1.0 gallons per fill cycle. This means that around 360,000 dishwashers use an average of 0.75 gal/cycle. The total water used by dishwashers that fall into that fill cycle is: 360,000 dishwashers * 0.75 gal/cycle * 4.96cycles/load * 0. 4 loads/day = 540,000 gallons/day (about 607 AF/yr).

**Table 2-9**
Distribution of the Fill Volume and Water Use for Dishwashers (2000)

| Gallons Per Fill Cycle | Percent of All Dishwasher Cycles | Water Used (AF/yr) |
|---|---|---|
| 0.5 or less | 1.92 | 134 |
| 0.5 to 1.0 | 5.82 | 607 |
| 1.0 to 1.5 | 17.45 | 3,036 |
| 1.5 to 2.0 | 31.35 | 7,635 |
| 2.0 to 2.5 | 24.62 | 7,709 |
| 2.5 to 3.0 | 10.83 | 4,145 |
| 3.0 to 3.5 | 3.54 | 1,601 |
| 3.5 to 4.0 | 1.52 | 793 |
| 4.0 to 4.5 | 1.00 | 591 |
| 4.5 to 5.0 | .59 | 390 |
| 5.0 to 5.5 | .36 | 263 |
| 5.5 to 6.0 | .30 | 240 |
| 6.0 to 6.5 | .22 | 191 |
| 6.5 to 7.0 | .14 | 132 |
| more than 7.0 | .35 | 341 |
| **Total** | | **27,809** |

This same methodology was used to calculate use to 2020 assuming no improvement in water use of dishwashers. Based on DoF housing statistics, we used the REUW study fill volume data to estimate these business-as-usual values.

We also used information from manufacturers to check our estimates of current water use. Data on the water use of current models pointed to a natural break in water-use efficiency at six gallons per load (gpl) (Table 2-10). Anything above 6 gpl was categorized as inefficient, and anything equal to or below 6 gpl was considered efficient. The potential water savings was calculated by multiplying the total number of dishwashers by the volume of water used by the higher-efficiency appliances now on the market. Most manufacturers have a high-efficiency machine in their product line. Table 2-10 shows the difference in water use between an average and a more efficient machine. Manufacturers have paid considerable attention recently to energy efficiency in developing new models. Energy savings are achieved by reducing the length of the cycles (Whirlpool DU912PF), by installing a turbidity sensor (Maytag

MDB7100), or by other methods that have the added benefit of reducing water use. As water becomes more of a concern, we expect there will be continued improvements in the water-use efficiency of newer models. The most efficient machine in our survey used 4.5 gallons for a normal-sized load. However, to determine maximum practical savings we used the same method that we did for clothes washers of comparing similarly priced models and concluded that efficient machines used about 5.3 gpl.

**Table 2-10**
Dishwasher Water Use

| Load Type | Whirlpool Standard Model (gal/load) | Whirlpool Energy Star Model DU912PF (gal/load) |
|---|---|---|
| High Temperature | | 9.1 |
| Pots and Pans | 8.64 | 6.9 |
| Normal | 7.20 | 4.8 |
| Light | 5.76 | N/A |
| Rinse | 2.88 | 2.2 |

### *Water Savings of Efficient Dishwashers*

Applying the distribution of fill volume provided in the REUW study to the number of dishwashers in California, we estimated that dishwashers used almost 28,000 AF of water in 2000. If all of these dishwashers were to be replaced with the more efficient 5.3 gpl models, use in 2000 would have been reduced to under 15,000 AF. Figure 2-5 shows water use by dishwashers extended to 2020. The top line is current estimated water use by dishwashers in California calculated using the REUW study estimates. The middle line assumes machines use on average 5.3 gpl as an estimate of maximum practical savings using existing technology. The bottom line represents the maximum technical savings of 4.5 gpl.

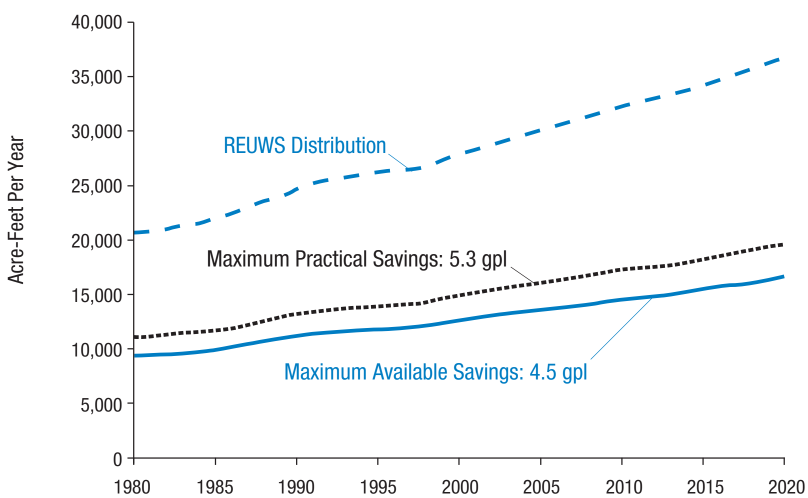



**Figure 2-5**
Water Used by Dishwashers (1980 to 2020)

Water used by current dishwashers is compared with water that would be used if all machines used 5.3 gallons per load or the maximum technical savings currently available of 4.5 gallons per load.

### *Energy Savings of Efficient Dishwashers*

For this analysis, we assumed that 75 percent of dishwasher energy use goes to water heating (Sullivan 1995, Bill McNary, personal communication, 2000). Based on the categorization of machines we established to determine maximum practical savings, we found that energy use per load averaged 2.4 and 1.7 kWhr/load for conventional and efficient machines, respectively, a difference of almost 30 percent (USDOE 1996). This savings per machine works out to about 64 kWhr per year (or 2.74 therms/yr) using the conservative frequency and penetration assumptions described in the previous section. See the Appendices for yearly energy savings estimates (http://www.pacinst.org/reports/urban_usage/).[12]

## Faucets

In 1992, the California Plumbing Code mandated that all faucets have a maximum flow rate of 2.2 gpm. This standard was replaced by the federal standard for faucets of 2.5 gpm enacted January 1, 1994. Prior to this, faucet flow rates ranged from 2.75 to 7.0 gpm. Faucet flow is trickier to link to water use than showerheads because faucet use is largely volume based – filling a pot will require the same volume of water regardless of flow rate. The amount of water used for brushing teeth while leaving the faucet running, however, will be larger with a faucet that flows at a higher rate. Thus, a low-flow faucet may or may not reduce water needs, depending on the use and individual behavior.

There are widely varying estimates about the extent to which retrofitting faucets or installing aerators saves water. In Brown and Caldwell's 1984 study, the authors estimated that installing aerators and complying with the 2.75 gpm standards of the time would save only about 0.5 gpcd, reducing average use from 9 to 8.5 gpcd. The REUW (Mayer et al. 1999) also observed few savings. The authors of the REUW study assume that penetration of 2.2 gpm faucet aerators is 50 percent and that average use without conservation is about 11.1 gpcd. They estimate that this can be reduced to 10.8 gpcd, saving a mere two percent – the lowest savings by far of any household conservation technology option. In comparison, in a larger survey, Seattle's Home Water Saver Apartment/Condominium Program installed faucet aerators in 65,702 multi-family units and found that faucet use dropped by almost 18 percent, adding up to almost 650,000 gpd of savings in its first year (Skeel and Hill 1998). This saving resulted from an average flow rate reduction of 0.7 gpm.

### *Faucet Results*

Lack of consistent data on potential savings limits us from being able to make reliable assumptions regarding conservation potential. Because of the uncertainties in this area, we choose not to model any savings from installing low-flow faucets. Instead, we provide an estimate of overall water use by faucets based on the REUW study finding of 10.9 gpcd average use and assume that this rate does not change in the future. Technological options combined with change in users behavioral patterns do, however, have the potential to significantly affect faucet water use over time. One example is an automatic shutoff device that can be installed on any sink, such as a bar mounted in front of the sink at hip

12 As with washing machines, there is a discrepancy between the frequencies of use assumed by the EPA and by the REUW analysis. The EPA document assumes 322 dishwasher loads per year, but to maintain consistency we used the REUW study assumption of 0.4 loads per day or 146 loads per year. Using the EPA data would more than double the overall energy savings.

level that the user must press or lean against to turn on the faucet. When the user moves away, the faucet shuts off. This device also has a locking device and constant flow option.[13]

Comparable examples commonly seen in commercial use sites are self-closing faucets. These either involve a spring-loaded lever that closes the faucet a prescribed period of time after it is opened or an infrared sensor that turns on the water when it detects hands under the faucet. At this point in their development, both these technologies are better suited to bathrooms than kitchens, and to commercial uses. These options, which involve the user more directly, need to be examined because faucet use is currently the fourth-largest use in the home and will become proportionately more important once other conservation technologies are installed.

## Leaks

Leaks within a home, including faulty faucets and toilets, are responsible for significant water losses. Leak repair, therefore, is an area that warrants evaluation and potential investment – a conclusion reached by a number of studies (USHUD 1984, Marin Municipal 1994, DeOreo et al. 1996, Steirer and Broder 1997, A&N Technical Services 1999, Mayer et al. 1999). The main difference between this measure and some of the ones previously discussed is that leak detection and repair generally do not require investment in new equipment and can often be performed by the homeowner with information and guidance from the utility. We exclude from this analysis any leaks that occur in water distribution systems before reaching a home, typically called "unaccounted-for water." In some places, unaccounted-for water is also a significant water loss requiring attention and investment.

Residential leak rates have been documented in a number of studies.[14] The early HUD study (1984) estimated leakage to be five to 13 percent of total indoor water use. The REUW study found average leakage was 12.7 percent of indoor use, but with an unusual distribution: The 100 homes with the highest water use had leakage rates of 24.5 percent. In five of their twelve study regions, per capita leakage rates exceeded total faucet water use. DeOreo et al. (1996) analyzed use for 16 single-family homes in Boulder County, Colorado and found that leaks averaged 11.5 percent of indoor water use, or 20.8 gpd per account and 7.2 gpcd. In all these studies, toilets are the leading "leakers", Table 2-11 lists the findings of some of the studies that have quantified water loss from leaks.

**Table 2-11**
Water Lost Due to Household Leaks

| Total Households | Single-Family | Multi-Family | Location/Service Provider |
|---|---|---|---|
| **Percent of toilets that leak** | | | |
| 20% | | | Various |
| 15% | | | City of San Diego |
| | 5% | 8% | Marin Municipal |
| | 8% | 10% | EBMUD |
| **Percent of showerheads that leak** | | | |
| | 13% | 13% | EBMUD |
| **Percent of faucets that leak** | | | |
| | 3% | 3% | EBMUD |

Sources:
Toilets
Various – USHUD 1984
City of San Diego – Steirer and Broder 1997
Marin Municipal – Marin Municipal 1994
EBMUD – CTSI 1998
Showerheads
EBMUD – Opitz and Hauer 1995
Faucets
EBMUD – Opitz and Hauer 1995

13 This is a fairly new product, so there has not been prolonged testing or extensive studies comparing water use. According to company estimates, this device can cut faucet water use in the kitchen and bathroom (excluding leaks) by about 83 percent. For more information, go to www.conservativeconcepts.com.

14 These studies do not differentiate between indoor and outdoor residential leaks. We include all leaks with indoor water use, presented as the percentage of indoor use.

Leak rates are highly variable. In general, a small proportion of housing units accounts for the largest proportion of leaks. In the REUW study 10 percent of the homes were responsible for 58 percent of the leaks. Mean daily per capita leakage ranged from 3.4 to 17.6 gpcd, but the standard deviation ranged from 6 to 40.3 gpcd. Two-thirds of the homes leaked an average of 10 gpd or less, but the median leakage rate was only 4.2 gallons per household per day. The average leakage rate per household was 22 gpd, meaning that the top third of leaky households were more than doubling the average of the entire sample. In San Diego, Steirer and Broder (1997) found toilet leaks alone varied from 20 gpd to an extreme of more than 4,000 gpd.

The potential savings from reducing leaks are high. A&N Technical Services (1999) estimate that approximately 8 gpd can be saved for each leaking toilet repaired and that other household leak repairs can save an additional 12.4 gpd. The HUD study of apartment buildings in Washington, D.C. found that fixing leaking toilets saved 48 gpd per unit, with two toilets per unit (in most units, both toilets were leaking). Fiske and Weiner (1994) estimate that leak detection and toilet repair can save about 20 gpd per toilet and that faucet leak repair can save 4 gpd per leaking faucet.

This variability suggests that leak-reduction programs would be most effective if they were targeted at homes with the highest leakage rates. The authors of the REUW study suggest targeting the homes in the top tier of winter water use, since their data show that there is a 76 percent probability that those homes with water use exceeding 400 gallons per day have leakage exceeding 130 gpd. The other option they suggest requires a sorting and filtering routine that allows a billing database to identify accounts with dramatic increases in their use patterns. Audits can then be performed at these sites in order to identify the cause of the change. Targeting the high-end water users would make audits more cost-effective to the utility.

A number of utilities in California have been using this kind of targeted approach. The City of San Diego has experimented with mailing out letters and brochures to the highest 36 percent of residential water users, and the highest 10 percent receive a follow-up phone call. In addition, the Water Department investigates abnormal or exceptional water use with a specific software program that can recommend a field investigation for accounts with possible leaks (Bill Jacoby, personal communication, 2002).

Comprehensive surveys of property-side leaks have not been done for California as a whole. Utilities and state agencies measure leaks as the difference between the water coming into the system and the water going out to customers (correcting for meter error, hydrant use, and other uses of water that have not been accounted for and cannot be controlled through leak detection). Until fairly recently, as far as the utility was concerned, customer-side leaks were not considered a loss because the water showed up in the utility's accounting method as a sale (Charlie Pike, personal communication, 2000). As the concern shifts from a focus on lost revenues to the need to minimize water waste, more attention is being paid to controlling customer-side leaks. This concern was formalized in California with best management practice #1 (BMP 1), which requires residential water audits to include property-side leak detection.

### *Leak Results*

While leaks may average about 10 gpcd, this value does not provide much insight regarding the range of water loss or the potential to reduce it. For this assessment, we used the REUW study information to estimate the volume of water lost to leaks, the volume lost by the high-leaking homes, and the potential savings if the leaks in these homes were reduced to reasonable amounts. Although comprehensive audits and proper maintenance can reduce residential leaks to zero, in practice, we assume there always will be a minimum level of lost water. We adopt here the median leakage rate of 4.2 gallons per household per day as a target. Total water savings is estimated as the amount of water that is saved by reducing the distribution of residential water leaks down to this level. Water savings from leak reduction are shown in Figure 2-6; the top line represents the water lost to leaks and the bottom line is leakage if all homes reduced leakage rates to the average rate of 4.2 gpd – a total savings of 240,000 AF/yr. For more detail on leak losses and potential savings, see the Appendices (http://www.pacinst.org/reports/urban_usage/).

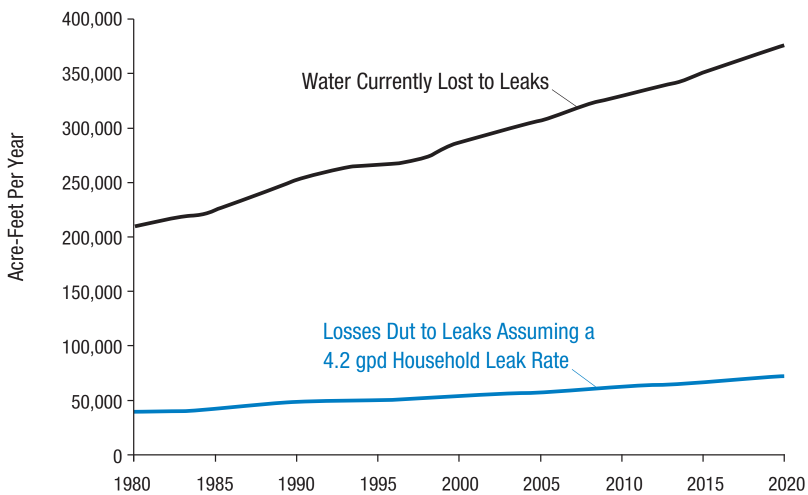



**Figure 2-6**
Water Lost to Leaks and Potential Savings (1980 to 2020)

The top line represents water currently lost to leaks in California homes. The bottom line represents total leakage if all homes reduced leakage rates to an average of 4.2 gallons per day – equal to the median leakage rate today.

## A Comment on the Non-Water Benefits of Conservation

In evaluating the overall benefits of improving the efficiency of water use, it is important to look at non-water savings that may also bring economic savings to consumers or water agencies. In particular, as we have noted above and in Section 5 on the economics of water conservation, the energy benefits of certain water improvements turn out to be significant. Omitting these from the indoor residential economic analysis would result in an artificial bias against conservation. We therefore quantified the energy savings where appropriate and included them in our economic evaluation. There are other benefits to improving water efficiency that we have not quantified. These include ecosystem benefits of taking less water from rivers and lakes, lower wastewater treatment costs that result from using and polluting less water, and reductions in greenhouse gas emissions that result from using less energy, among others. While all of these effects are important and would serve to make water conservation investments even more attractive, they are outside the scope of this study, but we urge more work on analyzing and quantifying them.

## Summary

Despite the significant and important progress that Californians have made in reducing indoor residential water use, substantial potential for conservation improvements remains untapped. At present, Californians use about 2.3 MAF of water to meet indoor domestic needs, much less than the three million acre-feet per year that would have been necessary without past conservation programs. But we estimate that indoor use could be reduced by approximately another 40 percent by replacing remaining inefficient toilets, washing machines, showerheads, and dishwashers, and by reducing the level of leaks, even without improvements in technology. Table 2-2 at the beginning of this section summarizes our estimate of the potential to reduce existing indoor residential water use. In the next section we examine outdoor residential water use and the potential for improving efficiency in that sector. In Section 5 we discuss the economic implications of these efficiency options.

# 3

# Outdoor Residential Water Use and Conservation Potential

A substantial amount of water is used outside of California homes to water lawns and gardens. While there are great uncertainties about the volume of total outdoor residential water use, our best estimate is that just under 1.5 million acre-feet were used for these purposes in 2000. Some limited efforts have been made to improve the efficiency of this use, but we estimate that further improvements of 25 to 40 percent (a reduction of 360,000 to 580,000 AF/yr) could be made with improved management practices and better application of available technology, economically and relatively quickly. These improvements have the potential to substantially reduce total and peak water demand in California.

There are additional benefits to such improvements as well. These include a reduction in energy and chemical use, mowings and other maintenance needs, and waste created. While we have not quantified these benefits, we describe them below and urge that more work be done to understand and to quantify their scope. Given the magnitude of current outdoor residential water use in California, improved conservation programs, more data collection and monitoring, and better reporting by urban agencies should be top priorities for water policymakers and planners.

## Introduction to Outdoor Residential Water Use

Substantial amounts of water are used in the outdoor residential sector, primarily for landscape irrigation, although great confusion accompanies estimates of actual use because of varying methods for calculation, lack of real data, limited metering, uncertainties about landscape area, and other variables.

Two separate Department of Water Resources publications in 1994 provide at least three different estimates of 1990 outdoor residential water use, ranging from 1.34 million acre-feet to 2.23 million acre-feet (see Table 3-1). Matyac (personal communication, 2002) estimates that watering gardens and lawns accounts for half of all residential water use statewide, and as much as 70 percent of residential use in some parts of the state. No new estimates were provided in the most recent California Water Plan (Bulletin 160-98). These data and reporting differences exemplify the current confusion and uncertainty over outdoor water use. In our assessment, we look at several approaches to evaluating current and projected landscape water use in homes and quantify the potential to reduce that water use with existing technologies and cost-effective management approaches.

Many options are available for reducing residential landscape water use. Improving water use in gardens and landscapes could free up substantial quantities of water for new demands, ecological restoration, or other uses. And there are additional benefits from outdoor water conservation, such as reducing peak period demand. Outdoor water use rises to a maximum during the summer when California water supplies are most constrained; as a result, residential landscape use plays a large role in driving the need for increases in system capacity and reliability. Furthermore, much of this water is lost to evaporation and transpiration and is thus no longer available for capture and reuse, unlike most indoor use.

Overall, we estimate that even a subset of available conservation options can reduce outdoor use by 25 to 40 percent through a variety of cost-effective techniques. Based on our estimate of average outdoor residential use of 1.45 MAF/yr in 2000, this suggests that savings of 360,000 to 580,000 AF/yr are readily available. Unfortunately, at present there are few effective outdoor water conservation programs in the state, although there are successful examples where savings of 25 to 50 percent were achieved with relatively modest efforts. Those that are successful tend to target large institutional water users such as government lots, schools, golf courses, and municipal landscapes (discussed in Section 4). Residential outdoor use is generally a low priority and is often considered an investment risk because outdoor use varies widely with both weather conditions and individual behavior and preferences (Driver, personal communication, 2000).

Efficient irrigation involves two things: proper design and proper landscape maintenance. Proper landscape maintenance requires that the homeowner be informed and diligent – difficult things for an agency to predict, control, or monitor. For example, planting a water-efficient landscape or installing a sophisticated irrigation system will not save water if the homeowner fails to match the irrigation schedule with plant needs. And a manual irrigation system on a traditional landscape can be efficient if it is properly maintained and used. In contrast, projecting the savings from an efficient toilet or showerhead program is relatively straightforward. When an agency decides whether to invest in a retrofit program, they can reliably calculate savings from switching their existing stock to ULFTs and from that determine the costs and benefits of such a program. A similar evaluation of landscape programs is more difficult and is constrained by lack of data and consistency.

Farmers and, increasingly, large-lot landscape managers have been taking advantage of tools such as improved irrigation technologies, rebates, audits, and weather station data in planning and designing irrigation systems and schedules. While these tools are often available in the residential sector, homeowners are less likely to have the time, inclination, incentive, or expertise to adopt them. One challenge thus lies in educating, motivating, and in some cases requiring residential homeowners and managers of smaller residential lots to adopt proper irrigation scheduling and techniques.

## Current Outdoor Residential Water Use in California

No satisfactory or consistent estimates of current outdoor residential water use are available for California. CDWR provides a variety of indirect estimates in different studies, mostly for a baseline of 1990. Given the uncertainties in the data, we felt a range of estimates would better capture the wide variation in the data and allow us to examine different scenarios. We initially developed five separate baseline estimates of outdoor residential water use for 1990, described in detail in Appendix B (http://www.pacinst.org/reports/urban_usage/). Table 3-1 summarizes the results of four of those estimates (we exclude here the "winter watering" estimate, because of inconsistency in the results), together with three separate estimates from the Department of Water Resources. The results of our calculations ranged from 850,000 to 1,650,000 AF/yr – a factor of nearly two – showing the high uncertainties about actual outdoor residential water use. One of CDWR's estimates is even higher: 2.23 million acre-feet (Table 3-1).

**Table 3-1**
Estimates of 1990 Outdoor Residential Water Use

| Institute Method | Result (AF/year) |
|---|---|
| "Average month" | 850,000 |
| "Minimum month" | 910,000 |
| "Hydrologic region" | 1,090,000 |
| "Representative city" | 1,650,000 |
| CDWR Bulletin 160-93 | 1,520,000 (a) |
| CDWR Bulletin 160-93 | 1,340,000 (b) |
| CDWR Bulletin 166-4 | 2,230,000 (c) |

Notes: Estimates are rounded.
For details see Appendix B (http://www.pacinst.org/reports/urban_usage/).
(a) This estimate uses CDWR's applied urban demand of 7.8 MAF in 1990, assumed ratio of residential use-to-total urban use (0.57), and assumed ratio of outdoor-to-total (0.34).
(b) This estimate uses CDWR assumed outdoor per capita value (40 gpcd) and 1990 population of 30 million.
(c) CDWR 1994b lists total residential use as 4.55 MAF (Table 2-7) and indoor residential use as 2.32 MAF (Table 2-9), leaving 2.23 MAF of outdoor use.

We used the "average month" method result to represent the low end of our range, and we offer results based on the low and high estimates and on the average of the high and low estimates. The 1990 estimates were then projected to generate an initial 2000 and 2020 baseline using the CDWR assumption that per capita use remains constant (Table 3-2).

**Table 3-2**
Projections of Outdoor Residential Water Use (2000 and 2020)

| Estimate | Water Use 2000 (AF/yr) | Water Use 2020 (AF/yr) |
|---|---|---|
| Low | 983,000 | 1,290,000 |
| High | 1,900,000 | 2,510,000 |
| Average | 1,450,000 | 1,890,000 |

Lack of good data has greatly hindered progress in both capturing and measuring efficiency improvements in the residential landscape sector. There is agreement that the potential for saving water is substantial, but the tools to quantify and evaluate specific savings in specific landscapes are only beginning to be developed. Most agencies know little about the characteristics of their residential landscapes; they do not always have reliable estimates of outdoor water use, let alone landscape acreage, type of plantings, or irrigation methods. Residential customers typically do not have dedicated irrigation meters, so site-specific information can be a challenge to collect. Because of the expense involved and because it is difficult for agencies to quantify savings, outdoor water-use data collection and analysis has traditionally been considered a low priority.[1] Few districts have collected data on residential landscapes. Statewide estimates are even less reliable.

One estimate of conservation potential is the difference between an efficient water budget and current water use. To establish a water budget we need weather data and information on the nature and extent of irrigated acreage. Weather data are available from the CIMIS weather stations throughout the state (Gleick 1999). The latter is more difficult to obtain. In order to develop baseline estimates of residential landscape areas, we contacted agencies, irrigation and landscape associations, and various organizations and individuals working on landscape issues. The only statewide estimates available come from the Department of Water Resources, which estimates that in 1995 there were 1.2 to 1.4 million acres of urban landscape, most of which is irrigated.[2] This value is modified from preliminary estimates made during the 1980s of the ratio of landscape acreage to total urban acreage derived from land-use surveys (CDWR 1998). These ratios differ widely by county and can vary up to 40 percent (CDWR 1998). CDWR projections also assume that landscape acreage will increase proportionately to projected population growth. Implicit in this assumption is that current conditions, such as housing density and type, will remain constant in the future. CDWR staff suspect that the 1.2 to 1.4 million acres estimate may be high because the amount of water one million acres would require (based on the product of landscape area, reference evapotranspiration, and crop coefficients) is considerably higher than most urban water budgets (Matyac, personal communications, 2000). Another possibility is that the estimate of water use per unit area is too high, an assumption we explore below.

While preparing Bulletin 160-98, CDWR staff conducted a telephone survey of landscape experts to ask whether they knew of any studies done to estimate statewide landscape acreage. That survey yielded widely varying estimates: 673,000 acres of turf according to a 1995 USEPA study; 1.4 million acres of turf according to a 1980s UC Riverside study; and 1.8 million acres of irrigated landscape according to an estimate made by the Council for a Green Environment. However, most of the

1 There are a handful of agencies, such as the EBMUD and IRWD, that have been trying to collect information on outdoor water use by landscapes. There has also been increased interest in obtaining this information and research and the most appropriate methods to do so. For these studies see the Landscape Area Measuring Study Final Evaluation Report, October 1999. Prepared for the U.S. Bureau of Reclamation by the Contra Costa Water District, http://watershare.usbr.gov/. See also the Annual Water Allocation and Methodology, Pilot Project Executive Summary. May 1998. Prepared for MWDOC, MWDSC, USBR, and the Moulton Niguel Water District by Psomas and Associates.

2 http://wwwdpla.water.ca.gov/urban/land/irrigatedland.html.

respondents said that they were unaware of reliable data on statewide landscape acreage (Matyac, personal communications, 2000).

Other estimates of outdoor residential water use are derived from simple assumptions of the proportion of indoor to outdoor use, differences between certain types of billing periods, and other approaches using data that water agencies collect more directly. The latest estimates are that outdoor water use ranges from 30 percent of residential use in coastal areas up to 60 percent in hot inland areas (CDWR 1998). In some parts of the state, more than twice as much water is used in the summer than in the winter (Figure 3-1). In the latest California Water Plan (Bulletin-160-98) CDWR estimates urban outdoor use (including commercial, industrial, and institutional sites; parks; and other large landscapes) at 2.4 million acre-feet per year, about 60 percent of which (1.4 million acre-feet) is assumed to be residential. CDWR then assumes that per capita use will remain constant as the population grows, forecasting that 2020 outdoor urban use will increase to about 3.6 MAF. The assumption behind these numbers is that in 2020 irrigation rates will be 0.8 and 1.0 $ET_o$ for new and existing landscapes respectively (CDWR 1998).

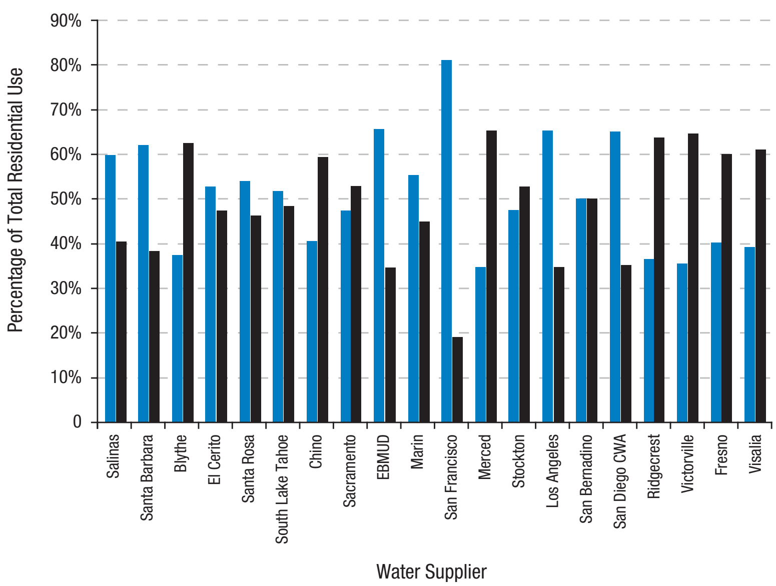



**Figure 3-1**
Residential Water Use:
Indoor, Outdoor Breakdown

Indoor and outdoor residential water use for different regions of California, in percent of total residential water use. Note the substantial differences – in the San Francisco Bay Area, for example, nearly 80 percent of all residential water use is indoors, while in many other regions, 60 percent or more of residential water is used outdoors.

Source: Matyac, personal communication, 2002.

## Existing Outdoor Conservation Efforts and Approaches

Some efforts have been made at the regulatory level to improve landscape water use in California. California Assembly Bill 325, the Water Conservation in Landscaping Act of 1990, required that the Department of Water Resources develop a Model Water Efficient Landscape Ordinance. This Model Ordinance, the only residential landscape-specific state regulation, was adopted and went into effect January 1, 1993. The ordinance applies to all new and rehabilitated landscaping for public agencies and private development projects that require a permit, and developer-installed landscaping of single-family and multi-family residential projects.[3] Landscapes must exceed 2,500 square feet to be subject to the ordinance. Cities and counties have the option of adopting the Model Ordinance, adopting their own ordinance, or issuing findings that no ordinance is necessary. If no action is taken, the Model Ordinance automatically goes into effect. By the late 1990s, more than 60 jurisdictions had issued findings that no ordinance was necessary, and the Model Ordinance or a similar water budget ordinance was being used in more than 250 jurisdictions. Turf limits or other approaches to water conservation had been adopted by nearly 200 jurisdictions. In a 1997 CDWR survey, 86 percent of communities questioned felt the ordinance was improving their landscape water-use efficiency. Most of those who felt the ordinance made no difference explained that their community was small or nearly built out and very few projects were in the development phase (http://wwwdpla.water.ca.gov/urban/land/itworks.html).

**Evapotranspiration**

Evapotranspiration (ET) is the rate at which plants use water. This rate is influenced by environmental conditions, such as wind, temperature, and humidity, as well as plant type and growth stage. The California Irrigation Management Information Services (CIMIS) stations located throughout the state provide daily estimates of ET demands for irrigated grass (reference ET), which are referred to as 100 percent $ET_o$. Individuals are able to adjust this information to their specific conditions and determine the actual evapotranspiration requirements of their vegetation and the amount of water they should apply to their landscape.

The concept behind AB325 is that by establishing a water allowance based on 80 percent of reference evapotranspiration (see sidebar), and adhering to it through a variety of technology, planning, and management techniques, landscapes will be maintained to ensure water efficiency. To ensure proper irrigation, the ordinance requires documentation for each landscape that includes a calculation of maximum applied water allowance, applied water use, total water use, and an irrigation design plan. This concept is sound, but a few substantive problems with this ordinance limit its effectiveness. First, there is no requirement for the installation of dedicated irrigation meters. The ordinance also fails to specifically address the idea of saving water by reducing the amount of irrigated area in new developments, and the applied water allowance is too high; reference evapotranspiration is based on thirsty, cool-season grasses (Osann, personal communication, 2001). Finally, enforcement of the ordinance falls under the jurisdiction of the city planning department rather than the local water supplier.

A statewide implementation review of AB 325 (Bamezai et al. 2001) found that coverage of the model ordinance is fairly good, but its effectiveness is poor. The ordinance's greatest weakness, according to the review, is a lack of enforcement and monitoring. Many stakeholders confided that maintenance contractors rarely irrigate appropriately regardless of the efficiency of the equipment or design. Few developers and contractors interviewed were even aware of the ordinance. Only two among the 66 agencies responding to the survey had ongoing outreach programs. The reviewers concluded that the key to improving the success of the ordinance is more education, economic incentives (pricing), and better integration of enforcement efforts between land-use agencies and water suppliers.

The California Urban Water Conservation Council has partly addressed residential landscape water use in the Best Management Practices by folding it into residential audits (BMP #1). The audit includes a check of the customer's irrigation system and timers and a review of their irrigation schedule, and recommends measurement of landscaped and total irrigable area. The CUWCC estimates that these audits can reduce outdoor water use by 10 percent, but there are no reduction or implementation requirements specified in the BMP. A separate and more comprehensive BMP (#5) targets large landscape conservation (see Section 4).

3 For more information on the Model Water Efficient Landscape Ordinance see http://wwwdpla.water.ca.gov/cgi-bin/urban/conservation/landscape/ordinance.

## Outdoor Residential Water Conservation: Methods and Assumptions

There are a large number of options available to the homeowner for reducing the amount of water used for landscape purposes. The options range from relatively simple and inexpensive practices such as maintaining a proper irrigation schedule to more demanding practices such as retrofitting an irrigation system with new efficiency options or changing landscape design. We split the efficiency options into four general categories: management practices, hardware improvements, landscape design, and policy options, and used existing field studies, audit results, technical reports, and related published literature on these options to help us quantify the potential water savings. We applied the potential savings estimates to the three different estimates of use. While in some cases the savings may be additive, in general they are not.

The following are some examples of studies and programs in the residential landscape sector as well as the potential savings that can be achieved.

### Management Practices

Proper management of outdoor water use is the most effective way to reduce water waste. Without it, no amount of investment will make an irrigation system efficient. Proper management practices can stand on their own as an efficiency measure by ensuring that plants are being watered according to their needs, or, ideally, they can be used to enhance the savings from other options. Efficient landscape management practices include ET-based irrigation scheduling, regular system maintenance (such as checking for leaks and fixing broken or misaligned sprinkler heads), and proper horticultural practices (such as fertilization and soil aeration).

Successful management involves an understanding of the irrigation system, an ability to recognize problems with the system, and an ability to adapt landscape needs to various conditions. These practices are not difficult, but because they are so dependent on individual behavior, they are difficult to quantify or predict.

A few studies have quantified the effects of proper management on landscape water use. The following are some of the results from these studies:

- Western Policy Research (1997) evaluated the combined effects of irrigation scheduling, system maintenance, and proper horticultural practices on 16 test sites. Within five years water use dropped by 20 percent and excessive peak-season irrigation was eliminated.[4]

- In a 17-month experimental study, Pittenger et al. (1992) studied six of the most common groundcover species in southern California to determine the minimum amount of irrigation required to maintain the species. The authors concluded that with proper irrigation (scheduling, frequency, and run time) and soil maintenance (mowing and mulching), these species could be consistently maintained with an acceptable appearance when seasonal irrigation plus rainfall totaled 33 percent of $ET_o$ (0.33 $ET_o$) or even less – a vast reduction over the assumed plant "need."

4 Total landscape water use was actually cut in half during this study. The rest of the reduction was attributed to an inclining block rate structure that was put in place during this period.

- Similarly, the University of California Cooperative Extension evaluated the water needs for over 1,900 species of garden plants. They found that the large majority could be properly maintained with water applications far lower than the 0.8 $ET_o$ CDWR suggests is the highest level of efficiency the state can hope to attain.

- Using a soil-moisture monitoring system that precisely determines moisture content at the root zone, researchers in Australia were able to accurately set an irrigation schedule and reduce water used for turf irrigation by up to 63 percent (Moller et al. 1996).

- A pilot study of residential weather-based irrigation scheduling in Irvine, California suggests that by targeting the top third of homes, evapotranspiration (ET) controllers might be expected to save roughly 57 gallons per household per day, a reduction of 10 percent in their total water use or 24 percent of outdoor use (Hunt et al. 2001).

Table 3-3 lists some of the various management options analyzed here and their potential savings, assuming no change in landscape area or design. The simplest approaches to proper landscape management could reduce baseline (2000) water use by about 145,000 AF/yr; more sophisticated efforts could produce savings of more than 900,000 AF/yr (Table 3-4) depending on the option chosen. If actual landscape areas in California are closer to the high end of our estimates, total savings could exceed one million acre-feet. Savings can vary widely depending on climate, geography, and behavioral patterns among other things, but these estimates help to define and bracket the potential options. While the individual options have some overlap (for example, irrigation/soil maintenance includes proper turf maintenance and irrigation scheduling) and therefore individual savings cannot be added, practices can be combined to increase savings.

**Table 3-3**
Management Options for the Reduction of Landscape Water Use

(a) Includes thatching, aerating, over-seeding, and top-dressing.

| Reduction Options | Potential Savings | Source |
|---|---|---|
| Turf maintenance (a) | 10 percent | SPUC 1998, 1999 |
| Turf maintenance, irrigation system maintenance, irrigation scheduling | 20 percent | WPR 1997 |
| Mulching in ornamental gardens | 20 percent | SPUC 1998, 1999 |
| Soil amendments (compost) | 20 percent | SPUC 1998, 1999 |
| Irrigation scheduling | ~25 percent | Steirer and Broder, SPUC 1998, 1999 |
| Irrigation/soil maintenance | 65-75 percent | Pittenger 1992 |
| Allow lawn to go dormant | 90 percent | SPUC 1998, 1999 |

**Table 3-4**
Estimated Potential Water Savings from Outdoor Residential Management Practices for California

These estimates are based on statewide outdoor residential landscape water use of 1,450,000 AF/yr.

| Management Practice | Annual Average Savings Potential over Current Use (AF/yr) |
|---|---|
| Turf maintenance (thatching, aerating, over-seeding, and top-dressing) | 145,000 |
| Turf maintenance, irrigation system maintenance, irrigation scheduling | 290,000 |
| Soil amendments (compost) | 290,000 |
| Irrigation scheduling | 363,000 |
| Irrigation and soil maintenance | 940,000 |

5 http://www.owue.water.ca.gov/docs/wucols00.pdf

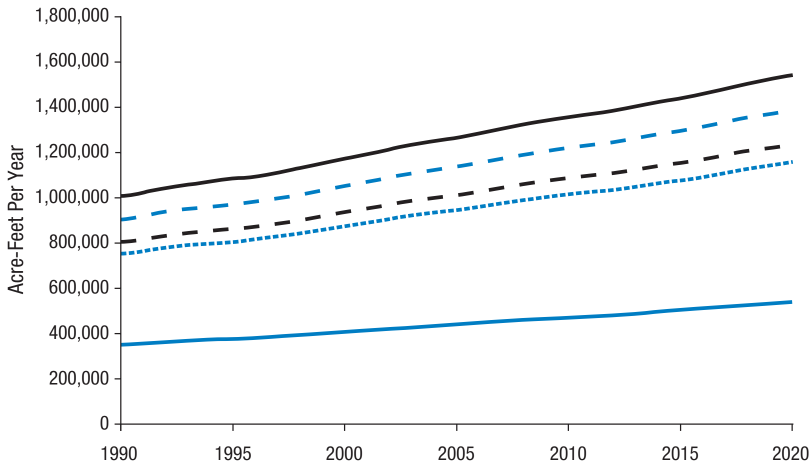



**Figure 3-2**
Projected Savings from Proper Landscape Management (1990 to 2020)

No conservation
Turf maintenance
Mulching/soil amendments
Irrigation scheduling
Irrigation/soil maintenance

Potential savings from various landscape management options from proper maintenance of turf to comprehensive efficient irrigation systems and soil maintenance.

## Hardware Improvements

Hardware devices that reduce water use in outdoor residential gardens vary widely in cost and sophistication. For example, a handheld probe that measures soil moisture may cost around $12. At the other extreme, home plumbing systems can be redesigned and a "gray-water" system installed, which permits replacing potable water use in gardens with household water that has been used once for some other purpose. Savings from devices also range widely, from about 10 percent for automatic rain shut-off devices, to 50 percent for drip-irrigation systems, to gray water systems, which can potentially eliminate use of all potable water for landscape needs (Table 3-5) (for more detailed information on irrigation systems and devices see Vickers (2001) and other hardware-specific sources).

**Table 3-5**
Hardware Improvement Options for the Reduction of Landscape Water Use

| Reduction Options | Potential Savings | Source |
|---|---|---|
| Auto rain shut off | 10% | SPUC 1998, 1999 |
| Soil moisture sensors; soil probes | 10 to 29% | SPUC 1998, 1999 |
| | | Allen 1997, Lessick 1998, Wong 1999 |
| Improved performance (a) | 40% | SPUC 1998, 1999 |
| Drip/bubbler irrigation | 50% | SPUC 1998, 1999 |
| Gray water (b) | Up to 100% | SPUC 1998, 1999 |
| Rain barrel catchment | Up to 100% | SPUC 1998, 1999 |

(a) This includes repair, removal, or adjustment of in-ground system components.

(b) This option is used to reduce the volume of potable water used; it does not affect the total volume of water used.

Installing water-saving devices alone does not ensure that less water will be applied to the landscape. The landscape can be just as easily be overwatered with a sophisticated drip irrigation system as with a traditional sprinkler. Effectiveness depends on the homeowner knowing to how to use their irrigation system, reset run times as the season warrants, and match water application to water needs. Similarly, soil probes are useful only if the homeowner properly uses the results to design a scheduling system.

To ensure that water-saving technologies meet their full potential, conservation programs must address behavioral variations. Some tackle the problem by trying to make the technology as independent of the homeowner as possible. A pilot study of irrigation controllers that are linked to CIMIS stations and automatically respond to weather changes was recently conducted in Orange County. These controllers allow the landscape to be irrigated according to its climate needs without requiring any involvement from the homeowner. The pilot program resulted in a 24 percent reduction in outdoor use (Hunt et al. 2001). Other conservation programs emphasize proper use of the available tools through public policy programs. These programs can include public education, outreach, rebates, loans, and rate structures, among other things. Using these tools alone, the Irvine Ranch Water District reduced overall landscape water use by about 27 percent (Lessick, personal communication, 2002, Wong 1999). They later included soil probes and irrigation software (which they continued to support with a public education program) and succeeded in reducing use to 50 percent of baseline.

The projected savings for hardware improvements were applied to our estimates of statewide use to get following potential savings (Table 3-6) and projected to 2020 (Figure 3-3).

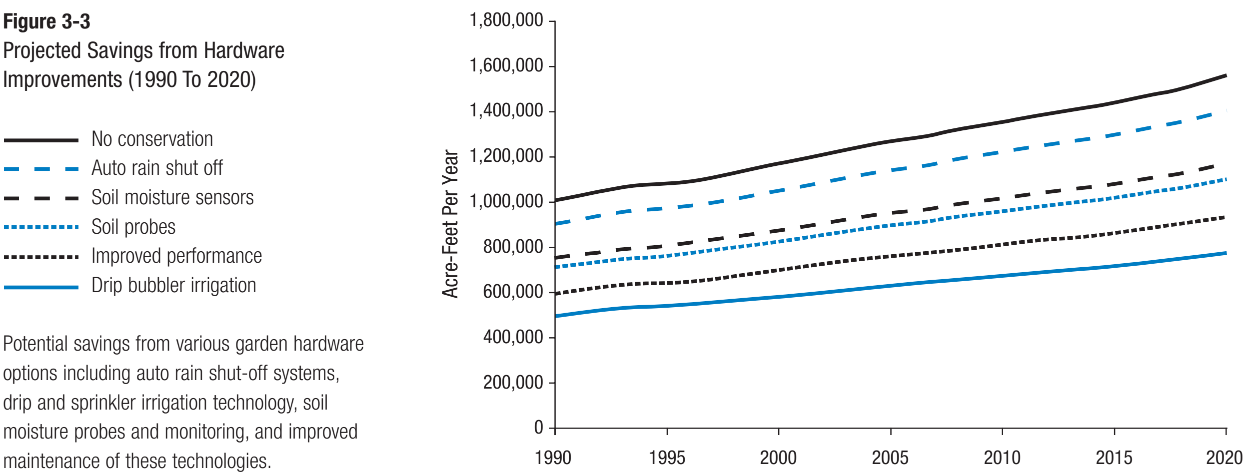
**Table 3-6**
Estimated Potential Water Savings from Outdoor Residential Hardware Changes for California

(a) Includes repair, removal, or adjustment of in-ground system components.

*These savings are not necessarily additive. These estimates are based on statewide outdoor residential landscape water use of 1,450,000 AF/yr.

| Hardware Improvement | Annual Average Savings Potential over Current Use (AF/yr) |
|---|---|
| Auto rain shut off | 145,000 |
| Soil moisture sensors | 363,000 |
| Soil probes | 290,000 |
| Improved performance (a) | 580,000 |
| Drip/bubbler irrigation | 725,000 |
| Gray water | Up to 100% |

**Figure 3-3**
Projected Savings from Hardware Improvements (1990 To 2020)




Potential savings from various garden hardware options including auto rain shut-off systems, drip and sprinkler irrigation technology, soil moisture probes and monitoring, and improved maintenance of these technologies.

## Landscape Design

One of the most reliable ways of eliminating variability in effectiveness of outdoor conservation options is to modify the design of gardens and landscapes. We do not base our estimates of statewide potential on this approach, because of our fundamental assumption that there be no change in the "service" provided by water, even though we believe that xeriscaping and reduction in turf area produces perfectly acceptable, and sometimes even improved, garden aesthetics. Nevertheless, the potential for significant reductions in outdoor water use is high, and we discuss that potential here as an option available to all homeowners.

There are two aspects to landscape design: the choice of plants and the physical layout of the landscaped area. Water needs of different plant species vary considerably, and some vegetation is better equipped to withstand the hot, dry regions and periods of parts of California than others. Water requirements for vegetation commonly found throughout the state range from up to 1.0 $ET_o$ for cool season grasses (Kentucky bluegrass, rye, tall fescue, red fescue, etc.), 0.7 $ET_o$ for warm season grasses (Bermuda, Zoysia, etc.)[6], 0.5 $ET_o$ or less for groundcovers, to 0.2 $ET_o$ for shrubs and trees (http://www.owue.water.ca.gov/docs/wucols00.pdf) (CDWR 2000). Proper landscape layout involves controlling the area and perimeter of turf, minimizing narrow paths or steep areas that cannot be irrigated efficiently, and grouping plants with similar irrigation needs.

A limited number of studies have quantified savings from xeriscape practices, typically defined as water-efficient landscaping (Table 3-7). The North Marin Water District conducted a series of such studies and found that proper choice of plants and careful landscape design could reduce water use by up to 54 percent (Nelson 1994).

**Table 3-7**
Potential Water Savings from Landscape Design Improvements

| Reduction Options | Potential Savings | Source |
|---|---|---|
| Landscape design (a) | 19-54% | Nelson 1986, CDWR 2000 |
| Turf reduction (b) | 19-33% | Nelson 1994, Sovocool and Rosales 2001 |
| Choice of plants (c) | 30-80% | CDWR 2000 |

(a) Based on minimizing turf area and perimeter.
(b) Non-turf areas are not necessarily comprised of low-water-use plants.
(c) Savings based on $ET_0$ range of 0.2 to 1.0 and a current $ET_0$ of 1.0.

These percentages applied to our estimates of use provide the range of potential savings shown in Table 3-8 (and Figure 3-4).

Less water use was not the only benefit – the water demands of the xeriscape landscapes were more level throughout the growing season and lacked the dramatic peak demands common to traditional landscapes. The Southern Nevada Water District compared the water use of traditional landscapes with those that had been converted to xeriscape. They found that relatively few properties in each group used vastly more water on a per-unit area basis than the bulk of the rest of the sample. Mean monthly household consumption dropped an average of 33 percent following conversion. The xeriscaped landscapes consumed, on average, 20 to 25 percent as much water as the traditional landscapes. These savings took place in the year following conversion and remained stable during the following three years of analysis.

6 The Water Use Classification of Landscape Species puts these requirements at 0.8 and 0.6 $ET_0$ for cool and warm season grasses, respectively. For more information on species water needs see CDWR (2000).

**Table 3-8**
Estimated Potential Water Savings from Outdoor Residential Landscape Design Changes for California

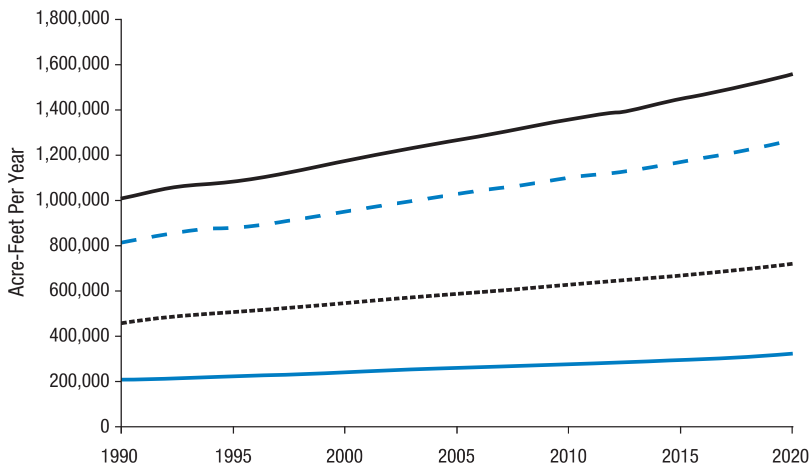
These estimates are based on statewide outdoor residential landscape water use of 1,450,000 AF/yr.

| Landscape Design Options | Annual Average Savings Potential Over Current Use (AF/yr) |
|---|---|
| Landscape design | 275,000 to 780,000 |
| Turf reduction | 275,000 to 480,000 |
| Choice of plants/xeriscape | 435,000 to 1,160,000 |

**Figure 3-4**
Projected Savings from Landscape Design Improvements

No conservation
Landscape design
Turf reduction
Choice of plants

Potential savings from various landscape design improvements including minimizing turf area and replacing turf with water-efficient plants.




## Rate Structures, Outreach

Properly designed rate structures can be a valuable tool to help homeowners improve the efficiency of their water use. There are few agencies in the state that effectively employ rates to encourage conservation, but some innovative utilities successfully use rates to encourage efficient water use. One of the most well-known examples is the Irvine Ranch Water District (IRWD).[7] In 1991, IRWD replaced its flat rate-per-unit charge with an increasing block rate structure (Table 3-9). These rates are structured so that conservation is rewarded and unreasonable use is penalized. The point at which rates go up to the next block is based on a percentage of initial allocation provided each customer. The new rate structure was combined with a well-developed public outreach and education program that allowed the district to help customers identify why they might fall into more expensive blocks and how they can reduce their use to save money.

**Table 3-9**
Summary of Ascending Block Rate Structure for Residential Customers at IRWD
Sources: Wong 1999; Lessick, personal communications, 1998, 2002.

| Tier | Water Use (as percent of base allocation) | Price per Unit Used in Each Tier |
|---|---|---|
| Low Volume Discount | 0-40% | Base Rate |
| Conservation Base Rate | 41-100% | Base Rate |
| Inefficient | 101-150% | 2x Base Rate |
| Excessive | 151-200% | 4x Base Rate |
| Wasteful | 201% and above | 8x Base Rate |

7 For more details see chapters 2 and 4 in the Pacific Institute's Sustainable Uses of Water: California Success Stories (Wong 1999, Owens-Viani et al. 1999).

The base allocation is based on the number of household residents, landscape area,[8] actual daily weather, and ET. Customers receive a fixed allotment for indoor use based on the number of residents (75 gallons per person per day), while the landscape allotment is calculated as a function of landscape area, cool-season ET for grasses, the crop coefficient, and irrigation efficiency.

IRWD coupled the new budget-based rate structure with an aggressive education and outreach program. During the first two years following implementation of the rate structure (drought years), water use fell by 19 percent from the pre-program baseline. Water use rebounded slightly after the drought in the late 1980s and early 1990s, but remained below pre-program levels. On average use has remained about 12 percent below 1990-1991 levels.[9]

## Summary

Outdoor residential water conservation and efficiency improvements have the potential to significantly reduce total water demand in California and improve supply reliability by reducing both average and peak demand. Savings will result from improved management practices, better application of available technology, and changes in landscape design away from water-intensive plants. There are great uncertainties in total water currently used in the outdoor residential sector, with best estimates ranging from between one and two million acre-feet per year and averaging 1.45 MAF in 2000. We estimate that 25 to 40 percent of this water could quickly and economically (see Section 5) be saved through proven approaches, a reduction of 360,000 to 580,000 AF/yr or even more.

There are additional benefits to such improvements as well. While we have not quantified these benefits, we describe them briefly below and urge that more work be done to understand and quantify their scope.

Moller at al. (1996) found that precisely managing turf water applications with moisture sensors reduced vegetative growth by 73 percent, thus reducing the number of mowings required, energy expended, and waste created. They also saw water quality benefits; the correct placement of water and fertilizer through continuous monitoring and irrigation scheduling minimized leaching below the root zone and into groundwater sources, waterways, and estuaries.

Studies by Nelson (1994) not only showed water savings of 54 percent, but found that xeriscapes decreased resource requirements in general. The efficient landscapes studied reduced labor needs by 25 percent, fertilizer use by 61 percent, fuel use by 44 percent, and herbicide use by 22 percent. These reductions make investment in xeriscape more economically attractive and offer improvements in both water and air quality.

In the SNWA study, savings of both time and money of more than 30 percent were realized in sites converted to xeriscape. The xeric sites required 2.2 hours/month less to maintain than the traditional sites and cost $206 per year less to maintain on top of savings in the water bill

8 Landscape area was originally designated by type of home. Customers could apply for a larger allotment if their area was larger than what had been designated.

9 It is not possible to isolate the new rate structure as the only reason for this decrease, but it is reasonable to assume that it played the key role. In 1997-98, targeted audits and soil probes were added to the program.

(Sovocool and Rosales 2001). Added benefits include savings on wastewater disposal and a decrease in the amount of lawn care chemicals in garden runoff.

Better estimates of both total outdoor water use and the conservation potential in this sector are needed. Given the magnitude of current outdoor residential water use in California, improved data collection, monitoring of outdoor use, and reporting by urban agencies should be top priorities for water policymakers and planners.

# 4

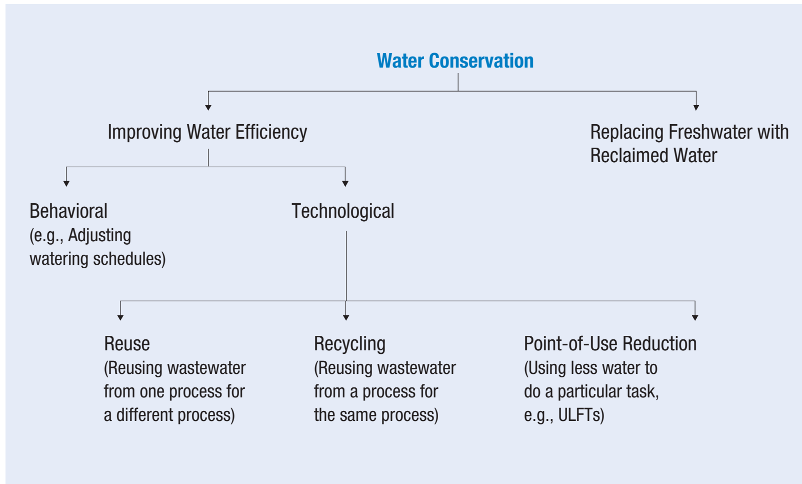
# Commercial, Institutional, and Industrial (CII) Water Use and Conservation Potential

California's commercial, institutional, and industrial sectors use approximately 2.5 million acre-feet of water annually, or about one-third of all the water used in California's urban areas. Previous studies of specific regions and industries have shown that the potential for water conservation in this sector is high. But none of these studies have attempted to aggregate potential water savings in sectors at the state level. This section uses data surveys and sectoral water studies to present, for the first time, a statewide assessment of the potential savings in the commercial, institutional, and industrial sectors (CII sector) from conservation and water-use efficiency. Our estimate of the potential for water conservation in the CII sector ranges from 700,000 to 1.3 MAF per year, with a best estimate of 975,000 AF/yr.

We examine two broad types of conservation measures: improving water efficiency and substituting reclaimed water. Improving water efficiency includes behavioral improvements, such as adjusting a watering schedule, and technological improvements. Technological improvements can involve on-site reuse of water or implementing point-of-use reduction technologies. On-site reuse of water includes reusing water in the original process, such as recycling water in cooling towers, or recovering process water for use in alternative applications, such as irrigation. Point-of-use reduction involves implementing fixtures such as ultra-low-flow-toilets (ULFTs) or auto-shut-off valves that reduce the amount of water used to accomplish a certain task. (See Box 4-1)

Because this is the first statewide assessment of CII water use and conservation potential, we devote several sections below to describing our methodology. We describe the methodology and data used, the important data gaps, and our assumptions. The focus of this effort is to inform future decisions about demand-side management in California's CII sectors. While we provide a general guide to the status of water conservation in the CII sector, these decisions will be better with improvements in data. As a result, we also suggest what type of data would be most useful for future research and decision-making.

**Box 4-1**
Defining CII Water Conservation




The potential conservation measures described in this section are "technically achievable" savings. How much of this potential can be realized depends on economics and the ability to overcome other barriers, as described in Section 1. Long-term conservation is an alternative to developing new sources of water supply, and is cost-effective as long as the cost per acre-foot of conserved water is less than the true cost of the cheapest alternative source of water. Unfortunately, firms do not apply the same criteria as water agencies to judge cost-effectiveness. They instead often look for paybacks of two years or less – a criterion that we show to be excessively stringent.

Most of the measures discussed in this report are cost-effective (as discussed in detail in Section 5). We do not attempt to determine the specific regional or sectoral cost-effective potential, since this depends on the water rates of individual agencies. It is important to note that as water becomes scarcer and the cost of water increases, the economically achievable potential will increase. In California, the popularity of conservation technologies should only increase in the future as competition for water grows, prices increase, and technology improves.

## Background to CII Water Use

Definitions of the commercial, institutional, and industrial sectors vary widely. We adopt the following definitions for these terms (Hagler Bailly 1997).

**Commercial:** Private facilities providing or distributing a product or service, such as hotels, restaurants, or office buildings. This description excludes multi-family residences and agricultural uses.

**Institutional:** Public facilities dedicated to public service including schools, courthouses, government buildings, and hospitals.

**Industrial:** Facilities that mostly manufacture or process materials as defined by the Standard Industrial Classification (SIC) code numbers 2000 through 3999.[1]

Studies of CII water use in California (and elsewhere) often group commercial and institutional users of water together for analytical purposes, since the distinction between what is considered commercial (i.e., a private school) and what is considered institutional (i.e., a public school) is somewhat arbitrary (Sweeten, personal communication, 2000). We followed this approach of grouping commercial and institutional users together.[1]

## Current California Water Use in the CII Sectors

Calculating water conservation potential requires knowing how much water various industries in the CII sectors use annually. Although the California Department of Water Resources has estimated CII water use by sector at the state level and a few other studies have calculated water use by industry in specific regions, no statewide estimate of water use by industry exists. Therefore, our first step in calculating water conservation potential involved estimating baseline CII water use by sectors and end use. Table 4-1 summarizes our estimate of current water use in California's CII sectors in 2000. All together we estimate that nearly 2.5 million acre-feet were used for these purposes – about 30 percent of all urban water use.

Within the CII sectors, water use varies among individual users in both quantity and purpose. Because of these differences in use, conservation potential varies from one industry to the next, and we had to examine each industry independently. Due to resource and data constraints, we examined industries that account for about 65 percent of total CII water use. Table 4-1 shows the industries we chose to examine in detail and their estimated water use in 2000. More general conclusions were made about the remaining sectoral end uses.

| Commercial Water Use (AF/Year) | | Industrial Water Use (AF/Year) | |
|---|---|---|---|
| Schools | 251,000 | Dairy Processing | 17,000 |
| Hotels | 30,000 | Meat Processing | 15,000 |
| Restaurants | 163,000 | Fruit and Vegetable Processing | 70,000 |
| Retail | 153,000 | Beverage Processing | 57,000 |
| Offices | 339,000 | Refining | 84,000 |
| Hospitals | 37,000 | High Tech | 75,000 |
| Golf Courses | 229,000 | Paper | 22,000 |
| Laundries | 30,000 | Textiles | 29,000 |
| | | Fabricated Metals | 20,000 |
| Unexamined Commercial | 621,000 | Unexamined Industrial | 276,000 |
| **Total Commercial (a)** | **1,852,000** | **Total Industrial** | **665,000** |

**Table 4-1:**
Estimated 2000 Water Use in California's CII Sectors, (AF/Year)
(a) Commercial water use, as reported herein, includes both commercial and institutional uses.

1 Note that the SIC system was recently replaced by the North American Industrial Classification System (NAICS). We use the SIC code system here because our largest single data set, the CDWR's industrial survey data (CDWR 1995a), is classified by SIC code.

## End Uses of Water

Although individual industries use water differently, nearly all of them use some water for similar purposes. Through examining water use in the industries shown in Table 4-1, we found that water use in all industries could be classified into six broad end uses: sanitation (restroom), cooling, landscaping, process, kitchen, and laundry. With the exception of process water use, the end uses (i.e., toilet flushing or dishwashing) are very similar among industries. For example, although a hospital and dairy plant use process water for very different purposes, they both use landscape water for irrigating turf and other vegetation and restroom water for flushing toilets and running faucets. We refer to the five end uses unrelated to an institution's processes as "common end uses."

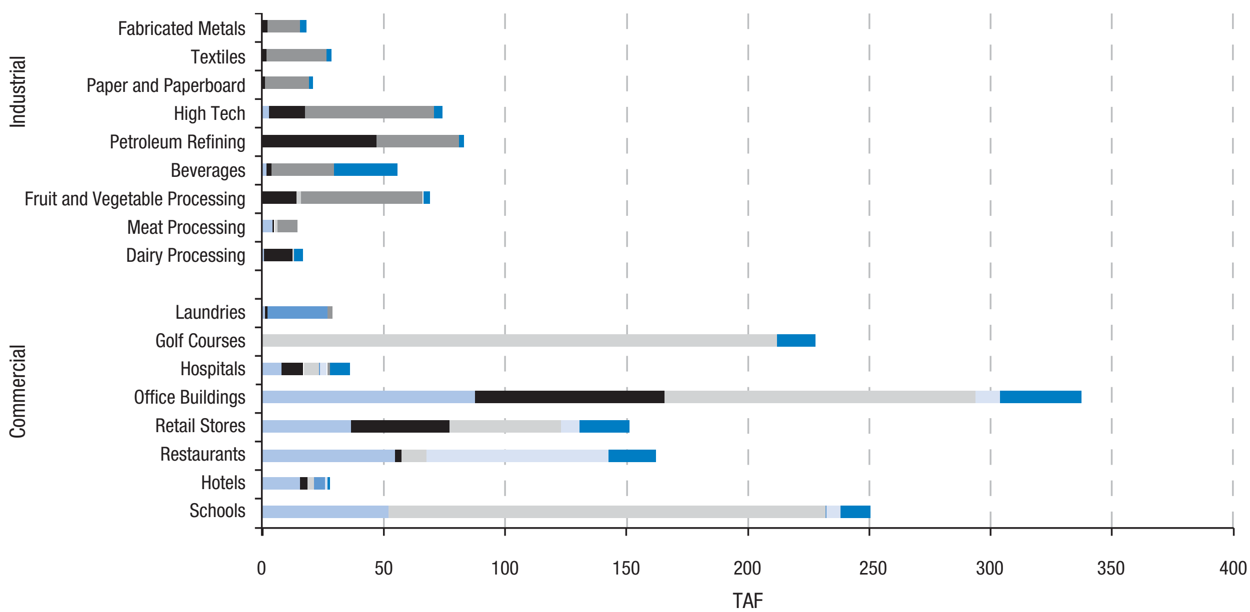
The mix of end uses and quantity of water they use varies widely by industry type. Industrial facilities tend to use water mostly for processes, although they do use (relatively) small amounts of water for common end uses. Commercial facilities tend to use water almost exclusively for common end uses. Figure 4-1 shows our estimated breakdown of CII water use into these six end uses.

Our estimates indicate that landscaping uses more water than any other end use in the CII sectors. Other significant end uses include restrooms, cooling, and process, which, combined, comprise close to fifty percent of total water use. The smallest end uses, in terms of total use, are kitchens, laundries, and other.

**Figure 4-1**
Estimated Water Use by End Use for the CII Sector (2000)

Restroom
Cooling
Landscaping
Laundry
Kitchen
Process
Other

Source: See Appendices C and D for derivations of use, by industry (http://www.pacinst.org/reports/urban_usage/).



### *Process*

Process water use includes any water uses unique to a particular industry for producing a product or service. In the Food Processing industry, for example, any water used in the production of canning tomatoes, whether for cleaning the equipment or cooking the tomatoes, counts as process water.

Unlike the common end uses, the sub-end uses of process water vary tremendously among industries. While hospitals use process water for x-ray machines, sterilizers, and vacuum pumps, beverage production plants use water for cleaning equipment and bottles and as part of the final product. Even within specific industries, process water use can vary greatly. In food producers who make tomato salsa, for example, plants that produce salsa from pre-processed tomatoes use water very differently from plants that produce salsa from whole tomatoes.

We estimated that process water use comprised approximately 18 percent (445,000 AF) of all CII use in 2000. Nearly all of this water use took place in the industrial sector, with the High Tech, Beverage, and Food and Vegetable industries using the most process water of the examined industries. In the commercial sector, only the Hospital industry used significant amounts of process water (see Figure 4-2).

**Figure 4-2**
Estimated Process Water Use, by Industry (2000)

Source: See Appendices C and D for derivations, by industry (http://www.pacinst.org/reports/urban_usage/).

**Figure 4-2**

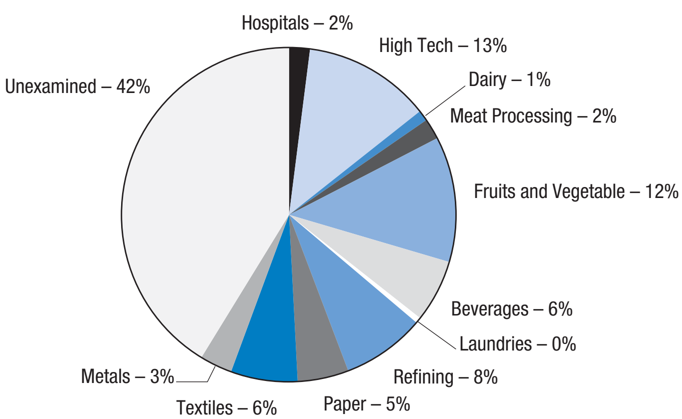
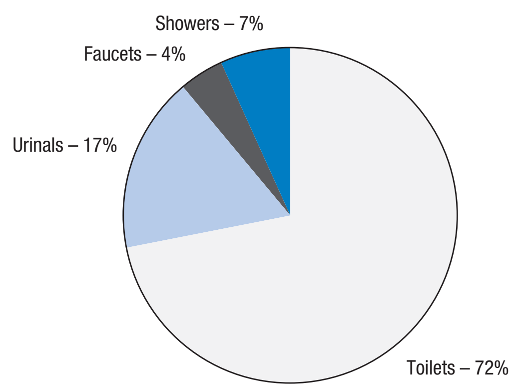



**Figure 4-3**




### *Restroom*

In restrooms, water is used for toilet and urinal flushing, faucets, and, in hospitals and hotels, showers. Our estimates indicate that toilets consumed nearly three-quarters of restroom water use (see Figure 4-3).

Approximately 15 percent (360,000 AF) of total CII water use in 2000 was used in restrooms. Restroom water use is ubiquitous across all industries, but it is most significant in the commercial sector, particularly hotels, where we calculate that it represents as much as 55 percent of total water use. In the industrial sector, restrooms often use a very small percentage of total water relative to process and cooling uses. For some

**Figure 4-3**
Water Used in Restrooms in the CII Sector (2000)

Source: See Appendix C (http://www.pacinst.org/reports/urban_usage/) for a detailed description of how restroom water use was estimated.

of these industries, therefore, restroom water use is combined with landscaping and kitchen into the generic category of "other."

### *Cooling*

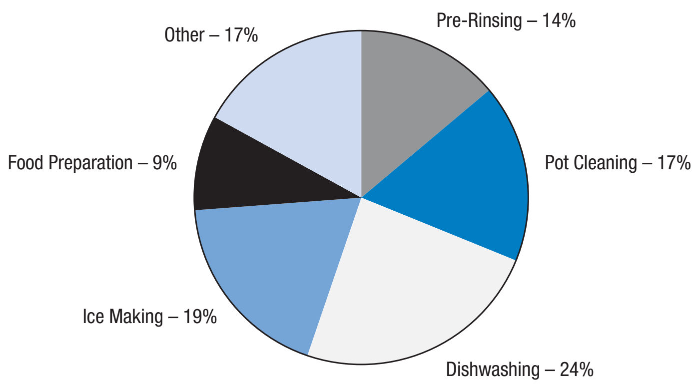
Cooling involves using water either as part of the production process or for air conditioning units. In the production process, water either directly cools heated equipment or components (contact cooling) or cooling towers chill the water, which then runs through heat exchangers to cool hot fluids or air (non-contact cooling). Cooling as part of the production process generally occurs in the industrial sector and is particularly significant in the Petroleum Refining and Dairy industries. Water use by air conditioning units is common in both industrial and commercial industries.

### *Kitchen*

Water is used in kitchens for a number of purposes including pre-rinsing and washing dishes and pots, making ice, preparing food, and cleaning equipment. As illustrated in Figure 4-4, we estimate that over fifty percent of "kitchen" water use goes to cleaning dishes and pots.

**Figure 4-4**
Water Used in Kitchens in the CII Sector (2000)

Source: See Appendix C (http://www.pacinst.org/reports/urban_usage/) for a detailed description of how kitchen water use was estimated.




We found that in 2000, approximately six percent (150,000 AF) of total CII water use occurred in kitchens. While restaurants provide the most obvious and significant example of kitchen water use, most industries use some kitchen water, whether in the cafeteria of a hospital, factory, or school or in the kitchenette of an office or deli of a retail store. In some industries, the amount of kitchen water use relative to the amount of water used in processing is so small that it is rarely counted separately. In these cases we assume that it falls in the category of other.

### *Landscaping*

Landscaping includes water used for irrigating turf and shrubs. Most landscaping water goes to turf irrigation because it is both more dominant and more water intensive than other vegetation used in landscaping. Figure 4-5 shows the breakdown between turf and other vegetation water use.

**Figure 4-5**

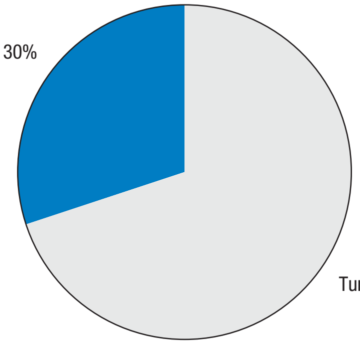



**Figure 4-6**

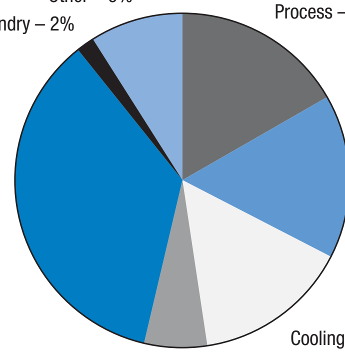



**Figure 4-5**
Landscape Water Use in the CII Sector (2000)

Source: This ratio is derived by averaging different California regional CII data sets on turf and vegetation extent (City of Santa Barbara 1996a,b, Contra Costa County 1996, Haasz 1999).

**Figure 4-6**
Estimated Water Use in the CII Sectors by End Use (2000)

Source: Consolidation of water use estimates by end use. These estimates were calculated in each of the industries examined here by applying end-use percentages (from multiple sources) to GED estimates of total water use. See Appendices C and D for these calculations (http://www.pacinst.org/reports/urban_usage/).

Many commercial and industrial facilities in the state use substantial amounts of water for landscaping. In 2000, 38 percent (965,000 AF) of CII water use went to landscaping statewide, according to our estimates. In many industrial facilities, water use for landscaping is so small relative to other uses that it is counted as "other," whereas landscaping generally comprises a sizable portion of water use in the commercial and institutional sectors, particularly in schools and office buildings.

### *Laundry*

Laundry water use includes water used to wash clothing and other fabrics in standard and commercial washers. Laundries use almost all of their water in the washing process (we classify it as process water use). Many establishments such as hotels, nursing homes, and universities offer coin laundry facilities. Some hotels and hospitals (about five percent) have in-house laundries, but increasingly they are outsourcing their laundry to commercial laundries. In establishments that do have in-house washing machines, laundry often represents a major percentage of water use, although laundry use may only represent a small percentage of water use for the industry as a whole because of outsourcing.

### *Other*

"Other" includes uses that do not fall in the end uses listed above or uses that represent such a small percentage of total water use that they are consolidated into one category. In the industrial sector, where almost all water is used for process purposes, other may describe all non-process uses and include restroom, kitchen, cooling, and landscaping uses. In both the industrial and commercial sectors, other often captures miscellaneous uses such as water use in janitorial closets in schools and hospitals or leaks in any type of industry.

## Estimated CII Water Use in California 1995 and 2000

We chose 2000 as our baseline year to make our savings estimate timely and comparable to CDWR data on CII water use. Because most of the comprehensive CII data on water use were from 1995, we first estimated water use in 1995 and then updated the 1995 estimate for 2000. The most useful data included a water-use survey of industrial users performed by CDWR in 1994 (but not previously released or analyzed for this purpose),[2] water use by sector as reported by nearly 150 water districts in 1995 and 2000, and a few studies based on surveys of water use primarily in southern California's commercial sector. A valuable source of information was the *Commercial and Institutional End Uses of Water* study published by the American Water Works Association Research Foundation (AWWARF) (Dziegielewski et al. 2000).

When estimating water use in the CII sectors in 1995, we used two independent approaches and then crosschecked our findings against other published estimates. The first approach (Method A) involved compiling, reviewing, comparing, and analyzing data gathered from CII water users around the state in various surveys (CDWR 1995a, Davis et al. 1988, Dziegielewski et al. 1990, and Dziegielewski et al. 2000). From these surveys, we calculated water-use coefficients (in gallons of water each employee used per day (GED)[3] for each two-digit Standard Industrial Classification (SIC) code.[4] Next, we combined the GED with statewide employment data to estimate total water use for each industry. In the second approach (Method B), we used water-delivery data by sector, as reported by water agencies across the state (CDWR 1995a and 2000). Both Methods A and B include estimates of CII water use by region as well as for the whole state. For more details on Method A and B, including modifications to the available data, see the online Appendix E at http://www.pacinst.org/reports/urban_usage/.

### Method A

In Method A, we estimated water use in the industrial sector from the 1994 survey conducted by CDWR (CDWR 1995b). More than 2,600 firms responded to this survey, and after carefully reviewing the data and eliminating errors associated with data conversions, data entry, or misreporting, 2,252 firms from the sample were used for this estimate.[5] For each of these firms, the CDWR collected information on the amount of water used (self-supplied and publicly supplied) and the average number of employees for the year. From these data, we calculated the weighted average GED[6] for each type of industrial user by two-digit SIC code.[7] We then multiplied these average GEDs by each region's employment by sector[8] to determine total regional water use by two-digit SIC code.

**California CII Water Use in Acre-Feet/Year**

$$\frac{\Sigma P_{I=15\text{ to}99}\ GED_I * Employees_I * 225}{325{,}851\ (g/AF)}$$

Note: The average work year, which excludes holidays and weekends, is 225 days/year.

2 Although the CDWR survey data were from 1994, we included them in our 1995 estimate because much of the other data were from this year. In doing this, we assumed that no drastic changes in industrial water use occurred between 1994 and 1995.

3 GED is a typical coefficient used to calculate water use in the CII sectors because of data availability, not because it is the most accurate coefficient.

4 The SIC system was recently replaced by the North American Industrial Classification System (NAICS). We use the SIC code system herein because the CDWR's industrial survey data (our largest data set) are classified by SIC code

5 For more information on detailed corrections performed on these surveys, see Appendix F.

6 The CDWR sample was skewed towards high water users so that using the arithmetic mean of the GED within a two-digit SIC code would yield a biased estimate. To correct for the skewed sampling problem we calculated the mean GEDs at the three-digit SIC code level, and weighted them by the statewide employment for the three-digit SIC code. This gave us a "weighted average" GED for each two-digit SIC code.

7 To test whether it was appropriate to use the same GED for all regions in the state, we also calculated GEDs at the regional level and compared them to each other. For the most part, the GEDs by region for each industry were comparable, although there were a few exceptions. In cases where regional differences were explicable, we used the region-specific GEDs. In cases where the differences could not be explained, the statewide GED was applied to all regions. See Appendix F for statewide GEDs, by SIC code, for the industrial sector.

8 The employment data were reported by county (California Employment Development Department, 1994). These data were distributed into hydrologic regions based on the proportion of a county's population in each hydrologic region.

To calculate water use in the commercial sector with Method A, we evaluated GEDs from various studies[9] and then chose a best estimate.[10] We used more than one report because none of the reports covered the entire commercial sector and the findings of the reports were often inconsistent. Moreover, while Dziegielewski et al. (1990) and Davis et al. (1988) classified findings by three-digit SIC code, Dziegielewski et al. (2000) reported findings by establishment type (i.e., restaurant, school, etc.). In most cases we used the GED estimates reported by Dziegielewski et al. (1990), because the data were based on only California-based surveys and the sample sizes were sufficiently large. We compared the two estimates by mapping SIC codes to establishment types. The comparison of the different estimates and the GEDs finally selected for Method A are shown in the online Appendix E and F at http://www.pacinst.org/reports/urban_usage/.

Corrections were made to two industries:

- SIC code 82 included only private schools, while public schools were categorized separately under "local education." We aggregated employment in public and private schools under SIC code 82.

- SIC code 79 included golf courses (SIC code 7992) in addition to other recreational facilities such as amusement parks and theaters. Water-use patterns at these establishments vary tremendously, and little data about water use in this industry exists. While these constraints prevented us from calculating water use for SIC code 79 as a whole, sufficient amounts of data enabled us to calculate water use at golf courses (SIC code 7992), one of the largest water users in SIC code 79.

### Method B

The second approach to estimating 1995 water use in the CII sectors involved using public water-supply delivery data reported to the CDWR by 147 water agencies across the state (CDWR 1995b).[11] After eliminating agencies that reported incomplete or inaccurate delivery information, the remaining agencies' water delivery numbers, by sector and population served, were categorized and subtotaled by region. Each region's sample population was divided by its actual population to obtain the percentage of the population sampled. The CII deliveries in each region were then divided by this percentage to produce regional estimates of deliveries from the public water suppliers.

Once publicly supplied water use was calculated from agency data, we had to estimate self-supplied water use not captured by the agencies. For the industrial sector, we applied our findings of the percentage of industrial water that was self-supplied in Method A (38 percent) to our regional industrial estimates in Method B. And for the commercial sector, we used a USGS estimate of self-supplied commercial water use (20 percent of total use) (Solley et al. 1998).

### Best Estimate

The total CII water-use estimates calculated in Methods A and B were within ten percent of each other (Table 4-2). Published estimates for specific hydrologic regions, known sources of errors inherent in the data,

9 See Davis et al. 1988, Dziegielewski et al. 1990, and Dziegielewski et al. 2000.

10 The GEDs often varied from one study to the next. In some cases, we chose a GED that was close to the GED calculated in more that one study, while in other cases we chose the GED that was based on the largest sample population.

11 Over 470 agencies were listed in the CDWR file, but most of these agencies did not differentiate between commercial, institutional, and industrial uses and, therefore, could not be included in this analysis.

and sample sizes were used to guide our decision on which estimate to choose for each region.[12]

The next step involved updating the 1995 water-use estimates for 2000. Again, the two approaches, Methods A and B, were used.

**Table 4-2**
Estimates of CII Water Use 1995 (TAF)

| Hydrologic Region | Commercial Water Use | | | Industrial Water Use | | |
|---|---|---|---|---|---|---|
| | Method A | Method B | Best Est. | Method A | Method B | Best Est. |
| Central Coast | 97 | 56 | **76** | 25 | 96 | **25** |
| Colorado River | 33 | 50 | **35** | 8 | 4 | **8** |
| North Coast | 35 | 30 | **33** | 12 | 16 | **14** |
| South Coast | 1,065 | 1,289 | **1,065** | 319 | 293 | **306** |
| San Francisco | 421 | 261 | **341** | 149 | 76 | **120** |
| Central Valley | 309 | 452 | **381** | 144 | 202 | **144** |
| Lahontan | 42 | 65 | **54** | 18 | 75 | **18** |
| **Total (000 AF/year)** | **2,002** | **2,203** | **1,985** | **675** | **763** | **635** |

## Method A

Because no new survey of firms was available for the year 2000, we applied the 1995 GED estimates to the year 2000. In taking this approach, we encountered two challenges: how to account for efficiency improvements that took place between 1995 and 2000 and how to modify county-level SIC code employment estimates, since new data were not available for 2000. To address the efficiency omission, we assumed that Method A overestimated water use in 2000 when choosing our best estimate of water use.

We used several sources to overcome the SIC code employment data challenge. For the 1995 estimate we used County Business Patterns (CBP) SIC code employment data published by the U.S. Census Bureau. By 2000, however, CBP data had been updated to the North American Industrial Classification System (NAICS). While the California Employment Development Department (EDD) data did provide 2000 employment figures at the state level by two-digit SIC code, county information was often suppressed to maintain confidentiality. Eventually, county-level SIC code employment data for the year 2000 were extrapolated from 1995 data, county employment totals, and statewide SIC code employment totals. Although the SIC and NAICS systems do not match perfectly, we were able to use the 2000 CBP data as a crosscheck for our employment estimates. Once the employment data were in order, the total water use was calculated in the same way for 2000 as it was for 1995.

## Method B

DWR supplied us with the updated public supply data for the year 2000, and we repeated the Method B approach with the new data. No new information on self-supplied water use was available for the year 2000, so the 1995 percentages of self-supplied water were used.

12 For comparisons of our estimates to other published sources and for additional information about uncertainties inherent in the data, see Appendix F.

### Best Estimate

In choosing our best estimate of water use in 2000, we generally took the best regional estimates or an average of Methods A and B based on what we know about published estimates for specific hydrologic regions, known sources of errors inherent in the data, and sample sizes (see Table 4-3). In a few cases, regional information indicated that an overall average was not accurate and permitted adjustments in the best estimate.

**Table 4-3**
Estimates of CII Water Use 2000 (TAF)

| Hydrologic Region | Commercial Water Use | | | Industrial Water Use | | |
|---|---|---|---|---|---|---|
| | Method A | Method B | Best Est. | Method A | Method B | Best Est. |
| Central Coast | 115 | 61 | **88** | 28 | 19 | **24** |
| Colorado River | 39 | 30 | **34** | 13 | 15 | **14** |
| North Coast | 41 | 34 | **37** | 16 | 7 | **12** |
| South Coast | 1,232 | 828 | **828** | 323 | 294 | **309** |
| San Francisco | 489 | 355 | **422** | 153 | 75 | **114** |
| Central Valley | 362 | 410 | **386** | 155 | 166 | **161** |
| Lahontan | 50 | 63 | **56** | 21 | 45 | **33** |
| **Total (000 AF/yr)** | **2,337** | **1,781** | **1,852** | **709** | **621** | **665** |

### Interpretation of 1995 and 2000 Estimates

Comparing the two methods' estimates for 1995 and 2000 provided us with some valuable insights. Using Method A, water use in the CII sectors was estimated to increase slightly between 1995 and 2000 because it failed to account for efficiency improvements over this period. The Method B estimate, which is based on actual public deliveries, showed a decrease in CII water deliveries from 1995 to 2000. Some of this difference can be attributed to errors in sampling, employment, etc., but at least part of it must be from actual conservation efforts.

For both years the Method A estimate tended to be higher for the coastal regions, while the Method B estimate was higher for the inland regions. An examination of regional conservation efforts (below) shows that the coastal regions have made greater efforts to improve CII efficiency than the inland areas. This finding supports our expectation that applying average GEDs to all regions biases the regional Method A estimates – the estimate will be too high if the region has a higher-than-average conservation track record and too low if the region has a below-average conservation record.

We needed industry-level water use data in order to estimate the overall conservation potential. The only comprehensive estimate we had was the Method A estimate, which we considered somewhat high, as described above. For 2000, we modified the Method A GED estimates to account for efficiency improvements put in place in the late 1990s.

## Data Challenges

Truly accurate estimates of current total CII water use cannot be developed without better information, an improvement in reporting methods, and more detail on regional and agency variations in water use and conservation. While some water agencies currently break out their urban water use into residential and non-residential sales and the more advanced water agencies further classify their non-residential sales into commercial, institutional, and industrial sectors, even these data are not always comprehensive. A handful of water agencies, such as Sacramento, East Bay Municipal Utility District, and Torrance, break up their sales by user type. Unfortunately, the agencies that do classify their sales by sector or user type do not use a standard classification system, making comparisons difficult. Many agencies also fail to accurately report the population served, at either the county or hydrological region level.

If each agency implemented a standard customer classification system, however, calculating the state's CII water use by industry would simply require adding up the water delivered by customer categories. Creating such a system would require water agencies to add a few extra fields to each customer record, including the NAICS code and facility description (office building, educational, manufacturing, restaurant, hospital, parking lot, etc.), in addition to refining their population counts. Standardized database maintenance could be encouraged through numerous means, including adding such requirements to Urban Water Management Plans or BMP reporting.[13]

The addition of another field to each record – the number of employees/residents at the customer facility – could further improve the reported information. While the 1995 CDWR Water Survey was an excellent attempt to collect such data, the routine collection of employment data and its entry into a central CDWR database would allow CDWR to better spend its funds in collecting more detailed water-use surveys.

## The Potential for CII Water Conservation and Efficiency Improvements: Methods and Assumptions

Improving the efficiency of water use in the CII sectors can be accomplished with a broad range of technologies and actions that decrease water use without affecting production. We typically refer to these technologies and actions as conservation measures. Water conservation potential varies greatly among technologies, industries, and regions. The water manager often has several options to choose from when improving water efficiency, and these technologies and actions vary in their potential water savings, cost, and payback period. Industries, which use varying quantities of water for different purposes, have historically implemented conservation measures at different rates, giving each industry a unique conservation potential. Conservation potential also varies among regions because of differences in industrial concentrations and in the extent of past efforts to improve water-use efficiency in a given area.

13 Accuracy of data entry would also have to become a priority because, as suggested by Sweeten (2002), in districts that currently categorize users, errors often exist due to low prioritization of this task.

Through literature and audit reviews, discussions with equipment manufacturers, and meetings with water managers, we identified the most common conservation measures that apply to the different end uses, including process use by the various industries.[14] As shown in Figure 4-7, we identified most of these measures as point-of-use reduction measures, although several involve on-site reuse. The potential savings from these technologies depends on their specific water-saving characteristics, economic factors, and other barriers to implementation.

Very few measures identified involve water reclamation or behavioral modifications.[15] For purposes of this report, only a few behavioral modifications that were judged to be long-term measures, such as switching from turf to other vegetation, were included. Short-term measures that are usually instituted in response to drought situations, such as lawn-watering restrictions, were excluded. This conservative assumption also means that these kinds of responses are still available during drought periods.

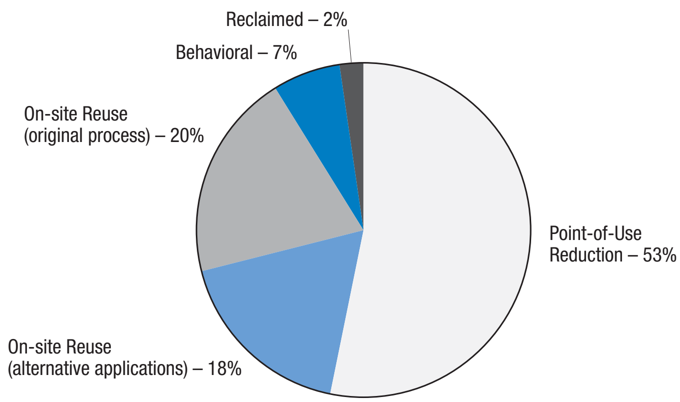



**Figure 4-7**
Approaches for Reducing CII Water Use: Current Technologies and Policies

Source: Based on the technologies reviewed in Appendix C and D (http://www.pacinst.org/reports/urban_usage/).

## Potential Water Savings Summary

The total amount of water that these measures can save in the CII sector varies tremendously by industry and end use. Our estimates of savings also vary within industries because different sources report different or vague penetration rates[16] and potential savings. To address these differences, we report potential savings as "best" (what we judge to be the most accurate estimate based on source of the data, age of the data, and/or sample size), "low" (assuming high penetration of the conservation technologies), and "high" (assuming low penetration of the conservation technologies). Overall, we estimate that the range of potential savings is between 710,000 AF/yr and 1.3 MAF/yr over current use. Our best estimate of potential savings in the CII sector is about 975,000 AF, or 39 percent of total current annual water use (see Tables 4-4 and 4-5).

Using our best estimates of potential savings as a guide, the greatest percentage of water savings could be realized in the traditional heavy industries, such as Petroleum Refining, which could potentially save nearly

14 See Appendix C and D for a complete glossary of all of the technologies examined here.

15 Even though behavioral or reclaimed water measures were mentioned very few times, they can still save significant quantities of water. Indeed, if all potable water currently used at golf courses was replaced with reclaimed water, 229,000 AF more could be saved annually.

16 The rate at which conservation technologies have already penetrated a market.

three-quarters of its total current water use (see Figure 4-8). Other industries that could save a large percentage of their total water use include Paper and Pulp (40 percent), Commercial Laundries (50 percent), and Schools (44 percent).

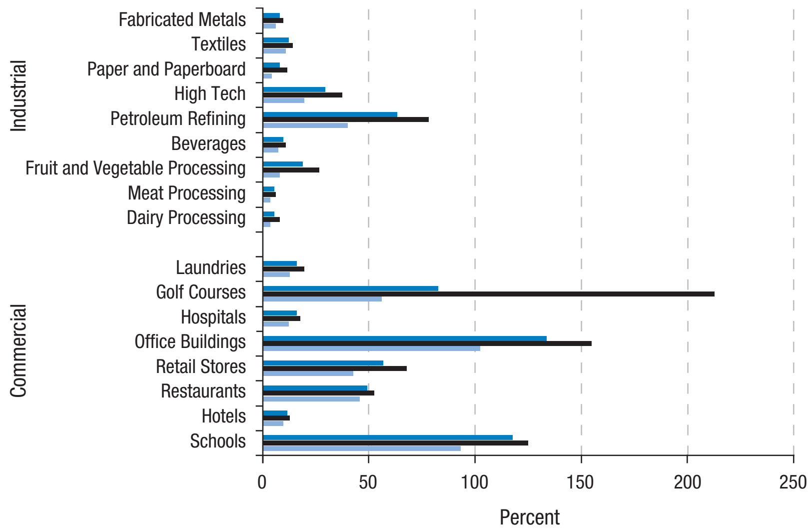



**Figure 4-8**
Estimates of Potential Savings in the CII Sectors for 2000 (High, Low, Best)

Best
High
Low

Source: See Appendices C and D for derivations (http://www.pacinst.org/reports/urban_usage/).

Although many of the largest percentages of water savings relative to use appear in the industrial sector, our findings suggest that the largest *quantities* of water could be saved in the commercial sector, because commercial facilities use more water overall. Our best estimate shows, for example, that office buildings and schools could each save approximately 120,000 AF/yr if all recommended conservation measures were implemented. In contrast, potential savings for the Petroleum Refining industry, which has the highest potential savings in the industrial sector, are about 62,000 AF/yr.

**Table 4-4**
Estimated Potential Savings in California's Commercial Sector for 2000 (TAF/yr)

Note: The Commercial Sector includes California's institutional water use (government buildings, schools, and universities).

Source: See Appendices C and D for details (http://www.pacinst.org/reports/urban_usage/).

| Commercial | Potential Savings (AF) | | |
|---|---|---|---|
| | Low | High | Best |
| Schools | 92,000 | 124,000 | 116,000 |
| Hotels | 9,000 | 11,000 | 10,000 |
| Restaurants | 44,000 | 51,000 | 48,000 |
| Retail Stores | 41,000 | 67,000 | 56,000 |
| Office Buildings | 101,000 | 154,000 | 133,000 |
| Hospitals | 11,000 | 17,000 | 15,000 |
| Golf Courses | 56,000 | 212,000 | 82,000 |
| Industrial Laundries | 11,000 | 18,000 | 15,000 |
| Unexamined Industries | 185,000 | 330,000 | 239,000 |
| **Total Commercial** | **551,000** | **984,000** | **714,000** |

**Table 4-5**
Estimated Potential Savings in California's Industrial Sector for 2000 (AF/yr)

| Industrial | Potential Savings (AF) Low | High | Best |
|---|---|---|---|
| Dairy Processing | 2,000 | 7,000 | 5,000 |
| Meat Processing | 2,000 | 5,000 | 4,000 |
| Fruit and Vegetable Processing | 7,000 | 25,000 | 18,000 |
| Beverages | 6,000 | 10,000 | 9,000 |
| Petroleum Refining | 39,000 | 78,000 | 62,000 |
| High Tech | 19,000 | 37,000 | 29,000 |
| Paper and Pulp | 3,000 | 10,000 | 7,000 |
| Textiles | 9,000 | 13,000 | 11,000 |
| Fabricated Metals | 5,000 | 9,000 | 7,000 |
| Unexamined Industries | 66,000 | 138,000 | 108,000 |
| **Total Industrial** | **158,000** | **331,000** | **260,000** |

We estimate that approximately half of these total savings would come from reductions in landscaping water use, which could be cut by 50 percent with the conservation measures recommended here (see Figure 4-9). Implementing the recommended conservation measures could also reduce restroom and laundry water use by approximately 50 percent. The potential savings for restrooms (158 TAF) is much higher than for laundries (26 TAF), however, because restrooms comprise a larger percentage of total CII water use than laundries. And we estimate the potential savings in kitchens and cooling at approximately 20 percent of their total use, which would total over 100 TAF annually.

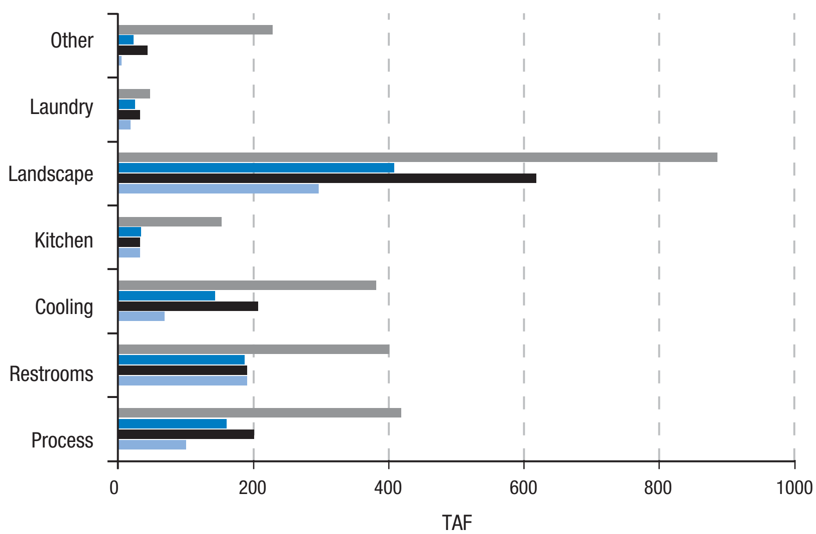



**Figure 4-9**
Estimated Potential CII Water Savings, by End Use

Source: See Appendices C, D, and E for details (http://www.pacinst.org/reports/urban_usage/).

## Conservation by Region

Conservation potential also varies by region. For water-planning purposes, the CDWR divides California into ten hydrological regions that approximately correspond to the state's major drainage basins (CDWR 1998). For our analysis, we combined some of the hydrological regions with small urban populations and minimal CII water use data. These combinations are shown in Table 4-6.

**Table 4-6**
Hydrological Regions

| DWR Hydrological Regions | Pacific Institute Regions |
|---|---|
| North Coast | North Coast |
| San Francisco Bay | San Francisco Bay |
| Central Coast | Central Coast |
| South Coast | South Coast |
| Sacramento | Central Valley |
| San Joaquin | |
| Tulare Lake | |
| Colorado River | Colorado River |
| North Lahontan | Lahontan |
| South Lahontan | |

California's regions have implemented conservation measures at different rates depending on the reliability and adequacy of the regional water supply. Problems with water-supply reliability often manifest themselves in terms of increased water rates, poor service, accelerated implementation of conservation measures relative to other regions, or the development of new supplies.

In many regions of California, the population continues to grow, but options for increasing supply remain limited, leaving these regions susceptible to shortages, especially in times of drought. This situation has encouraged some water agencies to raise water rates and promote the implementation of conservation measures to improve efficiency and reduce demand.

In an attempt to measure regional differences in the implementation of water conservation measures, we calculated conservation scores for each region based upon the following indicators: the conservation measures listed by water agencies in the Best Management Program (BMP) reporting to the California Urban Water Conservation Council (CUWCC) and in the Urban Water Management Plans (UWMP) submitted to the CDWR; the number of agencies filing BMP reports and UWMPs; dollars spent on BMPs; and the amount of reclaimed water used. Details on these indicators are provided below.

Using these indicators, we found that water agencies in the coastal regions appear to be more aggressive in implementing conservation measures than those in the interior regions. Specifically, our calculations show that the North Coast and the South Coast regions are implementing more comprehensive conservation measures than the Central Valley and Colorado River regions. Given these results, the state's interior regions have the greatest remaining conservation potential as a fraction of total use, though overall remaining savings may be higher in coastal regions. We also note that all regions have considerable untapped conservation potential.

## Methods for Estimating CII Water Use and Conservation Potential

Calculating water conservation potential in California's CII sector requires taking account of differences in how individual industries use water. Because time, resource, and data limitations prevented us from calculating conservation potential in every industry, we selected a group of industries to examine in detail. Ultimately, we examined industries that use approximately three-quarters of the CII sector's water.

After selecting a group of industries to represent both the commercial and industrial sectors, we looked closely at each industry. We first determined how much water was used by each end use, crosschecked these estimates when possible, and then listed the conservation measures corresponding to each end use before calculating the potential savings. Finally, we added up the potential savings from each end use to get an overall potential savings for each industry. Below we describe our methodology; in the Appendices (at http://www.pacinst.org/reports/urban_usage/) we provide the detailed steps used to calculate water use and conservation potential for each end use and industry.

Several differences between commercial and industrial facilities required that we use different criteria for selecting industry groups and different methodologies for computing conservation potential. A primary difference between these sectors is that commercial facilities use much less water per facility than industrial facilities, but commercial facilities are more numerous and use more water overall. Differences in water use also affected how we selected the industries; while commercial facilities use water mostly for common end uses, industrial facilities use water mostly for processing products, in boilers to generate steam, or in process cooling.

Since commercial facilities use water primarily for common end uses, it was easier to identify general conservation measures for this sector. A program for a commercial group as a whole, such as giving away free pre-rinse nozzles to restaurants or low-flow showerheads to hotels, will yield most of the savings. In contrast, potential savings at each industrial facility must be examined individually. For example, the state's 500 fruit and vegetable plants use water for diverse purposes ranging from peach canning to producing tomato paste. Such differences usually require a detailed site audit followed by an economic analysis to identify what technologies are cost-effective for each facility.

### Commercial

For the commercial sector, the industries were grouped by type rather than by examining SIC code water use. We used this approach because SIC code classification is not a relevant indicator of water use in the commercial sector. For example, psychiatrists' offices, engineering firms, and banks use water in similar ways, even though they belong to completely different SIC codes. Conversely, psychiatrists' offices and nursing homes are classified under SIC code 80, even though the nursing homes use water more like a multi-family residential complex.

To avoid these inconsistencies, we selected the top five commercial groups from the AWWARF study of commercial and institutional end uses of water (Dziegielewski et al. 2000), along with other commercial groups with reliable and relatively comprehensive data sets. In total, the groups we selected accounted for 73 percent of commercial water use.

### Industrial

To select the industrial groups, we first identified the most water-intensive industries at the two-digit SIC code level, in terms of both water used per facility as well as total industry use. Then, within each of these two-digit SIC codes, we examined how the individual industries at the more detailed three-digit SIC code level used water.

For some industries, water use at the three-digit SIC code level was similar enough that the entire two-digit SIC code was included in our analysis. In the case of the Textiles industry (SIC code 22), for example, the three-digit sub-classification was based on the type of fabric being processed, and the water-intensive processes such as dyeing, printing, and finishing were common to all fabrics. Given this similarity in process water use, SIC code 22 was selected as one industry group. Similarly, in the case of SIC codes 35, 36, and 38, the processes were similar enough that we grouped these industries under one generic description, High Tech,[17] in our analysis.

In other industries, however, processing varied greatly among the three-digit SIC codes, and only certain sub-industries were included in our analysis or the entire industry was omitted. The Paper and Pulp industry (SIC code 26), for example, includes paper mills, pulp mills, and paperboard production. While paper and pulp mills use very water intensive processes to convert raw fibrous material into a finished product, paperboard and converted paper products industries (SIC codes 264 and 265) merely cut and assemble boxes out of raw paperboard and use no process water. Because these differences in use were so great, we included only the water-intensive industries (SIC codes 261, 262, and 263) in our analysis. A more extreme example occurred in the Chemical (SIC code 28) industry, which is one of the state's more water intensive industries. Because this industry includes sub-industries as diverse as pharmaceutical drugs, industrial resins, petrochemicals, and fertilizers, we could not conduct a detailed analysis of how water is used in the general Chemical industry.

Once we selected industries for more detailed assessment, we searched the literature for data about water use and conservation in these industries. The goal of this initial data search was to gather enough information on each industry to list conservation technologies that are currently being implemented or are in the development stage (in either research or pilot testing), identify the typical magnitude of savings for each technology as a percentage of total or process water use, and determine the penetration rates of each technology.

Penetration rate data were the hardest to find. Data used here consist of surveys of specific sectors and best estimates from conservation and efficiency experts. A few important sectors were omitted from our analysis due to the lack of data.

17 Our definition of the High Tech industry is based on the one used by the Portland Water Bureau (Boyko et al. 2000).

| Commercial | Water Use (TAF) 1995 | 2000 | SIC Codes |
|---|---|---|---|
| Schools | 263 | 251 | 821, 938 |
| Hotels | 36 | 30 | 701 |
| Restaurants | 186 | 163 | 58 |
| Food and beverage stores | 43 | 35 | 54 |
| Other retail stores | 128 | 118 | 53, 55, 56, 57, 59 |
| Office buildings | 336 | 339 | 60-67, 86 |
| Hospitals | 46 | 37 | 806 |
| Golf courses | 305 | 342 | 7992 |
| Coin laundries | 5 | 5 | 7215 |
| Industrial laundries | 34 | 30 | 721 (except 7215) |
| Unexamined commercial | 603 | 502 | |
| **Total Commercial/Institutional*** | **1,985** | **1,850** | **17-19, 41-99** |
| **Percentage water use selected** | | **73%** | |

**Table 4-7a**
Estimated Water Use in the Commercial and Institutional Sectors (1995 and 2000)

*Total may not add up precisely due to rounding.

| Industrial | Water Use (TAF) 1995 | 2000 | SIC Codes |
|---|---|---|---|
| Food processing | | | |
| Dairy | 16 | 17 | 202 |
| Meat | 14 | 15 | 201 |
| Fruit and vegetable | 92 | 70 | 203 |
| Beverages | 45 | 60 | 208 |
| Petroleum refining | 102 | 84 | 291 |
| High tech | | | 28 |
| Semiconductors | 14 | 15 | 3674 |
| Other high tech | 56 | 60 | 358, rest of 36, 38 |
| Paper and paperboard mills | 26 | 22 | 261, 262, 263 |
| Textiles | 21 | 29 | 22 |
| Fabricated metals | 19 | 20 | 34 |
| Unexamined industrial | 255 | 273 | rest of 20-39 |
| **Total Industrial*** | **635** | **665** | **20-39** |
| **Percentage water use selected** | | **59%** | |

**Table 4-7b**
Estimated Water Use in the Industrial Sectors (1995 and 2000)

*Total may not add up precisely due to rounding.

## Estimating Water Use by Industry and End Use

Upon selecting the industries, we went beyond our preliminary examination of total water use and quantified how much water each industry used for specific end uses, such as restroom or kitchen use.[18] The first step involved reviewing case studies, a summary of the Metropolitan Water District's (MWD) CII audit data (MWD 2002), technical papers, and CII water conservation materials to determine the average breakdown of water use, by end use, for each industry.[19] These percentages were then multiplied by the industry's total water use to calculate the quantity of water going to each end use.[20]

After calculating these breakdowns for each industry, we attempted to crosscheck our findings against additional sources. Because of differences between the commercial and industrial sectors, as explained above, we used different approaches for each.

18 For a complete discussion of end uses, see Appendix C.

19 In a couple of industries, such as Golf Courses and Textiles, end-use allocations had to be estimated because the literature did not include these industries.

20 An industry's total water use, as used throughout this report, was derived from the GED estimates presented earlier.

### Commercial

For each commercial industry, we attempted to cross-check our GED-derived estimates of water use by end use against modeled estimates of water use. We modeled water use based on assumptions about the industry derived from industry statistics, case studies, and calculations from our end-use studies (see Appendix C, http://www.pacinst.org/reports/urban_usage/). The modeled estimates of water use were for a single unit for each industry; examples of the units include meals for restaurants, occupied rooms for hotels, or students for schools. For instance, in the Hotel industry, we started out with the number of hotels of different sizes in California, the typical number of rooms, and occupancy. By using industry averages for cooling load; landscape area; percentage of hotels with pools, restaurants, and banquet rooms; the number of guests per room; and the amount of water used in showers, toilets, and faucets, we calculated the gallons/room/day.

Because the models generally used industry-specific units to measure water use, crosschecking our GED-derived estimates required converting these estimates into an appropriate comparable unit. Once we determined the appropriate unit for an industry, we divided the total annual water use for each end use by the number of units in the state and then by the number of workdays in that industry to get the gallons/unit/day of water used in that industry.[21]

The daily per unit water use for the two approaches was then compared to check our GED-derived estimates of water use. Although we ultimately used the GED-derived estimate of end uses because inadequate data prevented explanation of the differences, crosschecking allowed us to gauge the accuracy of our GED-derived estimates for each commercial industry.

### Industrial

In the industrial sector, the GEDs were based on an actual survey of firms in California in 1995 (CDWR 1995a). Ideally, crosschecking our GED-derived estimates of water use in the industrial sector would have involved comparing our estimates to a gallons/ton of product (or comparable) benchmark. Unfortunately, paucity of data prevented us from taking this approach for most industries. Specifically, production figures for individual facilities were rarely made available, even in detailed case studies, and statewide production figures were reported in dollars, not tons, for practical reasons.

However, for a few SIC codes, we were able to break the water use down to the four-digit SIC code level and obtain production figures at that level. These figures were then compared to industry benchmarks as rough checks. For example, in poultry processing (SIC code 2015), which includes processing broilers, turkeys, and other birds and egg production, we used existing data to calculate a gallon/bird estimate (California Agricultural Statistics Service 1995) that we compared to industry benchmarks. Details of these crosschecks can be found in Appendix D (http://www.pacinst.org/reports/urban_usage/).

21 The number of workdays varies by industry; the work year for the industrial sector and office buildings is 225 days, schools are 180 days, and all other commercial establishments are 365 days.

## Calculation of Conservation Potential

We calculated potential savings for each end use from a variety of information on existing conservation measures. Our approach involved employing "modularity," a principle used by software engineers to break up a problem into components and find common solutions that can be applied over and over again. In our case, we calculated the conservation potential for each common end use and then applied the potential savings to all of the industries. Due to the diverse nature of process-related end uses, we had to calculate the potential process savings for each industry individually.

### Identification of Conservation Technologies and Their Savings

The first step of these calculations involved breaking down each end use into sub-end uses and identifying existing conservation technologies (and their savings) corresponding to the sub-end uses (see Appendix C for a glossary of identified technologies).[22] We used a number of sources, including case studies of individual facilities, technical industry papers, summary results from detailed surveys from the MWD, published audit summary results, and manufacturers specifications, to determine which technologies could be used to save water for each sub-end use.

### Estimate of Penetration Rates

Upon identifying the conservation technologies, we estimated their current penetration rates throughout the state using existing penetration information that we collected from various sources listed in Table 4-8 below.

**Table 4-8**
Sources of Market Penetration

| Data Source | Industry/End Use | Geography |
|---|---|---|
| Surveys from Industry Associations | Food Processing; Coin-Laundry; Golf Courses; Metal Finishing; and Semi-conductor | California; Southwestern U.S.; U.S. |
| Surveys from the U.S. EPA | Industrial Laundries | U.S. |
| Reclaimed Water Data from the State Water Resources Control Board | Schools; Golf Courses; Textiles; and Refining | California |
| Assumptions Used by Industry Experts | Various | Various |
| Interviews with Consultants and Industry Officials | Cooling; Textiles; Kitchens; and Paper and Pulp | U.S.; California |
| Individual Facility Data | Refineries | |
| Summary of MWD Survey Results | Restrooms; Landscaping; All Industries | South Coast Region, California |
| Survey or Audit Results from Water Agencies | Various | Various |

22 We performed this exercise once for each of the common end uses and then applied our findings to each industry but, for process water use, we had to perform this exercise for each industry.

While these sources provided fairly complete information on penetration rates for some technologies, several gaps remained. For some technologies and/or industries, little or no penetration rate data existed. And even where the data were available, the descriptions of penetration were often qualitative, using terms such as "very few" or "several" to describe the number of facilities using such measures. When actual penetration rates were unavailable, we generally estimated penetration based on the age of the technology or, more commonly, on any qualitative data we could collect. We converted the qualitative data from phone conversations with industry experts or general discussions in the literature into penetration rate percentages. The following interpretations were applied: "very low" to five percent; "low" to 20 percent; "medium" to 50 percent; "high" to 70 percent; and "very high" to 95 percent. When footnoting these conversions in Appendices C and D (http://www.pacinst.org/reports/urban_usage/), we specifically state that the percentages were *estimated* from the source (as opposed to taken directly from the source).

**Box 4-2**
Definitions

**Technology Savings:** Percentage of water saved by implementing a particular technology, assuming service provided remains the same

e.g., Technology savings from ULFTs =

$$\frac{\text{Water use in 3.5 gpf toilet} - \text{Water use in 1.6 gpf toilet}}{\text{Water use in 3.5gpf toilet}} = (3.5\text{-}1.6)/3.5 = 54.3\%$$

**Measure of Technology Penetration:** Percentage of the total number of potential sites using the efficient technology

$$\text{e.g., Penetration of ULFTs} = \frac{\text{Number of ULFTs}}{\text{Total population of toilets}}$$

**Conservation Potential Percentage:** Percentage of the total water used for a particular purpose that can be eliminated

e.g., Conservation potential percentage from replacing all toilets by ULFTs =

$$\frac{\text{(1- Penetration of ULFTs) * Technical savings from ULFTs}}{\text{(1- Penetration of ULFTs * Technical savings from ULFTs)}}$$

## Calculation of Conservation Potential

Upon identifying the appropriate conservation technologies, the savings from implementing them, and their penetration rates, we could apply this information to water use in each sub-end use to determine the total conservation potential due to the technology. Based on the type of information available for a particular technology and sub-end use, we used one of two methods to calculate conservation potential.

The first method involved the "best case" scenario, and we used it when comprehensive data were available. The information required includes water use per unit or per event by the efficient and inefficient technology (e.g., gallons per flush for toilets, gallons per minute for showerheads, gallons per rack for dishwashers, or gallons per load for clothes washers); the penetration rate of efficient and inefficient models; and the total number of units/events per year for the industry (i.e., total number of toilet flushes per year, total loads of laundry per year, or total minutes of showering per year). When we had this information, we could calculate the current water use by the efficient and inefficient models. Then, we took the difference between the current use and the most efficient use (assuming 100 percent penetration of the efficient model) to yield the technical potential available (see Box 4-2).

## Conservation Potential: Method 1

We used Method One when the maximum amount of information is available (water use per unit or per event by the efficient and inefficient technology, penetration rates, total number of units or events per year in the industry). With this approach, we calculated the current water use by the efficient and inefficient models. The difference between the current use and the minimum technical use (assuming 100 percent penetration of the efficient model) yields an estimate of conservation potential.

### *Sample Calculation: Toilet flushing*

The current "efficient" toilet technology uses 1.6 gallons per flush (gpf); the inefficient technology uses 3.5 or 5.0 gallons per flush.

Water use in 5.0 gpf toilets = 5.0 * Number of Flushes in 5.0 gpf toilets
= 5.0 * PR of 5.0 gpf toilets * Total Flushes in Industry
$= FV_{5.0} * PR_{5.0} * TF$

*Similarly,*

Water use in 3.5 gpf toilets $= FV_{3.5} * PR_{3.5} * TF$

Water use in 1.6 gpf toilets $= FV_{1.6} * PR_{1.6} * TF$

*Thus*

Current Water Use in Toilets = Water Use in 5.0 gpf toilets
+ Water Use in 3.5 gpf toilets
+ Water Use in 1.6 gpf toilets.
$= TF * \Sigma_{i = 5.0,3.5,1.6}(FV_i * PR_i)$
$= TF * AFV$

*Where*

FV = Flush Volume of toilet type i
PR = Penetration Rate of toilet type i
TF = Total number of flushes per year
$\Sigma(FV_i * PR_i)$ = AFV = Average Flush Volume

Water use under implementation of Best Available Technology (BAT), i.e., all toilets are replaced by 1.6 gpf toilets:

Conservation scenario water use in toilets = 1.6 gpf * TF

BAT Conservation Potential = (Current Water Use – BAT Water Use)
= (AFV * TF – 1.6 * TF)
= (AFV – 1.6) * TF

**Conservation Potential (AFPY) = (Average Use – Efficient Use) * Total Uses**

**% Conservation Potential = (Average Use – Efficient Use)/Average Use**

This methodology was applied to dishwashers, clothes washers, pre-rinse nozzles, etc., where the total level of activities were well known (such as minutes of washing or number of dishwasher cycles per year).

### Method 2

For some technologies, very limited data were available on water use per unit or event, or they were not applicable to all facilities within the industry group. Often we only had the typical savings from implementing the technology at individual sites (or typical savings from implementing a basket of technologies) and/or a rough estimate of penetration rates for the technology or basket of technologies. In these cases, we used a second method. We found that the following simple formula tended to underestimate conservation potential:

Potential Savings = Technology Savings * (1- Penetration Rate)

Instead, we found that the appropriate formula was

$$\text{Percentage Conservation Potential} = \frac{(1\text{-}p) * c}{(1\text{-}p * c)}$$

*Where*

p = Penetration Rate
c = Technical Savings

*The above formula can be proved as follows:*

Consider an industry group that manufactures widgets. There exist a basket of technologies (e.g., good housekeeping, auto-shut off valves, low-flow high-pressure nozzles) which collectively yield savings of c percent, and these have been implemented in approximately p percent of the facilities.

*Assume*

Water use per widget in an inefficient facility = w
So, water use per widget for an efficient facility = $w*(1-c)$,
since an efficient facility uses c percent less water.

If p percent of the widgets use the efficient technology

Current water use = Water use at efficient facilities + Water use at inefficient facilities

= $w(1-c) *$ Number of widgets produced at efficient facilities
+ $w *$ Number of widgets produced at inefficient facilities

$= w(1-c) * PR_{efficient} * TW + w * PR_{inefficient} * TW$

*Where*

TW = Total Number of widgets produced in the industry
$PR_{inefficient}$ = Percentage/Penetration of efficient facilities = p
$PR_{efficient}$ = Percentage/Penetration of inefficient facilities = 1-p

Current water use $= (p * w * (1-c) + (1-p) * w) * TW$

$= (pw-pwc + w-pw) * TW$

$= (w-pwc) * TW$

**Current water use** $\mathbf{= (1-pc) * w * TW}$

In the Best Available Technology scenario (BAT) we assume that ALL facilities use the efficient technology

**BAT Water use** $\mathbf{= w * (1-c) * TW}$

Conservation potential = Current water use-BAT water use

$= [( 1-pc)-(1-c)] * w * TW$

$= [c-pc] * w * TW$

$= (1-p) * c * w *$ Number of widgets

When there are limited data on w (water used per widget) or TW (total number of widgets) produced, we cannot get the conservation potential

$$\text{Conservation potential percentage} = \frac{\text{Conservation potential}}{\text{Current water use}}$$

$$\text{So instead we determine the conservation potential percentage} = \frac{(1-p) * c * w * TW}{(1-p* c) * w * TW}$$

By applying this percentage to current process water use, we estimated the conservation potential in AFPY.

$$\text{Conservation potential (AFPY)} = \text{Total AFPY} * \frac{(1\text{-p})c}{(1\text{-pc})}$$

$$\text{Percentage conservation potential (\%)} = \frac{(1\text{-p})c}{(1\text{-pc})}$$

This formula is best illustrated through an example. If 50 percent of facilities have implemented a technology that has cut water use per widget by 50 percent from 2 gallons/widget to 1 gallon/widget, then the current water use is as follows:

$$\begin{array}{r} 50 \text{ widgets} * 1 = \phantom{0}50 \text{ gallons} \\ + \ 50 \text{ widgets} * 2 = 100 \text{ gallons} \\ \hline 150 \text{ gallons} \end{array}$$

In this example the technology savings is 50 percent, and the penetration rate is also 50 percent. If the Best Available Technology potential uses 1 gallon/widget and if all facilities convert to the Best Available Technology, then the new potential would be:

$$\begin{array}{r} 50 \text{ widgets} * 1 = \phantom{0}50 \text{ gallons} \\ + \ 50 \text{ widgets} * 1 = \phantom{0}50 \text{ gallons} \\ \hline 100 \text{ gallons} \end{array}$$

*Thus,* the conservation potential is 50/150 = 33 percent.

We can verify that

Percentage Conservation Potential =

$$\frac{(1\text{- Penetration Rate}) * \text{Technical Savings}}{(1\text{- Penetration Rate} * \text{Technical Savings})} =$$

$$= \frac{(1\text{-}50\%) * 50\%}{(1\text{-}50\% * 50\%)} = \frac{25\%}{75\%} = 33\%$$

Once the conservation potential percentage for each end use was obtained for a particular industry, it was multiplied by the water used by the end-use category in 2000 to obtain the potential water savings by end use. The potential water savings for the different end uses were summed to obtain a total savings potential. An illustration is shown below in Table 4-9.

**Table 4-9**
Sample Calculation of Potential Savings

| Industry Group End Use | Water Use in 2000 (AF) | Conservation Potential (percent) | Potential Savings (AF) |
|---|---|---|---|
| Restroom | 50,000 | 30% | 15,000 |
| Kitchen | 150,000 | 20% | 30,000 |
| Cooling | 200,000 | 15% | 30,000 |
| Irrigation | 200,000 | 10% | 20,000 |
| Process | 400,000 | 30% | 120,000 |
| **Total** | **1,000,000** | **21.5%** | **215,000** |

## Applying Conservation Potential

The conservation potential percentages must be applied to the appropriate portion of water use to get the conservation savings.

### Complementary Technologies

In many cases several technologies can be applied *simultaneously* to a particular end use in an industry. For instance, we know from case studies that using low-flow nozzles and auto-shut off valves each have savings potentials of 50 percent and can be simultaneously implemented at the same facilities. Clearly, the savings are not additive, because if we implement both water use does not decrease by 100 percent. We describe technologies as *complementary* if they can be simultaneously implemented at one facility.

If the technologies have savings of $S_i$ and penetration rates of $P_i$, respectively, the savings possible for each technology is:

$$C_{Nozzles} = \frac{(1 - P_{Nozzles}) * S_{Nozzles}}{(1 - S_{Nozzles} * P_{Nozzles})}$$

The total savings from implementing both technologies is:

$$\text{Total Conservation Potential \%} = 1 - (1 - C_{Nozzles}) * (1 - C_{Auto\text{-}shutoff})$$

Generalizing for complementary technologies

$$\textbf{Total Conservation Potential \%} = 1 - \Pi(1 - C_j)$$

### Mutually Exclusive Technologies

Another situation occurs when technologies are mutually *exclusive* and either one or the other is applicable depending on some specific characteristic of the facility. An example of this type of a situation is in landscape water use, where different technologies apply to turf and shrubs. In this case we need to find how much of the total water use is used by turf and shrubs, respectively. Let's define $C_{Turf}$ and $C_{Shrubs}$ as the percentage conservation potential from turf and shrubs, respectively, and t% and s% as the share of water devoted to turf and shrubs, respectively (t+s= 100%). The total savings from implementing both technologies is:

Total Conservation Potential % = $t\% * C_{Turf} + s\% * C_{Shrubs}$

Generalizing for exclusive technologies

**Total Conservation Potential % = $\Sigma\ i\% * C_i$**

### Technologies Applicable to a "Sub-end Use"

A third situation occurs when technologies apply to only a *component* of the water use. For instance, kitchen water use includes dishwashing, prerinsing, and icemakers. Different technologies apply to each of these components of water use viz. efficient dishwashers, low-flow pre-rinse nozzles, and efficient icemakers, respectively.

Let's assume that dishwashers use d% of kitchen water use, pre-rinse nozzles uses n%, and icemakers use i% of kitchen water use, such that d+p+i = 100%

In this case, total savings from implementing both technologies is

Total Conservation Potential % =

$$d\% * C_{Dishwashers} + n\% * C_{Nozzles} + i\% * C_{Icemakers}$$

**Total Conservation Potential % = $\Sigma\ i\% * Ci$**

## Data Constraints and Conclusions

As we've noted elsewhere in this report, data constraints affect our final estimates of conservation potential in the CII sectors. These constraints were encountered when calculating current water use by specific end uses, penetration rates, and potential water savings.

The primary data constraint is a fundamental lack of key information. At the most basic level, reliable end-use analyses for a few industries in the industrial sector, such as textiles, were unavailable. Without this basic information, we had to estimate the amount of water these industries used for specific tasks, adding uncertainty to our estimate. The penetration rates of several technologies were also unavailable, forcing us to estimate potential savings and adding another level of uncertainty to our estimate of conservation potential.

Even when data were available, they often contained limitations that further affected the reliability of our estimates. Much of the penetration data we used were reported at the national level. The typical flow rate of restroom faucets, for example, was not available for California, so we used a generic number for the U.S. (Vickers 2001). Using this generic estimate may have resulted in an overestimate of faucet water use, because we suspect that the penetration of conservation measures in California tends to be somewhat higher than in the rest of the country.[22] We also relied upon a series of EPA reports that estimate the conservation potential for several technologies used in the industrial sector based on nationwide data. Like the faucet use data, these reports may overestimate savings potential if California has already captured more of the potential savings than the rest of the nation.

And when California-specific data were available, several factors often limited their usefulness. Although we found numerous estimates of potential savings in the literature, details of how these savings were realized were omitted from many studies, particularly for the industrial sector. For example, the literature may report potential savings for process water in a given industry, but it often does not report the amount of this water being saved from the sub-end uses of processing, such as rinsing and sterilizing. Without these breakdowns, crosschecking estimates of potential savings is more difficult and reduces our ability to independently check the reliability of the estimates. In the commercial sector, we encountered problems when data were in formats such as gallons/employee/day, gallons/square foot/day, or gallons/meal served/day. Each conversion of these numbers into a comparable figure risks introducing uncertainty.

We also faced problems with the timeliness of conservation technologies. When data on specific technologies were available, they were sometimes out of date. In the area of water conservation, technologies are continuously changing (see Box 4-3), and a water-savings technology may become obsolete a few years after implementation when an even better technology is introduced. Trying to sort out the mix of several existing technologies, and the potential for new technologies, further complicates calculating conservation potential.

22 We did not adjust the calculation, because we do not have definitive proof that this assumption applies to faucets.

**Box 4-3**
Evolution of Water Conservation Technologies

Water conservation technologies are constantly evolving. The technologies that were adopted in the 1970s and early 1980s were the easiest and cheapest to implement – "the low-hanging fruit." In this period, the water conservation literature focused on preventing waste, and typical water conservation measures implemented included auto-sensors to turn off water when production lines were not in use, elimination of single-pass cooling, reuse of non-contact cooling water, and replacement of 6 gpf toilets with 3.5 gpf toilets. Most of these measures were fairly low technology and paid back quickly.

In the late 1980s and 1990s, there were further improvements in water-efficient equipment (clothes washers and dishwashers, toilets, and pre-rinse nozzles). More recently the focus has been on reducing overall fresh water demands by reusing treated wastewater streams. A detailed analyses of every waste stream of every industry is beyond the scope of this report, but the broad steps include segregating effluent streams, identifying the characteristics of each waste stream, identifying processes that can potentially use water of a lower quality, and treating effluent streams with chemicals and/or membrane filtration to increase quality for reuse.

This trend is expected to continue in the future, with more and more fresh water being substituted with treated internal waste streams or reclaimed water from a local water recycling plant. Indeed, some industries, such as Paper and Pulp, Industrial Laundries, and Metal Finishing, are beginning to develop "closed-loop" systems where all the wastewater is reused internally, with only small amounts of freshwater needed to make up for water incorporated into the product or lost in evaporation.

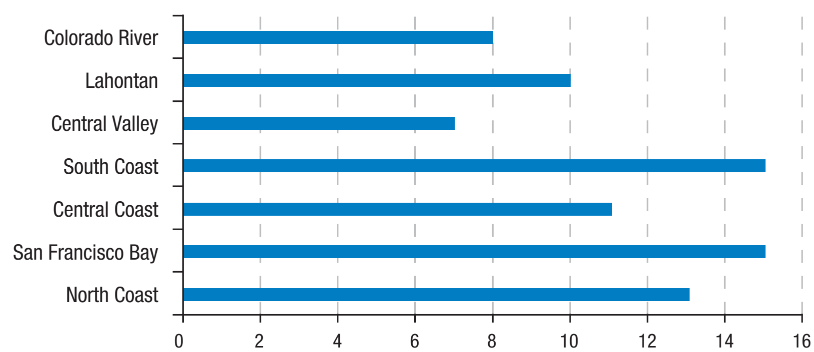
Despite these data constraints, working through the water conservation potential in this transparent manner provides a framework for further discussion and improvements. The "modular" approach we employed allows agencies with better information to update penetration rates or other components of conservation potential to reflect status in their service area. Similarly, industry associations with better information on conservation potential in process water use can adjust these figures without changing the conservation estimates for cooling or restroom use. And, most important, the process provides the first overview of the conservation measures in each industry and illustrates which measures will produce the most savings.

## CII Conservation Potential by Region: Discussion

Initially, we intended to calculate conservation potential achieved between 1995 and 2000 by region. Unfortunately, the quantitative data were inadequate for analyzing detailed regional conservation potential at this level. We include here, however, our initial analysis as an indicator of differences in conservation among regions.

Working with available data, we used six categories to rate regions on efficiency, and we examined population growth and future shortages to measure the pressure on regions to conserve. In each category, a range was created based on the lowest and highest scores recorded by the regions, and this range was used to classify each region as having implemented high (top 33 percent of range), medium (middle 33 percent of range), or low (bottom 33 percent of range) levels of conservation. Descriptions of these categories, explanations of why they can be used to determine the level of conservation in a region, and the methods used to calculate the conservation scores are presented in detail in Appendix G (http://www.pacinst.org/reports/urban_usage/). A summary of our findings is shown in Figure 4-10.

**Figure 4-10**
Score of Conservation Efforts by Region




We calculated a numerical score for each region by assigning points to each high, medium, or low score that the region received. A high score received three points, a medium score received two points, and a low score received one point. Based on these results, the San Francisco Bay Area and South Coast regions have made the most efforts to date in urban water conservation. The Central Valley, Colorado River, and Lahontan regions have made the least efforts. Table 4-9 summarizes these conclusions.

**Table 4-9**
Indicators of Conservation Efforts by Region

| Region | UWMP Score Weighted | UWMP % of Population Filing | Reclaimed Water Use | BMP Score Weighted | BMP % of Population Filing | $ Spent on BMPs | Overall Score |
|---|---|---|---|---|---|---|---|
| North Coast | low | high | medium | high | low | high | **13** |
| S.F. Bay | high | high | low | high | high | medium | **15** |
| Central Coast | medium | low | medium | medium | low | high | **11** |
| South Coast | medium | high | high | medium | high | medium | **15** |
| Central Valley | low | low | low | medium | low | low | **7** |
| Lahontan | medium | high | low | medium | low | low | **10** |
| Colorado River | low | low | high | low | low | low | **8** |

## The North Coast

Despite low pressure for population growth and potential shortages, the North Coast scored overall as a region making considerable efforts in improving efficiency. The only two categories that the region receives low scores for are the UWMPs (weighted score) and the percentage of BMP reports filed. Note that the UWMP score was based on a very small sample (three percent) and is probably unreliable.

## San Francisco Bay

There was some variability in the San Francisco region's scores but, overall, the region appears to have relatively strong efficiency efforts in place even though the pressures to conserve are low. Water providers in the Bay Area are good about filing UWMPs and BMP reports and their efficiency scores are high in the BMP category, but they use very little reclaimed water and spend only a medium amount on BMPs.

## Central Coast

The Central Coast appears to have implemented a medium number of efficiency measures to address its low population growth and medium shortage potential. The region has low UWMP and BMP report filing rates, but it reports medium efficiency in these categories, spends the second highest amount per capita on BMPs, and uses a medium amount of reclaimed water.

## South Coast

The South Coast appears to have strong conservation measures in place. The region received all medium and high scores for conservation to address population growth and high shortage potential. The percentage of water providers filing BMP reports and UWMPs was high and the South Coast uses the second-highest percentage of reclaimed water (after the Colorado River region).

### Central Valley

Of all regions, the Central Valley appears the least focused on conservation. Indeed, the region received the lowest conservation scores despite high population growth and potential for shortage.

### Lahontan

Compared to other areas of the state, the Lahontan region seems to be planning poorly for potential shortages in supply as it faces both high population growth and high shortage potential. While the region received medium UWMP and BMP scores, all other scores were low.

### Colorado River

Despite high population growth (109 percent), the Colorado River region has a low potential for shortage and low conservation scores. A remarkably high level of reclaimed water use – ten percent of the region's total use – is the exception to consistently low conservation scores. Note that the sample sizes for the UWMP and BMP conservation measures are small, 10 and 15 percent, respectively, reducing the reliability of these scores.

## Recommendations for Commercial, Industrial, and Institutional Water Conservation

### Encourage Conservation Through Proper Water Pricing, Including Wastewater Charges

Incentives for improving water efficiency and conservation are always higher when the price of water accurately reflects its true costs. We urge all water providers to charge appropriate prices for water, including charging for wastewater separately, by volume of water. When wastewater charges fall below the cost of pollutant disposal, industries often choose to use extra water to dilute their wastewater streams until the pollutant levels reach acceptable levels. Wastewater charges can be adjusted to discourage this practice.

### Encourage Conservation Through Wastewater Permitting

When an industry wants to expand its operations, it usually undergoes a permitting process. Several water districts have successfully incorporated water conservation requirements into this process so that as companies grow, and their demand for water increases, they increase their level of water conservation.

### Encourage Smart Management Practices at the Industry Level

Often, industry managers will introduce conservation measures, but differences in management and worker goals can prevent the full implementation of these measures. For example, not budgeting additional worker time for implementing water conservation technologies contributes to poor implementation rates and may even increase water use. In some cases, workers have drilled large holes in low flow nozzles to increase the speed of the nozzles' performance. If managers take such worker concerns into consideration, however, they can achieve more long-term results.

Managers also need to remember that, like all equipment, conservation devices have regular maintenance or replacement requirements. The typical lifetime of industrial brass nozzles, for example, is four to five years for most applications.[24] After this time, the nozzles lose their cleaning ability and it takes longer to achieve the same level of cleaning, eclipsing any potential savings. Facilities must be encouraged to incorporate checking water-efficient fixtures as a part of routine maintenance.

Budgeting practices also frequently contribute to a poor conservation ethic. At large facilities, individual departments may not know how much water they use, much less how to conserve it, when a central office handles their accounts. Managers should provide the appropriate incentives to individual departments, such as deducting the utilities bill from the department's budget or ensuring that the facility's maintenance department receives a copy of the water bill.

### Educate Industry Decision Makers and the Public About Hidden Conservation Opportunities

Industries sometimes choose less-efficient technologies because they are operating with incomplete information. Discussions with the Champion dishwasher company, for example, revealed that sales of an inefficient dishwasher model (UH-150B) far exceeded sales of the efficient model in the same range (UH-200B) because the efficient model costs about ten percent more than the less-efficient model. The customers were unaware that an efficient commercial dishwasher pays back in about six months.

Other hidden conservation opportunities exist when an industry does not own its water-using equipment, but rents from an independent rental agency that charges a monthly or a use-based fee. In the case of some dishwashing rental companies, for example, the rental company makes most of its margin selling cleaning chemicals that require more water for rinsing. In this arrangement, these companies have a perverse incentive to lease inefficient dishwashers, and the customer pays for more chemicals and water.

Water agencies should also encourage the implementation of new technologies that are not intended to achieve reductions in water use but do so anyway. Occasionally, shifts to water-conserving equipment have occurred for reasons unrelated to water conservation. In hospitals, for example, water-ring vacuum pumps were historically installed because flammable gases were used as anesthetics. Once the flammable gases were discontinued, hospitals slowly shifted to oil-based pumps. Similarly, digital x-ray film processors that use no water are gaining market share for their superior ability to process, transmit, and manipulate x-ray images.

24 The "lifetime" depends on how critical the shape and flow of the water stream is to the particular industry. In certain high tech applications the stream shape is so critical that even a 5 percent deviation from ideal would be considered unacceptable, greatly reducing the lifetime of a nozzle.

### Give Industries an Opportunity to Tout Their Conservation Achievements

Programs such as promoting the most efficient water users in local newspapers or other media outlets during a drought or instituting green-certification programs often encourage industries to conserve water out of a desire to improve their public image. Instituting water-efficiency certification programs for industry groups such as hotels, restaurants, or hospitals can reinforce this trend.

### Promote Reclaimed Water as a Secure Source for Water Supply

The desire for a guaranteed water supply during drought conditions has driven some refineries to switch to reclaimed water for their cooling needs. Even if water is not a major cost component, an interruption of water supply can cause shutdowns in many industries and result in lost income. Promoting reclaimed water as a secure supply may encourage some industries to invest in the necessary infrastructure for using this water.

### Implement Financing Schemes That Encourage Conservation

Many conservation technologies are cost-effective for the water agency, but not for individual industries. When we consider cost-effectiveness in this report, we use the weighted average cost of capital (see Section 5), which is about seven to ten percent for most private companies, to calculate the $/AF cost of water. A technology is cost-effective for a firm if the $/AF cost if less that the current price of water.

Realistically (but unreasonably), however, most companies expect a payback period of two years or less. This translates to a discount rate of 40-50 percent, depending on the lifetime of the equipment. This is a major reason for the difference between the economically achievable conservation potential and what actually gets implemented. Energy efficiency programs could be used as models to address this problem. Financing schemes such as shared savings programs or leasing of efficient equipment would require little or no capital to be invested up front by the customer and pose possible solutions.

### Data Issues

As highlighted throughout this report, problems with data influenced our research and results. Although we calculated the most accurate water use and conservation potential estimates in the CII sectors with the information available, increasing the accuracy of future estimates requires water users, suppliers, and managers at all levels to increase the reliability and accessibility of water use and conservation data.

Currently, data are neither collected nor reported in standard formats. This lack of standardization affected the reliability of our estimates, because it prevented us from cross-checking some of our calculations and accessing key background data that were often lost in the reporting process. Privacy concerns also limited our access to data, while uncertainties about differences in data and various reporting units further affected our estimates. And, finally, the absence of certain data from the literature – such as end-use breakups of water use in certain industries – required that we estimate certain findings based on very general information.

Recommendations for addressing these problems, and thus increasing the accuracy of future estimates of water use and conservation potential, are presented below.

### *Definitions of water-related terms should be standardized.*

Currently, various agencies define water-related terms in the CII sector differently. For example, one water agency may define a nursing home as a multi-family residential establishment, while another agency classifies it as a commercial establishment. Until such terms are standardized, comparing data will remain difficult.

### *State agencies should develop standard formats for water-use audits.*

Every water agency and consulting firm uses a unique reporting form for data collection practices, reporting methods, and data categories. Standard forms should include fields that capture background information about each establishment, such as the area of the establishment, the number of employees, and other relevant facts that may vary by industry. Including these data would make comparisons of audits administered by different agencies more accurate.

Audits should also include a wide variety of data that audit administrators already collect for their final estimates, but that get lost somewhere between the field and the final report. Examples of such data include recording the amount of water used by the dishwasher, the sink, and the icemaker in kitchens rather than merely reporting "kitchen use." Similarly, an audit should capture information on specific conservation technologies in place, rather than simply report "process savings." Including these data would decrease confusion about what is included in each calculation and would consequently increase the accuracy of estimating conservation potential.

### *Reporting mechanisms currently used in the CII sector must be further standardized.*

Examples of reporting mechanisms include Urban Water Management Plans (UWMPs), BMP reports, and water-use data that the CDWR collects from water agencies. While these mechanisms can be useful, differences in defining terms, calculating results, and other areas often limit their usefulness. Perhaps the best method for standardizing these reports would involve creating detailed manuals on what to report and how to report it. Although some guidelines currently exist, strict requirements about which units are used, the definitions of specific terms (such as what a survey is), and the best way to obtain specific information are not always explicitly outlined. Adherence to these guidelines must also be enforced somehow beyond what currently occurs. If such standards could be reached, the data provided through these reporting mechanisms would increase in accuracy and thus reliability and usefulness.

*Water agencies should store customer records and audit results so that they can be shared with independent researchers while the privacy of the customer is protected.*

Access to data was often limited by privacy concerns. The simplest way to overcome such barriers may involve assigning an identification number to each record, rather than just the customer name. If an identification number was used on audit forms, for example, researchers could access the raw data contained within the forms without concerns about privacy violations. Access to these raw data would increase the amount of information available, which would in turn have increased the accuracy of our findings. This practice would prove particularly helpful if the format of audits was standardized, as suggested above.

*DWR and water agencies should work more closely with industry associations and national agencies on data collection.*

When industry associations and national agencies collect water use and conservation data, they often collect these data in the state of California and then combine them with data from other states to calculate a national estimate. If the CDWR could work with these associations and agencies or provide some funding to obtain the California data in a consistent format, this information could be used for future research.

*Reconcile data reported from individual water agencies, industry associations, and various other agencies.*

Data reported by one agency may conflict with what other agencies are reporting. For example, the State Water Resources Control Board reported different quantities of reclaimed water than the individual water agencies or industry associations. These differences should be reconciled so future estimates will either match or, if they do not match, the remaining differences are explained. This reconciliation would allow for greater crosschecking and increase the universe of reliable data.

*Provide a detailed explanation of how various reporting units overlap.*

Water agency boundaries do not always correspond to the BMP reporting units or to the CDWR public water system (PWS) boundaries. These differences make comparing data reported by the different groups nearly impossible. If there was a detailed explanation of where the overlap occurs, however, and of populations served, comparisons could be made, increasing the reliability of these estimates.

*Collect additional data.*

Perhaps the most obvious – and labor-intensive – solution to increasing the accuracy of future estimates of water use and conservation potential in the CII sector involves the collection of additional data. While the standardization of data, increased access to data, and reductions in the reporting inconsistencies of water agencies would certainly generate more useful and accessible data, some types of data are simply not collected reliably. Data on self-supplied water, for example, was very limited. Two other key pieces of information that we could not uncover were end-use breakups for several industrial users and the penetration rates of certain conservation technologies. Because self-supplied water, end-use breakups, and technological penetration rates are central to accurate estimates of water use and conservation potential, we recommend improving current audits or using additional audits to collect this information.

## Summary

The good news is that organizations in the CII sector can save very substantial amounts of water with existing technologies and modest changes. We estimate that in 2000, the commercial, institutional, and industrial sectors used around 2.5 MAF and that nearly a million acre-feet of this water can be saved through existing cost-effective strategies and technologies. Much of this savings comes from improving efficiency in outdoor watering, bathroom, and kitchen use – thus, the same technologies that have proven so useful in the home can also cheaply save water in the CII sector. But changes in the way water is recycled and modifications to specific CII end-use processes also show considerable potential, despite the progress that has already been made to improve efficiency and reduce waste.

# 5

## The Cost-Effectiveness of Water Conservation and Efficiency Improvements

Sections 2 through 4 have identified the ranges of conservation and efficiency improvements that are achievable in California's residential, commercial, industrial, and institutional sectors using proven, publicly acceptable technologies and options. This section presents our assessment of the cost-effectiveness of those technologies and options in each of the urban sectors, using methods and data appropriate to those sectors. Economists use cost-effectiveness analysis to compare the unit cost of alternatives, for example, in dollars spent to obtain an additional acre-foot of physical water supply. Since each water conservation measure is an alternative to new or expanded physical water supply, conservation measures are considered cost-effective when their unit cost – which we call "the cost of conserved water" – is less than the unit cost of the lowest-cost option for new or expanded water supply.

Figures 5-1 and 5-2 present supply "curves" for conserved water in the residential and CII sectors of California, respectively.[1] The horizontal intercept of any assumed cost of new water with the supply curve identifies the quantity of conservation that is cost-effective. For example, Figure 5-1 shows that at least 663,000 AF are cost-effective to conserve in the residential sector if new water supplies cost just $50 per AF. Figure 5-2 shows that at least 147,000 AF are cost-effective to conserve in the CII sector if new water costs $103 per AF. Looking at both curves, more than 2 million acre-feet of water can be conserved for less than $600 an acre-foot.[2]

1 The curve summarizes a great many assumptions and calculations; indeed, it summarizes the entire economic analysis in this report. Consequently, the fallacy of misplaced concreteness should be avoided. These are best estimates, based on conservative assumptions, for cost-effective conservation statewide; but local conditions certainly vary considerably from statewide averages.

2 We are not aware of any significant new water supply project in California that is estimated to cost less than $600 per acre-foot. Our finding is similar to demand management analysis for energy in California (Rufo and Coito, 2002); they find that large quantities of energy can be conserved cost-effectively.

**Figure 5-1**
Cost of Conserved Water, Residential

A range of costs is presented for improving the efficiency of residential landscape water use because of differences in climate and landscape size around California. The costs estimated in the report range from $-370 to +580 per acre-foot. See Section 5 text for details.

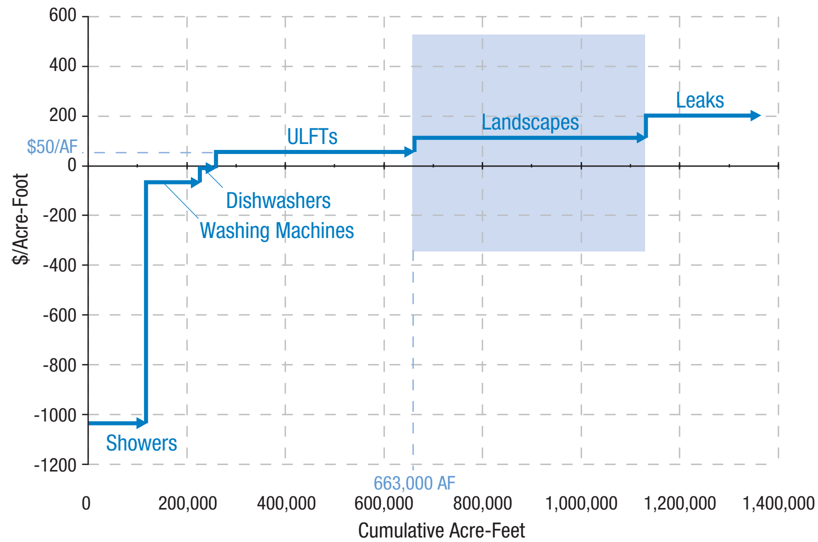
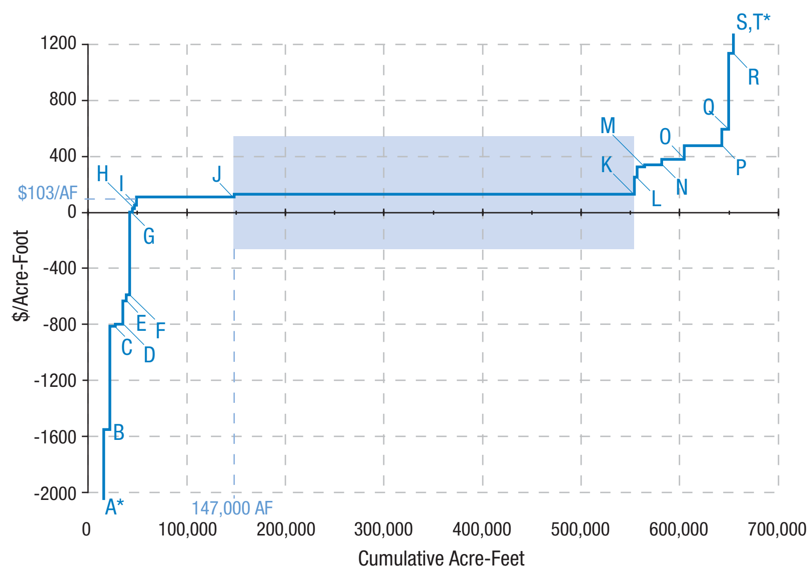



**Figure 5-2**
Cost Curve of Conserved Water, CII

A* Commercial Dishwashers
B Restaurant Dishware sensing
C Fruit/Veg RO Wastewater Recovery
D Restaurant Pre-Rinse Nozzles
E CII Toilets: Hotel Showers
F Coin Laundry H-Axis
G Meat Processing: Good Housekeeping
H Dairy Cow Water Resale
I Hospital Sterilizers
J CII Toilets: 30 flushes per day
K Landscaping
L Hospitals X-Ray
M Textile Dye Bath Reuse
N Textile Prep-water Reuse
O Commercial Laundry VSEP
P Refinery Boilers
Q Refinery Cooling
R CII Toilets: 15 flushes per day
S* Reverse Osmosis: Cow Water
T* CII Toilets: 6 flushes per day

* The most cost-effective conservation option in the CII sector is commercial dishwashers, which could save around 9,000 acre-feet annually and bring water and energy savings of more than $3,500 per acre-foot saved. This is not shown on the chart due to scaling issues. At the other extreme, some conservation options, such as reverse osmosis of "cow" water in the dairy sector and accelerated replacement of CII toilets that are only flushed 6 times per day are not cost-effective, costing more than $1,000 per acre-foot saved.




The estimated costs of some conserved water are negative for many measures. This means that water could be free and customers would still save money by implementing the conservation option. How is this possible? For some options, non-water benefits are sufficient by themselves to pay for the water conservation investment. This is especially true for those water-conservation options that save customers energy, but other "co-benefits" include savings in labor, fertilizer or pesticide use, or reductions in wastewater treatment costs. As noted elsewhere, many co-benefits are not evaluated here, but could further improve the economics of making water conservation investments.

In some cases, most notably landscaping, we could not separately identify quantities of water used or potentially conserved statewide in each of the eight sub-categories (e.g., turf, inland, large; or non-turf, inland, small;

etc.). In those cases, Figures 5-1 and 5-2 show our average, upper, and lower estimates of the cost of conserved water. The supply curve is drawn through the average estimate, but we note that this point on the curve is a simplification made purely for presentation purposes.

We conclude that it is much cheaper to conserve water and encourage efficiency in California than to build new water supplies or even, in some cases, expand existing ones. Many credible studies and sources indicate that the marginal cost of new or expanded water supply in most, if not all, of California is greater than most of our estimates of the cost of conserved water. For example, CalFed (1999) reports short-term marginal costs of $209 and $300 per acre-foot in the San Francisco Bay and South Coast Regions, respectively.

Our results also imply that the Federal and State mandates for low-flow toilets and showerheads are strongly cost-effective. These mandates ensure that water-efficient devices are used when natural replacement is required. Our results demonstrate that it would be cost-effective to prohibit the sale or installation of clothes- and dishwashers that are less water efficient (as defined later in this report) and to encourage (and even mandate) installation and use of devices that improve irrigation scheduling.[3]

The marginal costs cited from the CalFed report reflect costs that can be avoided by water utilities in the very short term: what economists call short-run marginal costs (SRMC). For example, delivering one less unit of water will reduce raw water purchase needs and electric and chemical use that same day or within a few weeks. It is important to recognize that marginal costs are higher over longer time periods, since utilities can avoid or defer other costs if demand reductions are permanent (e.g., labor or capital facilities). Economists refer to marginal costs over long time periods as long-run marginal costs (LRMC). SRMC and LRMC are opposite ends of a spectrum of marginal costs that depend on the time duration of the cost comparison. And more than one marginal cost may be relevant for a specific time duration (e.g., 10 years); for example, 10-year marginal operating costs and 10-year marginal capital costs may both be relevant to decisions. The relationships among marginal costs, volumetric water prices, rebates for conservation measures, and the time-value of money are technical issues presented in greater detail, with numerical examples, at the end of this section ("A Tale of Two Margins").

Longer-run marginal costs can be much higher than $200-$300 per AF. For example, the volumetric rates paid by commercial, industrial, and institutional (CII) customers, as discussed later in this chapter, are in the vicinity of $600 per AF. Many urban residential customers face volumetric charges higher than this.[4] If these rates represent the appropriate marginal cost of additional supplies, all CII conservation measures with costs less than $600 per AF would be cost-effective.

Because volumetric prices are often based on average costs calculated by blending the cost of more-expensive new supplies with the less-expensive cost of older supplies, the appropriate cost-effectiveness threshold may be far higher than $600 per AF. For example, long-run marginal costs in areas where new projects like seawater desalination are being considered can range from $800 per acre-foot to over $1,000 per acre-foot. The costs

3 This finding supports policies that require efficiency when water-using devices are naturally replaced or initially installed (e.g., in new construction). "Retrofit on resale" mandates may or may not be cost-effective, depending on local water prices/costs and other factors.

4 Unfortunately, most survey data for water rates in California (Black & Veatch 1999 and Raftelis 2002) do not separately identify volumetric and fixed charges. But the data suggest that many urban water systems in California currently have volumetric charges ranging from $1.50 to $2.00 per ccf, equivalent to $650 to $870 per acre-foot. ($1 per ccf equals $435/AF.)

of conserved water we estimate in this report are deliberately biased toward the higher end of the cost range. This is because we found that one need not include many favorable, but difficult to quantify, cost factors for the analysis to show that the water-conservation measures under consideration are cost-effective. These other factors are described, but not quantified, below.

Care should be taken in reading and using these numbers. While the basic approach taken to calculate cost-effectiveness is the same, some important details are different among the indoor residential, outdoor residential, and commercial and industrial analyses. For example, energy benefits of conservation were included in the indoor residential assessment, but not in the other sectors, because little energy is used (in outdoor residential water use) or data were not available (for the CII sectors).

Wastewater savings were included only in the CII sectors, because most industries pay separate and specific charges for wastewater discharges. Some special co-benefits were included in the outdoor landscape sector, including reduction in labor, green waste, and pesticide/fertilizer use. For every sector, see the detailed assumptions described in the write-up below.

All of the residential conservation potential identified in this report (nearly 1.4 MAF per year) is estimated to be cost-effective if the cost of water supply displaced by conservation is about $580 per AF or more.[5] This includes four indoor residential conservation measures – toilets, washing machines, showerheads, and dishwashers – under natural replacement, leak reduction on the customer side of the meter, and a package of irrigation management measures. The measures include scheduling improvements, minor investments like auto-rain shut-off devices, modest actions such as periodic adjustments of spray heads, and education and customer outreach efforts. We evaluated the irrigation package in two climate settings (coastal and inland), in two sizes of landscape (large and small), and for two types of landscape (turf and non-turf).

A far wider set of options was evaluated in the CII sector, with a variety of results. Examples of cost-effective options (described in more detail in this section) are natural replacement of all toilets, accelerated ULFT replacement in establishments where toilets are flushed 15 or more times per day, all low-flow showerheads, x-ray and sterilizer recirculating units in hospitals, a wide variety of "good housekeeping" options in all establishments, water-efficient dishwashers and pre-rinse nozzles in restaurants, efficient washing machines and recycling systems in laundromats, acid recovery and textile dye-water recycling in the textile industry, a wide variety of microfiltration systems in the food industry, and use of recycled/reclaimed water in refineries.

Unfortunately, it was not feasible to estimate the cost-effectiveness of all CII conservation measures due to constraints on the scope of this study and on the availability of data (discussed below). We found that at least approximately 650,000 AF of the 974,000 AF of potential CII conservation were cost-effective to conserve (67% of the CII potential we identified) if the cost of water supply displaced by conservation is about $600 per AF or more.[6] This is why our conclusions refer to the "minimum cost-effective level of CII conservation." Lack of information ***does not***

5 The highest relevant cost of conserved water is $582 per AF for conservation in coastal, small, non-turf landscapes. Most of the water can be saved for far less than this.

6 The highest relevant cost of conserved water is $598 per AF for toilet retrofits in office buildings that experience 15 flushes per toilet per day.

mean a measure is too costly. In fact, some of the measures that we did not evaluate economically have been installed in a variety of settings, suggesting that they are in fact cost-effective.

## Introduction: Residential Conservation

We evaluated the cost-effectiveness of five indoor and one package of outdoor residential water-efficiency measures. For indoor water use, we looked at ultra-low-flow toilets, low-flow showerheads, reduced leaks, higher-efficiency clothes washers, and higher-efficiency dishwashers. For outdoor water use, we evaluated irrigation management improvements along with some modest changes in irrigation technology. All conservation measures can be accomplished through a variety of devices or practices. As described in greater detail in Sections 2 and 3, we evaluated the cost of appropriate devices or practices in order to obtain estimates of the current unit costs for these measures.

We examined both natural and accelerated replacement for the indoor measures. Natural replacement refers to devices replaced due to age, failure, or remodeling, or when efficient devices are installed during new construction. Accelerated replacement refers to a device that is replaced before the end of its natural lifetime specifically in order to reduce water use.

We also examined both turf and non-turf landscapes in four specific settings for irrigation management improvements (as described in Appendix B, http://www.pacinst.org/reports/urban_usage/): large and small coastal and large and small inland (arid) landscapes. Conservation measures that improve irrigation scheduling typically involve installation of additional devices, rather than replacement devices. Consequently, the natural/accelerated replacement distinction does not apply to the outdoor conservation measures in our study.

The base-case cost estimates are conservative because they exclude many favorable but uncertain factors; for example, avoided wastewater treatment costs. Omitting favorable, uncertain factors biases the results upward, creating conservative estimates. We also assess the impact of other uncertain factors that are neither favorable nor unfavorable, and therefore might increase or decrease the cost of conservation, through "sensitivity analyses" that evaluate how the results vary with different plausible assumptions.

Furthermore, we include reasonably quantifiable and financially tangible "co-benefits" of water conservation as "negative costs" (i.e., as economic benefits). Co-benefits are benefits that automatically come along with the intended objective. For example, low-flow showerheads reduce water-heating bills and improved irrigation scheduling reduces fertilizer use. We have not evaluated all co-benefits, only those that could be quantified in a reasonably objective fashion. Even so, our results are much more favorable for water conservation than less-complete assessments that exclude such co-benefits. Including co-benefits dramatically affects the results we achieve, helping to explain why conservation is more economically desirable than some previous analyses have suggested.

Figure 5-3 presents our base-case unit cost estimates for four indoor residential water-conservation measures under natural and accelerated replacement. Figure 5-4 presents our base-case unit cost estimates for turf and non-turf irrigation scheduling improvements in the four landscape and climate settings.

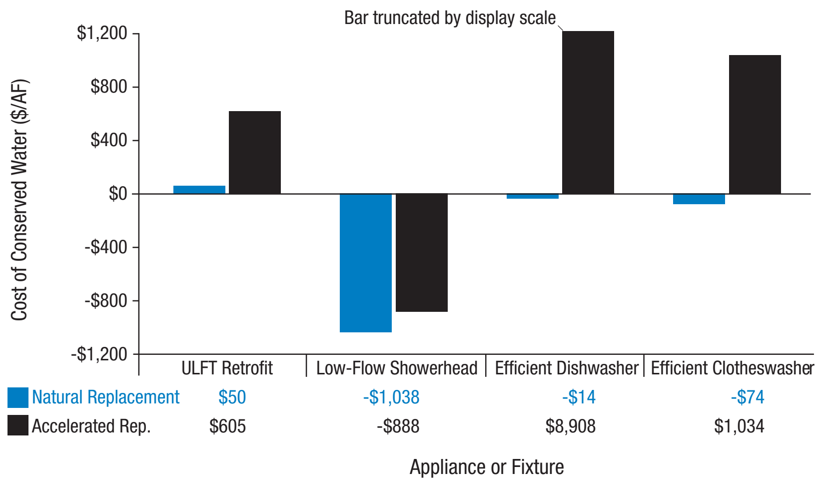



**Figure 5-3**
Cost of Conserved Water from Indoor Appliances and Fixtures

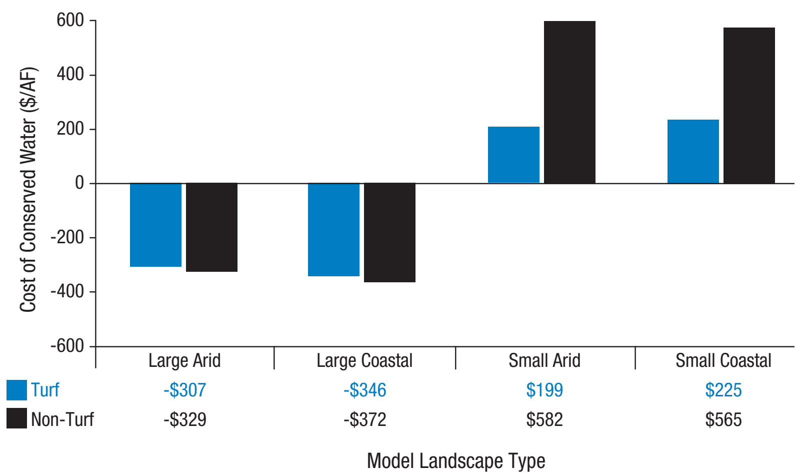



**Figure 5-4**
Cost of Conserved Water from Improved Irrigation Scheduling and Maintenance

## Analytical Method and Sample Calculation

Our analysis is done from the perspective of the consumer. We do not, however, evaluate water bill savings as a benefit to customers. Instead, we calculate the cost of conserved water based on the investment required of the customer and any changes in operations and maintenance costs they would experience from the investment (excluding water bill payments), then compare the cost of conserved water with the appropriate economic criteria, such as the short-run or long-run marginal costs described above.

We chose this approach because it addresses both costs and benefits to the water supplier – which are eventually passed on to customers – as well as costs and benefits customers experience apart from what they pay for water service. Costs and benefits to the water supplier can and should be accounted for when selecting the cost-effectiveness threshold against which the cost of conserved water, estimated from the customer perspective, is compared. Assessing benefits and costs for customers other than changes in their water bill shows that the cost of water-conservation measures is often much lower than it appears to be when evaluated more narrowly.

Our analysis is based on the methods developed in the field of energy economics. The energy approach determines the cost of conserving energy without a change in level of service experienced by the user of energy (Koomey et al. 1991, CPUC 2001). With water-using devices, however, it is somewhat more difficult to hold the level of service constant. For example, if switching from less- to more-efficient washing machines saves water without diminishing or improving washing service, the level of service is maintained. In many instances, however, more water-efficient devices have different service characteristics, such as slightly smaller maximum load sizes in clothes washers or quieter dishwasher operation.

The costs of conserved water in this report are deliberately biased toward the higher end of the cost range. This is because we found that one need not include many favorable, but difficult to quantify, cost factors for the analysis to show that the water-conservation measures under consideration are cost-effective. Difficult-to-quantify cost factors that would make our estimates of the cost of conserved water even more favorable include the following:

- The niche market status for many water-efficient products leads to mark-ups, limited product selection, slow product innovation, and unrealized economies of scale. While the current premium market prices for most water-efficient products may disappear over time through normal market transformations (standardization of products, larger-scale production, etc.), we use current retail prices taken from major national retailers and consumer evaluations. In particular, we have not included possible savings due to high-volume, wholesale purchases of water-saving devices by water suppliers, individually or as a group.

- Co-benefits that are quantified and included in the residential analysis are limited to avoided water heating costs for indoor conservation and avoided labor, fertilizer, and green-waste disposal costs for outdoor conservation. Other co-benefits, such as lower soap and detergent costs for clothes- and dishwashers and lower gasoline or electric costs for mowing and trimming, have not been quantified or included.

- The assumption of natural gas water heating is conservative. Some homeowners (especially those in the Sierra Nevada or other remote terrain) use more-expensive electricity for water heating. Revised estimates based on electric water heating dramatically lower the cost of conserved water from devices that use hot water. See Koomey and Camilla (1995) for general information on energy used in water heating in the US.

- Indoor residential water conservation will reduce wastewater treatment costs. These savings will accrue directly to the local wastewater treatment and sewer system agencies that are responsible for building and operating sanitation infrastructure, and might be passed on to ratepayers who use the infrastructure. These savings are in the range of \$15 to \$150 per acre-foot (McLaren 2000).

- The avoided costs from reduced or deferred water, wastewater, or energy infrastructure investments are not included in our analysis. Utility rebate programs are often used to "communicate" these costs to customers. We assume, in our base case, that there are no rebates or avoidable capital investments.

- Unlike new water from surface sources, the cost of the conserved water will stay the same for the life of the conservation device. This provides a cost-of-service reliability benefit whose value can be estimated, and is often quite significant, but is neglected in our study in order to keep our calculations as simple and transparent as possible.

- Conserved water will cost less per acre-foot if the device actually lasts longer than the estimated lifetime used in our analysis. Since we conservatively estimated device lifetimes, we have probably over-estimated the average cost of conservation from installing these devices.

- Lower "external" environmental costs, which can offset some of the financial costs of water conservation, have also been excluded from the analysis. These include environmental damages arising from freshwater withdrawals from natural systems and damages from sewage discharges to rivers, lakes, or bays, among other possible effects. The net result of accounting for these non-financial, but economically relevant, costs would be to further decrease the cost of conserved water.

## Equation for Estimating the Cost of Conserved Water

Mathematically, our estimate of the cost of conserved water is found from:

$$C_s = (A_s + \delta_{O\&M})/W_s$$

*Where:*

$C_s$ = Consumer's cost of conserved water from measure "s"

$A_s$ = Annual amortization of net investment in measure "s"

$$= \frac{NI_s * r * (1+r)^{N_s}}{(1+r)^{N_s} - 1}$$

$N_s$ = Useful life of conservation investment in measure "s" in years

$r$ = Cost of Capital as an annual percentage rate

$I_s$ = Consumer's gross investment in measure "s"

$R_t$ = Total agency rebates in \$/AF (\$0/AF assumed; term included for future use)

$NI_s$ = Net Investment in measure "s"
= $I_S - R_T$

$\delta_{O\&M}$ = Increase in annual costs (co-costs), caused by the investment (\$/yr), less benefits other than water savings (co-benefits) such as lower energy, sewer costs.

$L_s$ = Lifetime water savings from implementing measure "s" in AF per year

$W_s$ = Levelized[7] annual water saved = $L_s/N_s$ in AFPY

When the cost of conserved water from a specific measure ($C_S$) is less than the cost of water supply displaced by conservation, the customer and the water utility (collectively) will "make money" via the measure. If volumetric water rates and utility rebates do not reflect the appropriate marginal costs of supply, however, this benefit may be obscured. For example, if volumetric water rates are higher than variable costs associated with delivering water, the water utility will lose more revenue than the costs it can avoid. Of course these losses are less than the gains by customers, because the measure is collectively beneficial.

Collective benefits that cause utility losses, however, can and should be corrected by adjusting water rates to keep the utility financially whole. When collective benefits exist, customers will still save money after water rates are changed. It is critical to identify the cost of water supply displaced by conservation – both marginal variable costs and marginal capital costs – and to create volumetric water rates and rebates that do not penalize the utility when conservation takes place. This problem, in fact, is quite common, because neither utility staff nor customers are seeing the whole economic picture.

The rebate terms in our model allow one to investigate the impact of cost sharing between various parties and water customers. For example, a customer who invests in water conservation may reduce the investment required by the water supplier to provide water supply to future customers. If so, a rebate from the supplier to customers who invest in conservation may be the most cost-effective action possible for ratepayers as a whole. In the absence of a rebate, water rates will rise more than would be necessary if cost-effective water conservation opportunities were captured. This issue and the relevant economic terminology are discussed at length in the final part of this section ("A Tale of Two Margins").

Higher interest rates and shorter useful lifetimes for conservation measures would make our estimate of the cost of conserved water higher, and water conservation from that measure less attractive. Increases in customer expenses (other than water purchase) also make conservation less attractive; but decreases in customer expenses (such as avoided energy expenditures when hot water is conserved) have the opposite effect. These effects, and others, are illustrated in the sensitivity analysis later in this chapter.

7 Levelized annual water savings are the same as average water savings for the measures evaluated in this report.

## Sample Calculation

Imagine a consumer who spends about $90 more for a water-efficient clothes washer, compared to a standard model, when the old washer requires replacement. Suppose the efficient model is expected to last for 12 years, is paid for with money that costs 6%, uses about 3,700 gallons per year less water than the standard model, saves $11.56 per year in natural gas water heating expenses, and is not eligible for a rebate. Then the price of conserved water would be:

$$C_S = [(90\text{-}0)(.06)(1{+}.06)^{\wedge}12/((( 1 + .06)^{\wedge}12)\text{-}1)\text{-}11.56]/(3700/325{,}581)$$
$$= [(90)(.1193)\text{-}11.56]/(.011364) = (\text{- }\$74) \textbf{ per AF conserved}$$

A negative cost of conserved water means that the co-benefits of water conservation ($11.56 per year in this example) pay for the investment in water conservation and put money in the customer's pocket as well.

The sample calculation shows that natural replacement of water-efficient clothes washers is a cost-effective investment everywhere in California, because any negative cost of conserved water is less than the residential price of water throughout California. Delivered water is, at best, free. This shows that money is not the issue – unless the customer is unable to borrow or pay out of pocket the additional $90. Rather, lack of information and other obstacles are impeding water conservation and financially rational decision-making.[8]

Although the policy implications of our work are discussed in another section of this report, the sample analysis implies that educational programs that inform and motivate consumers and appliance dealers should be looked into carefully. The example also implies that rebates to purchasers of water efficient clothes-washers are not financially necessary under the illustrated conditions, though they may serve an important educational purpose.

## Cost Data and Assumptions

The cost parameters that affect our base case estimates of the cost of conserved water are capital cost, nominal and real (inflation-adjusted) interest rates, useful lifetime, Delta O&M, and average annual quantity of water saved. The data and assumptions we used are documented below.

## Capital Cost

Retail prices of water-using and water-conserving devices were obtained from a telephone survey. Costs to implement various activities or policies were obtained from field studies and case studies data from the literature. Table 5-1, for example, presents the retail prices and other relevant information for widely available clothes washers. We ranked the clothes washers by water use per load, and then split them into less- and more-efficient groups based on a natural or reasonable "breakpoint" in the quantities used. For clothes washers, the breakpoint was 32 gallons per load. We then calculated the *average additional* capital cost a consumer would pay for a more-efficient, rather than less-efficient, clothes washer. This *additional* capital cost is the marginal capital cost of an investment in a water-efficient clothes-washer.

8 Economists refer to consumer behavior that maximizes consumer well-being as "rational." Any behavior that "leaves a $20 bill on the sidewalk" reveals the existence of a constraint that prevents full rationality. For example, people may be doing the best they can, based on what they know, but could and would do better with more complete or credible information.

**Table 5-1**
Clothes Washer Data

| **More-Efficient Models** | | | | | |
|---|---|---|---|---|---|
| Brand | Model | Type | Average gal/load | Cost | KWH/yr |
| Frigidaire | Gallery FWTR647GHS | h-axis | 25 | $645 | 259 |
| Frigidaire | Gallery FWT449 | h-axis | 25 | $674 | 259 |
| Kenmore | 2904 | h-axis | 25 | $700 | 259 |
| Maytag | Neptune MAH4000A | h-axis | 25 | $1,000 | 282 |
| General Electric | Spacemaker WSXH208T | h-axis | 27 | $648 | 242 |
| Whirlpool | Resource Saver LSW9245E | v-axis | 21.5 | $525 | 447 |
| Whirlpool | Resource Saver GSW9545J | v-axis | 21.5 | $609 | 466 |
| Frigidaire | FWS223RF | v-axis | 31 | $380 | 936 |
| Frigidaire | FWX223LB | v-axis | 31 | $345 | 793 |
| Kenmore | 2996 Resource Saver | v-axis | 30 | $600 | 452 |
| Roper | RAX7244E | v-axis | 24 | $330 | 840 |
| **Average** | | | **26.0** | **$587** | **475.91** |

| **Less-Efficient Models** | | | | | |
|---|---|---|---|---|---|
| Brand | Model | Type | Average gal/load | Cost | KWH/yr |
| White Westinghouse | MWS445RF | v-axis | 35 | $340 | 891 |
| Frigidaire | FWS61/45SF | v-axis | 35 | $350 | na |
| Roper | RAS8245E | v-axis | 33 | $370 | 1023 |
| General Electric | Profile WPSR3100W | v-axis | | $390 | 855 |
| Maytag | Performa PAV3200A | v-axis | 39 | $430 | 875 |
| Speed Queen | LWS55A | v-axis | 35 | $440 | 942 |
| General Electric | Profile WPSR4130W | v-axis | | $470 | 880 |
| Whirlpool | Gold GSL9365E | v-axis | 33 | $480 | 906 |
| General Electric | Profile Perf.WPSF4170W | v-axis | | $480 | 880 |
| Amana | ALW210RA | v-axis | 35 | $499 | 914 |
| Amana | ALW540RA | v-axis | 35 | $549 | 914 |
| Kitchen Aid | Superba KAWS850G | v-axis | 38.8 | $550 | 1000 |
| Amana | ALW780QA | v-axis | 35 | $579 | 880 |
| Kenmore | 2891 | v-axis | 41 | $580 | na |
| Maytag | MAV6000A | v-axis | 42.8 | $640 | 983 |
| Fisher & Paykel | GWL08 | v-axis | 35 | $800 | 868 |
| **Average** | | | **36.4** | **$497** | **915.07** |

Sources: telephone survey, manufacturer's literature, and the US Department of Energy

Notes:
1 "na" means data not available.
2 Installation cost estimated at $110 (2 hours of professional labor x $55/hr).

When an older device fails, or remodeling takes place, or devices are being purchased for the first time in new construction, the marginal capital cost is the capital cost of water conservation from that device. Installation of a device is necessary apart from the conservation decision, so the cost of installation and part of the capital cost of the device are irrelevant to the cost of conservation. When an older device is discarded before its useful life is over, however, the incremental capital and installation cost needs to be calculated, amortized, and divided by the annual water savings that result from replacement of an inefficient device.

By incremental capital and installation cost we mean the expenditures made today to replace the device minus the present value of the cost of replacing that device in the future when it wears out. Since it will need replacing in the future, the cost of water savings achieved by accelerating replacement is not the total cost of replacement now, but only the additional spending that results from the decision to act early.

We estimated the cost of device installation based on professional labor. Residents may, of course, install appliances themselves, but they are presumably less time-efficient than professionals who install such devices every day. Resident time is not free, but has a cost that varies depending on the after-tax wage of the resident. Self-installation may be more or less costly than professional installation, though we believe using the cost of professional labor to be a conservative value.[9] Table 5-1 assumes the cost of clothes-washer installation to be $110 (2 hours at $55 per hour).

Assigning a capital cost to replacement fixtures that meet mandated water-efficiency standards presents a unique problem. For example, since all new toilets and showerheads must meet federal water-efficiency standards, the cost of natural replacement with these fixtures might appear to be zero since the difference between the retail price of fixtures that satisfy the mandate and the average fixture available is zero. This is incorrect, however, unless models meeting the efficiency standard cost the same as the average fixture *would have cost* if efficiency standards had not been adopted. When regulations ban inefficient models, one still needs to estimate what the cost of an average model would have been without the ban. The ban makes investment in efficiency mandatory, but not costless.

In order to assess the cost of conserved water achieved through showerhead and toilet low-flow mandates, we examined the relative price of more- and less-efficient toilets in Canada.[10] The ratio of costs of more-efficient (1.6 gpf) to less-efficient (3.6 gpf) toilets was about 1.064. That is, Canadians are currently paying about 6.6 percent more for 1.6 gpf toilets than they are for 3.5 gpf toilets. Similar data from Canada were not available for showerheads, but we assumed a comparable difference. Consequently, we used 6.6 percent of the price of 1.6 gpf toilets and 2.5 gpm showerheads in the United States as the “embedded” marginal capital cost of water-conserving toilets and showerheads in the United States.

Tables 5-2 to 5-5 present the retail prices, installation costs, and other relevant information for widely available models of ULFTs, low-flow showerheads, dishwashers, and soil moisture monitoring/irrigation scheduling devices. These tables are just like Table 5-1, but for different water-conservation measures.

The capital and per AF costs of identifying and reducing residential leaks vary greatly, depending on the nature of the leaks, the kind of conservation program, and regional differences such as the age of the domestic water system. Information obtained from the California Department of Water Resources and other sources suggests that substantial leak reduction can be accomplished for under $200 per acre-foot (CDWR 2003b), and we adopt that cost here. Vickers (2001) notes that large leaks are especially cost-effective to stop – a factor we consider here in focusing on reducing the largest losses. A leak of one gallon per minute would lose 1.6 AF per year, which would cost an urban residential customer perhaps

9 One of the authors of this study purchased a high-efficiency washer and dryer from Sears in May 2003. Sears, which sells a majority of all major appliances in the United States, estimates standard delivery and installation of a washer and dryer at 30 minutes and charges $50 total. Moreover, they provided a rebate for the installation cost, making installation effectively free.

10 A better method would be to compare production costs for efficient and inefficient models, because our method implicitly assumes that all variation in retail prices between more- and less-efficient devices within each surveyed store in Canada is due to differences in water efficiency. Unfortunately, production cost data were not available.

$1,000. Even if it cost several thousand dollars to repair, the leak repair action would be cost-effective because these costs, amortized over the life of the repair, would cost less than $1,000 per year.

Table 5-5 is applicable to outdoor water conservation involving turf and non-turf landscapes, in all four size/climate zone settings (large and small, coastal and arid). As in the residential indoor analysis, we averaged the cost of implementing various packages of irrigation scheduling and related operation and maintenance improvements. For example, residents with in-ground irrigation systems on timers can add auto-rain shut-off or electronic moisture sensors that override the timers to prevent irrigation when it is not needed. Equivalently, residents with hose irrigation can install spring or battery driven hand timers that help to prevent over-watering.

**Table 5-2**
Toilet Data

| Model | Capital Cost | Marginal Cost |
|---|---|---|
| Cadet II EL 2174.139 | $123 | $8.09 |
| Hydra #2116.016 RF | $125 | $8.25 |
| Cadet II RF, #2164.135 | $141 | $9.31 |
| Cadet II EL | $170 | $11.22 |
| New Cadet EL 2898.012 | $174 | $11.48 |
| 10” RF Rough In | $188 | $12.41 |
| Savona #2095.012 RF | $445 | $29.37 |
| Caravell 305 Washdown | $320 | $21.12 |
| Berkeley 081-1595 | $420 | $27.72 |
| New Aqua Saver 21-702 | $86 | $5.68 |
| 21-702 RF | $99 | $6.53 |
| 21-712 EL | $135 | $8.91 |
| Rosario #K3434 | $370 | $24.42 |
| Alto 130-160 | $75 | $4.95 |
| Elderly 137-160 | $150 | $9.90 |
| Ultimate Flush N-2202 | $67 | $4.42 |
| Marathon RF | $99 | $6.53 |
| #CST703 RF | $99 | $6.53 |
| #CST704 EL | $120 | $7.92 |
| Ultimate #MS854114 | $319 | $21.05 |
| Nostalgia 4065 | $185 | $12.21 |
| Aris #822RF | $105 | $6.93 |
| Clinton #832EL | $135 | $8.91 |
| **Average** | **$180** | **$11.91** |

Sources: telephone survey

Notes:
1 Marginal cost is 6.6% of capital cost based on comparison of Canadian prices.
2 Installation cost estimated at $110 (2 hours of professional labor x $55/hr).

**Table 5-3**
Showerhead Data

Sources: telephone survey

Notes:
1 Marginal cost is 6.6% of capital cost based on comparison of Canadian prices.
2 Installation cost estimated at $27.50 (1/2 hour of professional labor x $55/hr).

| Model | Capital Cost | Marginal Cost |
|---|---|---|
| The Original Shower Massage SM-62P | $40.00 | $2.64 |
| The Original Shower Massage SM-82W | $45.00 | $2.97 |
| The Flexible Shower Massage SM-601 | $40.00 | $2.64 |
| Mastershower 3-way K-9505-CP | $55.00 | $3.63 |
| 500 Series XLF2.0 | $25.95 | $1.71 |
| Standard Showerhead | $5.80 | $0.38 |
| Adjustable Spray Showerhead | $8.00 | $0.53 |
| SaverShower | $7.38 | $0.49 |
| SaverShower (chrome) | $12.00 | $0.79 |
| ShowerPowerDecorator | $20.00 | $1.32 |
| Model 44-3S | $37.50 | $2.48 |
| Model 26-3S | $22.83 | $1.51 |
| Model 303-A | $26.25 | $1.73 |
| ClassicII Massage | $15.99 | $1.06 |
| B-101 OHM | $17.99 | $1.19 |
| The Incredible Head | $8.97 | $0.59 |
| Earth Showerhead (Chrome) | $12.45 | $0.82 |
| Motion LowFlow N-2133 | $9.99 | $0.66 |
| N-2825TW Prismiere Showerhead | $7.95 | $0.52 |
| Moenflo 40 (model#3940) | $43.00 | $2.84 |
| MoenFlo Deluxe2166 | $56.00 | $3.70 |
| Easy Clean 1533 Deluxe | $18.50 | $1.22 |
| Easy Clean 3900 | $13.00 | $0.86 |
| Moenflo 3905 | $39.00 | $2.57 |
| **Avg. for low-flow showerheads** | **$24.52** | **$1.62** |

**Table 5-4**
Dishwasher Data (More-Efficient Models)

Sources: telephone survey, manufacturers literature, and the U.S. Department of Energy

Notes:
Installation cost estimated at $110 (2 hours of professional labor x $55/hr).

| More-Efficient Models | | | | |
|---|---|---|---|---|
| Brand | Model | gpl | Cost | KWH/yr |
| Frigidaire | Ultra Quiet II Precision Wash FDB635RF | 6 | $300 | 587 |
| White-Westinghouse | Quiet Clean I MDB531RF | 6 | $300 | 518 |
| Frigidaire | Precision Wash System FDB834RF | 6 | $345 | 574 |
| Whirlpool | DU912PF | 5 | $349 | 555 |
| Frigidaire | Gallery FDB636 | 6 | $399 | 587 |
| Amana | SoftSound III DWA73A | 6 | $460 | 574 |
| Bosch | 30 Series | 5 | $530 | 546 |
| Maytag | MDB9100 | 5 | $550 | 555 |
| Bosch | 33 Series | 5 | $559 | 575 |
| Regency | Model# 660 | 5 | $645 | 526 |
| Miele | Model# G841 | 5 | $800 | 544 |
| **Average** | | | **$476** | **558** |

**Table 5-4 (continued)**
Dishwasher Data (Less-Efficient Models)

| **Less-Efficient Models** Brand | Model | gpl | Cost | KWH/yr |
|---|---|---|---|---|
| Hotpoint | HDA3430Z | 9 | $270 | 650 |
| Roper | RUD5750D | 8 | $300 | 667 |
| General Electric | Potscrubber Quiet Power I GSD3430Z | 9 | $330 | 621 |
| Kenmore | 1565 | 9 | $340 | 684 |
| Magic Chef | Tri Power Sweep Wash System DU6500 | 9 | $350 | 680 |
| Whirlpool | Quiet Wash Plus DU920PFG | 7 | $400 | 630 |
| Whirlpool | Gold Quiet Wash Plus GU940SCG | 7 | $430 | 638 |
| Frigidaire | Gallery FDB949GF(S) | 8 | $445 | 636 |
| Kenmore | Quiet Guard Plus 1570 | 7 | $450 | 667 |
| Maytag | IntelliClean Quiet PlusII MDB6000A | 7 | $460 | 629 |
| Kenmore | Quiet Guard Ultra Wash Sensor 1583 | 8 | $480 | 655 |
| Whirlpool | Gold Quiet Partner GU980SCG | 8 | $500 | 652 |
| General Electric | Profile Performance GSD4920Z | 9 | $500 | 624 |
| Jenn-Air | Intelliclean Quiet Series II JDB6900A | 7 | $540 | 629 |
| Maytag | InelliClean Super Capacity EQPlus MDB9000A | 7 | $600 | 593 |
| Kenmore | Active Quiet Guard Ultra Wash Sensor 1595 | 8 | $600 | 651 |
| Maytag | IntelliSense/EQ Plus DWU9962AA | 11 | $640 | 680 |
| KitchenAid | Whisper Quiet Ultima Superba KUDS24SE | 7 | $690 | 654 |
| **Average** | | **8** | **$463** | **647** |

Sources: telephone survey, manufacturers literature, and the U.S. Department of Energy

Notes:

Installation cost estimated at $110 (2 hours of professional labor x $55/hr).

**Table 5-5**
Irrigation Scheduling Device Data

| Measure | Maker | Material Cost | Installed Cost (Incl. Sales Tax) |
|---|---|---|---|
| Auto Rain Shut Off | Rainbird | $23.65 | $65.66 |
| | Rainmatic | $28.99 | $71.45 |
| | Toro | $28.99 | $71.45 |
| | Hunter Mini-Clik II | $24.98 | $67.10 |
| | WCS Rainguard | $73.80 | $120.07 |
| | SPUC (brand n/a) | $50.00 | $94.25 |
| | Rainbird Aquamiser | $40.00 | $83.40 |
| | **Average** | **$38.63** | **$81.91** |
| Automatic Soil Moisture | SPUC (brand n/a) | $150.00 | $202.75 |
| | Irrometer (automatic) | $239.00 | $299.32 |
| | Irrometer (Manual) | $135.00 | $186.48 |
| | Global Water AT-210 | $235.00 | $294.98 |
| | **Average** | **$189.75** | **$245.88** |
| Manual Moisture Probe | Greentouch moistmeter+pH | $10.99 | $31.92 |
| | Greentouch moist.meter | $7.99 | $28.67 |
| | IRWD | $12.00 | $33.02 |
| | Ratitest | $14.95 | $36.22 |
| | Rainbird | $14.99 | $36.26 |
| | **Average** | **$12.18** | **$33.22** |
| Hose Timers | Gardena Manual Hose Timer | $24.99 | $37.11 |
| | Gardena Auto. Hose Timer | $49.99 | $64.24 |
| | Electronic Water Timer for Hose | $39.99 | $53.39 |
| | **Average** | **$38.32** | **$51.58** |

Sources: telephone survey

Notes:

1 Sales tax at 8.5%.

2 Installation cost estimated at $40 (2 hours of labor x $20/hr) for auto-rain shut-off and automatic irrigation control with soil moisture sensors, $20 (1 hour at $20/hr) for manual soil moisture measurement devices, and $10 (1/2 hour at $20/hr) for hose timers.

## Nominal and Real Interest Rates

The nominal interest rate in our analysis is 6 percent, based on historic rates paid by the US Government on Treasury bonds with lives in the 10-30 year range. The nominal interest rate is used in all amortization calculations since home mortgage loans are amortized at nominal interest rates.

The real interest rate is the nominal rate minus inflation. Inflation-indexed Treasury bonds reveal the market's assessment of future real interest rates. We use 3 percent as both the real rate of interest and the rate of inflation (3% inflation + 3% real rate of return = 6% nominal rate of return). We use this real rate of interest to calculate the present value of future capital expenditures. For example, a $100 clothes washer in today's prices will cost $103 one year from now due to inflation. And $97 invested at 6% will be worth, approximately, $103 one year from now. So the incremental cost of buying a clothes washer that costs $100 today rather than that same washer one year from now is about $3. As the example shows, the real rate of interest (not the nominal rate) is the appropriate interest rate when calculating the incremental capital and installation costs of accelerated replacement decisions.

## Useful Life

We used a linear replacement rate as an approximation to actual replacement rates for the variety of devices in our analysis (see Koomey et al. 1991, p.6).[11] A linear replacement rate means that an equal fraction of fixtures of some type (e.g., toilets) will need replacement each year. Ten percent of fixtures with a useful life of 10 years will need replacement each year; five percent of fixtures with a useful life of 20 years will need replacement each year; and so forth. The useful lives used in our analysis are listed in Table 5-6.

**Table 5-6**
Useful Lives of Conservation Devices

| Device | Lifetime in Years |
|---|---|
| Clothes Washers | 12 |
| Gravity Flush ULFTs | 25 |
| Low-Flow Showerheads | 10 |
| Dishwashers | 10 |
| Auto Rain Shut Off | 20 |
| Soil Moisture Sensors | 20 |
| Soil Moisture Probes | 5 |
| Hose Timers | 10 |

## Change in Customer Operation and Maintenance Costs

As noted previously, the only change in customer Operation and Maintenance (Delta O&M) expenses that we have calculated for indoor conservation investments is a reduction in water-heating energy expenses. This change significantly lowers the cost of conserved water from investments in low-flow showerheads and more efficient clothes- and dishwashers. We also calculated the change in labor, fertilizer, and greenwaste disposal expenses for customers who conserve water by improved monitoring and scheduling of turf and non-turf irrigation.

11 Linear replacement is mathematically convenient, but not necessarily accurate. Alternate assumptions, such as a percentage of remaining old fixtures replaced each year, may be more accurate for some devices but wouldn't change our results significantly.

With respect to energy savings, we used the following assumptions and data:

- Natural gas is used rather than electricity for heating water. This makes our calculations more conservative. The increase in savings if electricity is used to heat water is discussed in the sensitivity analysis, below.

- The efficiency of natural gas water heaters is assumed to be 80 percent. Although newer models are considerably more efficient, many older models are still in use.

- The average cost per therm (100 cubic feet) of natural gas in California is $0.692 (EIA 1998). This is a very conservative assumption given recent events in California energy markets. We note that any increases in energy prices will make these water investments even more attractive.

**Table 5-7**
Energy Co-Benefits From Indoor Residential Water Conservation

| | Washing Machines | Dishwashers | Showerheads |
|---|---|---|---|
| Therms/year saved (a) | 16.7 | 2.7 | 14.3 |
| Savings ($/yr) | $11.56 | $1.87 | $9.91 |

(a) Water-use data for efficient washing machines are 350.4 loads/year (0.96 loads/day) and 10.4 gallons conserved per load. Water-use data for efficient dishwashers are 233.6 loads/year (0.64 loads/day) and 2.7 gallons conserved per load. Water-use data for low flow showerheads are 8.33 gallons conserved per day per fixture (this includes assumption of increased shower length with low-flow showerheads).

- Each therm contains 100,000 British Thermal Units (BTUs) of heat energy, and there are 3,413 BTUs per kilowatt-hour (kWhr).

- The energy savings for washing machines and dishwashers (in kWhr) are taken from the DOE's Energy Guide ratings and converted to therms of natural gas, assuming all of the energy savings are from reduced use of hot water (i.e., motive power is the same in conventional and efficient machines).[12]

- The energy savings for showerheads were calculated by using an assumed average inlet water temperature of 60° F and an average temperature of water used by showerheads of 105° F (Meier and Wright 1983).

The energy savings from applying these assumptions and data are presented in Table 5-7.

We used the following assumptions and data for our estimate of turf and non-turf landscape maintenance labor savings:

- The average California residence has 21 landscape "maintenance events" per year (twice per month for nine months plus once per month for three months).

- Each maintenance event takes 35 minutes per 1,000 square feet of turf landscape or 21 minutes per 1,000 square feet of non-turf landscape, on average.[13]

- Ten percent of maintenance time will be saved due to greater automation of irrigation timers, reduced need to fertilize, and reduced rates of plant growth.[14]

- Saved labor time is worth $20 per hour, whether the time is provided by the resident or by a paid landscape service.

12 Some of the energy savings result from lower motive power demand, so this part of the conserved energy will be in the form of electricity, not natural gas. Since electricity is more expensive than natural gas, our assumption is again conservative.

13 From Nelson's study over 8 1/2 months, assuming maintenance twice per month.

14 Nelson reports 30% (turf) and 21% (non-turf) declines in the labor required to maintain water-conserving landscapes. Sovocool and Rosales report that landscapes with at least 60% xeric vegetation had mean labor savings of about 1/3 compared with landscapes with at least 60% turf. Because the water-conserving landscapes studied by Nelson and Sovocool and Rosales contain vegetation that is less water demanding as well as better control of irrigation, we conservatively assume that only 10% of labor is saved due to better control of irrigation.

We used the following assumptions and data for our estimate of turf and non-turf landscape maintenance fertilizer savings:

- Four pounds of nitrogen are applied per 1,000 square feet of turf landscape each year. Four-tenths of a pound of nitrogen are applied per 1,000 square feet of non-turf landscape each year.[15]
- Fertilizer cost is $3.00 per pound of nitrogen.[16]
- A 20 percent reduction in fertilizer use is achieved without a reduction in landscape quality because excess irrigation water has been leaching fertilizer from the landscape.[17]

We used the following assumptions and data for our estimate of turf and non-turf landscape maintenance green-waste disposal savings:

- 15 pounds of green waste are generated per 1,000 square feet of landscape in each maintenance event. As listed above, there are 21 maintenance events per year.
- Green-waste collection and disposal expenses are $100 per ton.[18]
- A 35 percent reduction in the weight of green waste produced occurs when water and fertilizer are applied efficiently.[19]

Table 5-8 presents our estimate of the change in annual customer expenses per 1,000 square feet of turf and non-turf (on average) due to co-benefits of better control of irrigation water scheduling.

**Table 5-8**
Co-Benefits Associated with Improved Irrigated Scheduling

| Item | Annual Benefit Per 1,000 Square Feet | |
|---|---|---|
| | Turf | Non-Turf |
| Maintenance Labor | $24.50 | $14.70 |
| Fertilizer | $2.40 | $0.24 |
| Green-Waste Disposal | $5.51 | $5.51 |
| **Total** | **$32.41** | **$20.45** |

Notes: Turf and non-turf landscape labor and fertilizer avoided costs (co-benefits) differ based on data in the report. Data on green-waste disposal-avoided costs from non-turf areas were not available.

We assumed non-turf-avoided costs equal to those for turf, because non-turf areas generate brushy wastes that are voluminous, even if of lesser weight than grass clippings for a similar size area.

Finally, all packages of conservation measures require education and staff support by the water supplier. We conservatively assume that Delta O&M for outside water conservation includes an *additional* administrative cost that varies depending on the measure used. Auto-rain shutoff and automatic irrigation timers with moisture sensors are assumed to require an additional $10 per residence per year, while manual moisture probes and hose timers require an additional $30 per residence per year to be effective.

Conservation program budgets at water districts in California ranged from $1.55 to $6.73 per capita in 2000 and 2001 (Richard Harris, personal communication, August 2001). At 2.5 persons per household, this amounts to roughly $4 to $17 per household per year. Our assumption of $20 *additional* per average household per year exceeds the upper end of this range[20] but doesn't include the costs of installing equipment; those costs are treated as one-time expenses amortized over the life of the measure.

15 These figures are consistent with fertilizer application rates for turf reported in articles by Nelson and Snow, and for non-turf in the article by Nelson.

16 Based on the average retail price of granular lawn fertilizer with nitrogen content from 16-33%; prices posted on the Internet by Ace Hardware in December, 2002.

17, 18, 19, and 20 See next page.

Indoor residential conservation also requires spending for education and staff support, but our base case assumes that the *additional* administrative cost of customer investments in *indoor* residential water-conservation measures is zero. Most water suppliers in the state already have staff and budgets to address indoor conservation. These programs involve relatively fixed costs that likely won't change much as our findings are implemented. If administrative costs increase as conservation levels increase, their economic impact can be addressed outside our base case.

## Average Annual Quantity of Water Conserved

Water-use ratings for indoor appliances are provided in Tables 5-1 to 5-4. ULFTs rated at 1.6 gpf may replace 6 gpf or 3.5 gpf toilets presently in use. Annual water savings for a ULFT vary depending upon assumptions of flushing frequency and savings per flush. We based our calculations on data from the REUW (Mayer et al. 1999) study, which found the average number of flushes per toilet per day was 5.5 for all toilets. However, this frequency was found to be slightly higher for ULFTs compared to older toilets. Correcting for this "double flush" effect requires slightly reducing water savings. Our net gallons saved per toilet per year estimates are therefore about 75 gallons per year lower (see Section 2).

We assumed that water savings per flush for a 1.6 gpf are 4.4 gpf and 1.9 gpf when switching from 6 gpf and 3.5 gpf toilets, respectively. Recent evidence suggests that newer ULFTs may eliminate the difference in flushing effectiveness, but we adopt the more conservative assumption. The estimated mix of existing toilets in California for 1998 was 20 percent 1.6 gpf, 50 percent 3.5 gpf, and 30 percent 6.0 gpf toilets. Thus, the average savings per flush from retrofitting all conventional, inefficient toilets would be about 2.8 gpf [(0.50x1.9+0.30x4.4)/(0.50+0.30)]. Multiplying by 5.5 flushes per toilet per day and subtracting 75 gallons per ULFT per year yields annual water savings of about 5,621 gallons per average toilet retrofit.

Showerhead water savings come from replacing a showerhead rated at 5 gallons per minute (gpm) with one that uses only 2.5 gpm. In service, the actual water use is about 3.5 gpm and 1.8 gpm, respectively. This implies an actual **gross** savings of about 1.7 gpm for each showerhead replacement.

Data in REUW (Mayer et al. 1999) indicate that the average shower lasts 8.5 minutes for a low-flow showerhead and 6.8 minutes for a conventional one. The average daily use of all showerheads in the study sample was about 7.2 minutes per showerhead per day (Dziegelewski, personal communication, 1999). Correcting for the relative numbers of low-flow and conventional shower events in the study, average daily duration of use for low-flow and conventional showerheads is about 8.3 minutes and 6.6 minutes per day, respectively. Consequently, showerhead replacement yields an annual net water savings of about 3,000 gallons [(6.6x1.7)-(1.7x1.7)x365].

Data on dishwasher use frequency come from Koomey et al. (1995), the EPA Energy Star program, and the REUW study. We used the average dishwasher use frequency from these three studies, which was 0.64 loads per dishwasher per day. The water savings from replacing an average less-

17 Snow, James T., 1996, Loss of Nitrogen and Pesticides from Turf via Leaching and Runoff (available at www.usga.org/green/download/current_issues/loss_of_nitrogen.html) reports nitrogen and phosphorous leaching losses ranging from trivial to 7.7% for well-managed golf courses. More leaching occurs when soil moisture prior to rainfall or irrigation is high. This implies that overwatering has a non-linear and relatively large impact on nutrient leaching compared with leaching on properly watered turf. Nelson reports 24% (turf) and 43% (non-turf) decreases in fertilizer applied per square foot in a comparison of traditional and water conserving landscapes in multi-family residential complexes studied in Marin County, California. Because the water-conserving landscapes included changes in the vegetation used, as well as careful control of irrigation scheduling, we have conservatively assumed that a 20% reduction in fertilizer applied to both turf and non-turf landscapes will result from better irrigation control.

18 Average municipal solid waste and green-waste fees in California are in the range of $100-$200 per ton. Because rate structures differ enormously, and avoided cost savings are only captured when a customer is able to reduce their level of service (e.g., from a 64-gallon to a 32-gallon size container), we conservatively use the lower end of the range.

19 Moller, Johnston, and Cochrane report a 73% reduction in turf grass growth under a carefully managed irrigation regime compared with the regime typically used on turf grass in Perth, Australia in 1995. Nelson reports a 44% reduction in gasoline used for hauling non-turf clippings from water-conserving landscapes compared to traditional ones. Consequently, our assumption of a 35% reduction is again conservative.

20 That is, we assume at least a doubling of spending per capita for administration of residential conservation programs concentrated on landscape irrigation measures, since these programs have focused historically on more readily quantifiable, older technologies for indoor conservation.

efficient dishwasher with an average more efficient dishwasher is about 2.7 gallons per load. These parameters imply an annual water savings of about 631 gallons per dishwasher replacement [0.64x2.7x365].

Data on washing machine use also come from Koomey et al. (1995), the EPA Energy-Star program, and the REUW study. Again, we used the average clothes-washer frequency of use from these three studies of 0.96 loads per day. We conservatively assumed that households, on average, tend to fill their washing machines with normal-sized loads, not heavy loads, which in efficient clothes washers use much less water than in conventional washers. The average more-efficient washer used about 10.3 gallons per load less water than the average less-efficient washer. Annually, this amounts to about 3,600 gallons per year savings.

Finally, water conservation potential from improved landscape irrigation scheduling was estimated to average 32.5 percent of current landscape water use. Numerous sources indicate that improved irrigation scheduling will reduce water use from 25-40 percent. We used the center of this range in our base case. Table 5-9 shows the resulting annual water savings in turf and non-turf irrigation for the four size/climate zone landscape settings that we analyzed (large and small, coastal and arid).

**Table 5-9**
Irrigation Water Savings from Improved Scheduling

Note: Savings reflect a 32.5% reduction from current use, the average of the 25-40% range of reduction from improved control of irrigation documented in the water conservation literature.

| Size | Climate Setting | Landscape Category | Gallons/year |
|---|---|---|---|
| Large (1630 square feet) | Arid | Turf | 23,948 |
| Large (1630 square feet) | Coastal | Turf | 21,208 |
| Small (732 square feet) | Arid | Turf | 10,694 |
| Small (732 square feet) | Coastal | Turf | 9,470 |
| Large (3550 square feet) | Arid | Non-Turf | 41,845 |
| Large (3550 square feet) | Coastal | Non-Turf | 37,059 |
| Small (727 square feet) | Arid | Non-Turf | 8,615 |
| Small (727 square feet) | Coastal | Non-Turf | 7,628 |

## Sensitivity Analysis

As noted previously, our estimate of the cost of conserved water depends on the capital cost of conservation measures, including installation cost, the real interest rate, the expected useful lifetime of each conservation measure, the net change in annual operation and maintenance cost experienced by the customer (including costs borne initially by the water supplier but eventually passed on to customers through rate adjustments), and the amount of water conserved by each measure. The following sensitivity analysis shows how our base case results change with "symmetrical" changes in these variables. The illustrations are variations on the sample calculation presented above. The row in bold type in each table, below, is the sample calculation result presented previously.

Keep in mind that the difficult-to-quantify cost factors listed above and excluded from our base case analysis would always reduce the estimated cost of conserved water. In many cases, including these cost factors would more than offset the less-favorable results illustrated in the sensitivity analyses, below, and reinforce the favorable results of our base case analysis.

**Total capital cost** may be higher or lower for a variety of reasons. Appliance and labor costs will vary between water-supply service areas, as will utility rebates. The cost of installation is sometimes relevant (accelerated replacement) and sometimes not (natural replacement). Table 5-10 illustrates the sensitivity of our cost estimates to changes in total capital cost.

**Table 5-10**
Sensitivity to Changes in Capital Investment

| Conservation Measure | Marginal Capital Investment | $/AF Conserved |
|---|---|---|
| Natural replacement with a water-efficient clothes washer | $50 | -$505 |
| | **$90** | -$74 |
| | $130 | $356 |

Note: When the cost of conserved water is "negative," the customer saves money even if water were free because implementing this conservation measure also saves energy.

**The nominal interest rate** changes as macro-economic conditions change. At lower interest rates the cost per acre-foot of conserved water is less; at higher interest rates it is more. This is because the interest rate reflects the earnings one could have from investing in something other than water conservation. A higher cost of borrowed funds (a higher opportunity cost) means a higher cost for each acre-foot conserved. Table 5-11 illustrates the sensitivity of our cost estimates to changes in the nominal interest rate.

**Table 5-11**
Sensitivity to Changes in the Nominal Interest Rate

| Conservation Measure | Nominal Interest Rate | $/AF Conserved |
|---|---|---|
| Natural replacement with a water-efficient clothes washer | 0.04 | -$177 |
| | **0.06** | -$74 |
| | 0.08 | $35 |

Note: When the cost of conserved water is "negative," the customer saves money even if water were free because implementing this conservation measure also saves energy.

**The useful life of the conservation device or fixture** affects the cost of conserved water because shorter lives require amortization of total capital costs over a shorter time period. Table 5-12 illustrates the sensitivity of our cost estimates to changes in useful life.

**Table 5-12**
Sensitivity to Changes in Fixture Lifetime

| Conservation Measure | Useful Life | $/AF Conserved |
|---|---|---|
| Natural replacement with a water-efficient clothes washer | 10 | $61 |
| | **12** | -$74 |
| | 14 | -$169 |

Note: When the cost of conserved water is "negative," the customer saves money even if water were free because implementing this conservation measure also savings energy.

**The change in annual operation and maintenance costs** (avoided O&M cost) is a critical parameter. Table 5-13 illustrates the sensitivity of our cost estimates to changes in Delta O&M, using the cost of natural gas water-heating energy as an example. If electricity is used to heat water, the water-conserving clothes washer would be even more cost-effective.

In addition to the general sensitivity to Delta O&M illustrated in Table 5-13, one can see that water-efficient clothes washers conserve water cost-effectively at very low costs per kilowatt-hour (kWhr) when water is heated with electricity. The current average retail cost of electricity in California is very high – more than $0.13/kWhr. It is even higher for some commercial and industrial consumers (California Energy Commission 2003). As a result, this particular assumption greatly underestimates the overall energy savings that likely results in many parts of California from certain water-conservation options.

**Table 5-13**
Sensitivity to Changes in Operation and Maintenance Costs

Note: When the cost of conserved water is "negative," the customer saves money even if water were free because implementing this conservation measure also savings energy.

| Conservation Measure | Annual Delta O&M (Here, Avoided Natural Gas Expense) | $/AF Conserved |
|---|---|---|
| Natural replacement with a water-efficient clothes washer | -$5.78 (0.5x$11.56) | $447.00 |
| | **-$11.56** | -$74.00 |
| | -$17.34 (1.5x$11.56) | -$595.00 |

The amount of water conserved by a measure obviously affects the estimated cost of conserved water. Table 5-14 illustrates the sensitivity of our cost estimate to reduced use of the water-efficient clothes washer. In the particular example illustrated, the energy savings co-benefit is also reduced when the device is used less, amplifying the sensitivity of the estimate to less water conservation. Greater sensitivity to the amount of water conserved is typical (but not always the case) whenever co-benefits or co-costs are included in the analysis.

**Table 5-14**
Sensitivity to Changes in the Amount of Water Conserved

Note: When the cost of conserved water is "negative," the customer saves money even if water were free because implementing this conservation measure also save energy.

| Conservation Measure | Water Conserved Per Year | $/AF Conserved |
|---|---|---|
| Natural replacement with a water efficient clothes-washer | 1,800 gallons | $894 |
| | **3,600 gallons** | -$74 |
| | 5,400 gallons | -$397 |

Finally, **cost estimates are sensitive to changes in more than one cost parameter**. Sensitivity analysis that examines the impact of only one change at time can be misleading; different assumptions combine to yield different cost-effectiveness results. For example, clothes washers are clearly cost-effective under natural replacement but may not be cost-effective under accelerated replacement because total capital cost is increased by the cost of installation. On the other hand, accelerated replacement of a clothes washer machine would probably be cost-effective if the useful life of the washer were longer than the 12 years assumed in our base calculation or if electricity was being saved rather than natural gas.

## The Cost-Effectiveness of Economics of CII Water Conservation and Efficiency Improvements

This section presents an initial cost-effectiveness evaluation of conservation measures for California's commercial, industrial, and institutional (CII) sectors. With some exceptions, the analysis presented in this section is similar to that of the residential economics analysis above.

### Estimating the Cost of Conserved Water

Mathematically, our estimate of the cost of conserved water is found from:

$$C_s = (A_s + \delta_{O\&M})/W_s$$

*Where:*

$C_s$ = Consumer's cost of conserved water from measure "s"

$A_s$ = Annual amortization of net investment in measure "s"

$$= \frac{NI_s * r * (1+r)^{N_s}}{(1+r)^{N_s} - 1}$$

$N_s$ = Useful life of conservation investment in measure "s" in years

$r$ = Cost of Capital as an annual percentage rate

$I_s$ = Consumer's gross investment in measure "s"

$R_t$ = Total agency rebates in \$/AF (\$0/AF assumed; term included for future use)

$NI_s$ = Net Investment in measure "s"
= $I_S - R_T$

$\delta_{O\&M}$ = Increase in annual costs (co-costs), caused by the investment (\$/yr), less benefits other than water savings (co-benefits) such as lower energy, sewer costs.

$L_s$ = Lifetime water savings from implementing measure "s" in AF per year

$W_s$ = Levelized[21] annual water saved = $L_s/N_s$ in AFPY

When the cost of conserved water from a specific measure ($C_S$) is less than the cost of water supply displaced by conservation, the customer and the water utility (collectively) will "make money" by investing in the measure. If volumetric water rates and utility rebates do not reflect the appropriate marginal costs of supply, however, this benefit may be obscured. For example, if volumetric water rates are higher than variable costs associated with delivering water, the water utility will lose more rev-

21 Levelized annual water saved is equal to average annual water saved for the measures evaluated.

enue than the costs it can avoid. Of course these losses are less than the gains by customers, because the conservation in question is collectively beneficial.

Collective benefits that cause utility losses, however, can and should be corrected by adjusting water rates to keep the utility financially whole. It is critical to identify the cost of water supply displaced by conservation – both marginal variable costs and marginal capital costs – and to create volumetric water rates and rebates that do not penalize the utility when conservation takes place. This problem, in fact, is quite common, because neither utility staff nor customers are seeing the whole economic picture.

## Payback Period

Cost-effectiveness analysis reflects sound economics. In contrast, many businesses make investment decisions (including conservation decisions) based on the payback period. The payback period decision rule is often used blindly or inappropriately. As explained below, a conservation measure that is cost-effective but has a payback period that is "too long" is nonetheless economically desirable. The decision-maker may fail to see the very real economic benefits of conservation, or may be unable to capture those benefits without policy assistance of some type.

Using the definitions in the previous section, the payback period is defined as

$$Y_s = \frac{NI_s}{(Ws * Pw - \delta_{O\&M})}$$

*Where:*

$Y_s$ = Payback period in years

$P_w$ = Volumetric price of water in \$/AF

Many customers require payback periods of as little as two years, three in rare cases. In some industries firms operate on a contract basis, performing specific tasks for larger firms without taking ownership of the inventory – metal finishing and textiles are examples where this is extremely common.

These short payback period requirements reflect a myopic decision focus. Refusing to make an investment with payback longer than one year, for example, means that benefits from the investment after one year are of no value to the investor. This may actually be the case in firms that operate with a contract lasting only one year. Such facilities have extremely slim margins and will not invest in conservation if the payback period is more than a year. But such cases are rare.

This may also be a sign of severe risk-aversion, as is the case when a finance employee cares about protecting their reputation for fiscal prudence even when that means passing up investment opportunities with very high rates of return. For example, a two-year payback is approximately equivalent to a 45 percent rate of return, so insisting on a two-year payback implies that a 44 percent rate of return is not "good enough."

Or, short payback period requirements may mean that the actual cost of funds to an organization is inordinately high. If a business has to pay 45 percent per year for money (including the administrative cost of arranging the loan, etc.), investments with less than a two-year payback are undesirable. Again, this is extremely rare.

But in all three situations – short time horizon, severe risk aversion, and unusually expensive financing costs – the failure to satisfy a payback period requirement reflects a problem other than the core economic desirability or undesirability of the water conservation investment. This is critically important from a policy perspective. Water conservation and efficiency measures that are cost-effective often face financial implementation obstacles; but this does NOT mean that the water conservation measure is NOT cost-effective.

### Weakness of the Payback Period Method

One of the faults of the payback period measure is that it simply does not account for the durability of the investment, while the cost-effectiveness measure does. An investment of $1,000 made in a device that saves water for 20 years has the same payback period as an investment of $1,000 in a device that saves water for two years. The longer-lived investment is much more cost-effective, as common sense suggests it would be.

The informational inputs and outputs of the two approaches are somewhat symmetrical. The cost-effectiveness measure assumes a cost of funds and leads to a cost of conserved water (e.g., $/AF) that one can then compare with the appropriate marginal cost of water supply. If lower, the measure is cost-effective; if higher, it is not cost-effective. The payback period measure assumes a price of water purchases, and leads to an implicit rate of return on the conservation investment. If the implicit rate of return were used as the criterion for conservation investment, all would be well. Investments with implicit rate of return higher than the cost of funds are cost-effective; those with lower rates of return are not.

Unfortunately, that is not how the payback period criterion is used in practice. For example, a five-year payback period might be associated with an investment that would be cost-effective is money can be borrowed at 10 percent. This implies that one can make money if one can borrow money at a lower rate (say 6 percent). The investment is socially worth making at any interest rate below 10 percent even though the payback period is longer than most businesses require.[22]

To repeat the essential point: If the threshold rate of return that is implicit in a payback period requirement for investment is the same as the actual cost of funds faced by the firm, the two methods will lead to identical decisions. But when the payback period requirement is constrained to very short periods (e.g., 1-3 years) by factors other than the cost of borrowed funds (discussed above), the measures may lead to different decisions.

When a measure is cost-effective but has payback that is "too long" according to a payback period threshold being used by investors (e.g.,

22 Of course, in concept, an agency's spending per capita or household for outdoor residential irrigation water conservation efforts may be higher or lower than the overall average for conservation programs sponsored by that that agency. But we found no evidence that it is higher than the average, and it may be less than average given that many urban conservation programs in California have focused historically on more readily quantifiable, older technologies for indoor conservation, such as toilet, showerhead, and faucet retrofits.

two years), policy intervention may be warranted. For example, businesses often face higher borrowing costs than their water utility. When that is the case, loans from the utility or loan guarantees provided by the utility may be appropriate.

## Sample Calculation

The formulas for the cost of conserved water and the payback period for a conservation investment are illustrated by means of a sample calculation presented in Box 5-1. Data inputs and assumptions are in the upper part of the box; calculations are in the lower portion of the box.

**Box 5-1**
Sample Calculation for Commercial Clothes Washers

| **Assumptions** Items | Symbol | Value |
|---|---|---|
| Price of Water ($/Kgal) | Pw | 1.95 |
| Price of Wastewater ($/Kgal) | Pww | 2.56 |
| Price of Electricity ($/kWhr) | Pe | 0.10 |
| Price of Natural Gas ($/therm) | Pg | 0.75 |
| Weighted Average Cost of Capital | r | 6% |
| **Incremental Capital Cost of an Efficient Washer**[3] | **Is** | **$275** |
| **Inefficient Clothes Washer**[1] | | |
| Hot Water Use (gal/cycle) | HW i | 9.5 |
| Total Water Use (gal/cycle) | TW i | 35.5 |
| Motor Electricity Use (kWhr/cycle) | E i | 0.26 |
| **Efficient Clothes Washer**[1] | | |
| Hot Water Use (gal/cycle) | HW e | 2.4 |
| Total Water Use (gal/cycle) | TW e | 16.4 |
| Motor Electricity Use (kWhr/cycle) | E e | 0.13 |
| 1,000 Cycles Per Year (4 cycles/day)[2] | k | 1.46 |
| Lifetime of Efficient Washer (years) | Ns | 7 |
| Annual Fresh Water Reduction (Kgal/yr) | Ws' | 27.9 |
| Energy required to Heat Water (therms/kGal) | G | 7.0 |
| Natural Gas Energy Saved (therms/year) | Gs = G * HW s | 73 |
| Electricity Saved (kWhr/year) | Es = (E i - E e) * k * 1000 | 190 |

| **Calculations** Benefits for 1000 Cycles | Formula | Value |
|---|---|---|
| Reduced Wastewater Charges | Cww = Ws' * Pww | 33.50 |
| Gas Savings (from decreased hot water) | Cg = Gs * Pg | 72.60 |
| Electric Savings | Ce = Es * Pe | 19.00 |
| **Net Co-Benefits** | **Cb = Cww + Cg + Ce** | **125.00** |
| Water Savings in AF/yr | Ws | 0.086 |
| **Water Cost Savings** | **Cw = Ws' * Pw** | **54.40** |
| Annualized Capital Cost | As = Is * r * (1 + r)^N/((1 + r)^N - 1) | 49.26 |
| **Cost of Conserved Water** | **Cs = (As - Cb)/Ws)** | -$880.70 |
| **Payback Period (years)** | **Ps = Is/(Cw + Cb)** | **1.5** |

1 Assumptions for performance of clothes washers are taken from Sullivan and Parker (1999).
2 The coin laundry association estimates average use of 3 to 5 cycles per day per washer: Personal communication, Brian Wallace, Coin Laundry Association.
3 According to the Consortium for Energy Efficiency, some operators estimate that they pay approximately $275 to $450 more for a high-efficiency washer (Consortium for Energy Efficiency 1998).

### Estimates of the Cost of Conserved Water and Payback Periods

Our results are presented in Table 5-15. We considered a measure to be cost-effective if the cost of conserved water is less than $600/AF. An investment is labeled as desirable in the table by the payback period criterion if it has payback period of less than three years.[23] When the criteria disagree, the cost-effectiveness criteria should be followed, for reasons presented below.

23 Note that payback periods can be mathematically negative if increased operational costs due to the investment exceed water savings. A negative payback period would be worse than a very high, positive one. That is, the investment would never repay itself.

**Table 5-15**
Cost-Effectiveness of Selected Water Conservation Measures

| Restroom Water Use | | | | | | |
|---|---|---|---|---|---|---|
| Measure | $C_S$ ($/AF) | Desirable by $C_S$ Criteria?[A] (Y/N) | $Y_S$ (Years) | Desirable by Payback Criteria?[B] (Y/N) | Is the Payback Criteria Misleading?[C] (Y/N) | Source of Data/Assumptions |
| **ULFT – Accelerated Replacement** | | | | | | |
| Hospital Patient Rooms (6 flushes/day/toilet) | $2,576 | No | 28.4 | No | No | The average number of toilets was calculated using averages from samples of 127 schools, 33 supermarkets, 67 office buildings, and 87 restaurants (Dziegielewski et al. 2000). |
| Office Buildings (15 flushes/day/toilet) | $598 | Yes | 9.5 | No | Yes | |
| Restaurants, Supermarkets, Schools (30 flushes/day/toilet) | $103 | Yes | 4.7 | No | Yes | The capital cost of a ULFT retrofit is assumed to be $110 (two hours of labor at $55/hour). The cost of ULFTs varies from $100 to $500 per toilet. We assume $200 for a commercial establishment. This works out to a total capital cost of $310 without any rebates. |
| Airline Terminals, Movie Halls (50 flushes/day/toilet) | -$94 | Yes | 2.8 | No | Yes | |
| **Low-Flow Showerheads** | | | | | | |
| Replace low-flow showerheads in hotel rooms | -$803 | Yes | 0.9 | Yes | No | Capital cost $20 per low-flow showerhead, 16.8 minutes per occupied room (note that there are 1.5 guests on average per room), 60 percent occupancy rate, 50 percent of the water is hot water. |

Note:

A The cost of water assumed was $635/AF for commercial customers and $554/AF for industrial customers (converting from $1.95/Kgal for commercial and $1.70/Kgal for industrial customers), a measure is cost-effective if the cost of conserved water is less than this.

B Payback period < 2 years is assumed to be financially attractive.

C As discussed in previous sections the assumed criteria for payback is not always consistent with the assumed criteria for cost-effectiveness. This column specifies if the two criteria are consistent. If they are not, the payback period criterion is misleading.

| Measure | $C_S$ ($/AF) | Desirable by $C_S$ Criteria?[A] (Y/N) | $Y_S$ (Years) | Desirable by Payback Criteria?[B] (Y/N) | Is the Payback Criteria Misleading?[C] (Y/N) | Source of Data/Assumptions |
|---|---|---|---|---|---|---|
| **Cooling Water Use** | | | | | | |
| **Hospitals** | | | | | | |
| Recirculating Sterilizer Cooling Water | $143 | Yes | 3.5 | No | Yes | Cost and savings estimates from Malden Hospital case study (Pequod Associates 1995). |
| Recirculating Sterilizer Cooling Water | -$91 | Yes | 2.0 | Yes | No | Cost and savings estimates from Norwood Hospital case study (Black and Veatch 1995). |
| X-Ray Water Recirculating Units | $249 | Yes | 2.3 | No | Yes | Cost and savings estimates from C&A X-Ray. Capital cost of $4,200. Service charges (water and chemical change) of about $50 every two weeks, savings of about 980 kGal annually. |
| **Restaurants** | | | | | | |
| Closed Loop on Refrigeration Condenser | -$132 | Yes | 1.7 | Yes | No | Non-domestic water audit report for a steak house (MWRA 2002). Capital cost of about $28,000, water reduction of about 5.3 MGY. |
| **Process Water Use** | | | | | | |
| **PCB Manufacturing** | | | | | | |
| Good Housekeeping, Installing Photosensors to Stop Idle Flows | -$386 | Yes | 0.03 | Yes | No | Minnesota Technical Assistance Program (MnTaP 1994a). |
| **Meat Processing Plant** | | | | | | |
| Good Housekeeping Practices, Dry Clean-up, Installing a Blood Drain System, Improving the Paunch Handling Operation | -$595 | Yes | 1.2 | Yes | No | UNEP (2002), with BOD charges. |
| Good Housekeeping Practices, Dry Clean-up, Installing a Blood Drain System, Improving the Paunch Handling Operation | $1,360 | No | 4.9 | No | No | Without BOD charges. |
| **Restaurants** | | | | | | |
| Dishware Sensing Gate | -$3,575 | Yes | 0.4 | Yes | No | MWRA (2002). |
| Pre-Rinse Nozzles | -$808 | Yes | 0.4 | Yes | No | Nozzle prices from Spay systems (average $50 each), average savings of 2.0 gpm per nozzle replaced, run-time 30 minutes per day, and 50 percent of the water is hot water. |

**Process Water Use (Continued)**

| Measure | $C_S$ ($/AF) | Desirable by $C_S$ Criteria?[A] (Y/N) | $Y_S$ (Years) | Desirable by Payback Criteria?[B] (Y/N) | Is the Payback Criteria Misleading?[C] (Y/N) | Source of Data/Assumptions |
|---|---|---|---|---|---|---|
| **Restaurants (Continued)** | | | | | | |
| Water-Efficient Dishwashers | -$4,980 | Yes | 0.9 | Yes | No | Premium of $300 for an efficient dishwasher. Prices compared were the Champion UH-150B (inefficient) and UH-200B (efficient).<br>Medium volume restaurant (50 racks/day).<br>Performance data was taken from National Sanitation Foundation (2002).<br>Efficient dishwasher uses 1.2 gal/rack (UH-200B).<br>Inefficient dishwasher uses 1.8 gal/rack (UH-150B).<br>50 percent of water is hot water.<br>Chemicals savings of $500 per year were assumed (McCurdy, personal communication, 2002), but we think it is reasonable because it works out to about 3 c/rack of dishes. The motor of the UH-200B is slightly more powerful, translating to increased electricity costs of about $30 per year. |
| Water-Efficient Dishwashers | -$4,739 | Yes | 1.9 | Yes | No | We repeat the above calculation assuming only $250 of chemicals savings per year and a $600 premium. The economics are still in favor of the efficient model. |
| **Coin Laundries** | | | | | | |
| H-Axis Washers in Coin Laundries | -$632 | Yes | 1.7 | Yes | No | Assumptions on performance of washers from Sullivan and Parker (1999). Capital cost of an H-Axis washer assumed to be $400 more than an inefficient one. |
| **Commercial Laundries** | | | | | | |
| VSEP System: 80 Percent Recycling | $325 | Yes | 1.8 | Yes | No | Johnson (New Logic, personal communication, 2002). |
| **Metal Finishing** | | | | | | |
| Acid Recovery Systems | -$221 | Yes | 2.1 | No | Yes | MWRA (2002). |

| Process Water Use (Continued) | | | | | | |
|---|---|---|---|---|---|---|
| Measure | $C_S$ ($/AF) | Desirable by $C_S$ Criteria?[A] (Y/N) | $Y_S$ (Years) | Desirable by Payback Criteria?[B] (Y/N) | Is the Payback Criteria Misleading?[C] (Y/N) | Source of Data/Assumptions |
| **Restaurants (Continued)** | | | | | | |
| Water-Efficient Dishwashers | -$4,980 | Yes | 0.9 | Yes | No | Premium of $300 for an efficient dishwasher. Prices compared were the Champion UH-150B (inefficient) and UH-200B (efficient). |
| **Textile Industry** | | | | | | |
| Textile Dye Bath Reuse | $322 | Yes | 3.3 | No | Yes | Templeton (2002). |
| Textile Dye Water Recycling (Pilot Testing Phase) | -$564 | Yes | 0.5 | Yes | No | Johnson (New Logic, personal communication, 2002). |
| **Dairy Plants** | | | | | | |
| Reverse Osmosis of Cow Water | $1,137 | No | 7.3 | No | No | Pequod Associates (1992). Assumes that cow water is sent to the storm water drain so no wastewater charges are applicable. |
| Sale of Excess Cow Water to Another Industrial Facility by Expanding Filtration Plant | $1 | Yes | 3.2 | No | Yes | Pequod Associates (1992). |
| **Membrane Filtration Trials** | | | | | | |
| Recovery of Sugars from Orange Process Water Nano-Filtration, Ultra-Filtration, and Debittering | -$1,548 | Yes | 2.5 | No | Yes | CIFAR (1995a), with wastewater charges. |
| Recovery of Sugars from Orange Process Water Nano-Filtration, Ultra-Filtration, and Debittering | $135 | Yes | 12.4 | No | Yes | CIFAR (1995a), without wastewater charges. |
| Recovery of Sugars from Raisin Wash Water Using Nano-Filtration | -$26,203 | Yes | 0.1 | Yes | No | CIFAR (1995a), with wastewater charges. |
| Recovery of Sugars from Raisin Wash Water Using Nano-Filtration | -$24,938 | Yes | 0.1 | Yes | No | CIFAR (1995a), without wastewater charges. |
| Micro/Nano-Filtration of Tomato Flume Water | $3,022 | | N/A | | | CIFAR (1995a), with wastewater charges. |
| | $4,066 | | N/A | | | CIFAR (1995a), without wastewater charges. |

| Measure | $C_S$ ($/AF) | Desirable by $C_S$ Criteria?[A] (Y/N) | $Y_S$ (Years) | Desirable by Payback Criteria?[B] (Y/N) | Is the Payback Criteria Misleading?[C] (Y/N) | Source of Data/Assumptions |
|---|---|---|---|---|---|---|
| **Process Water Use (Continued)** | | | | | | |
| **Membrane Filtration Trials (Continued)** | | | | | | |
| Microfiltration of Pasta Blancher Water | -$983 | Yes | 2.0 | Yes | No | CIFAR (1995b), with wastewater charges. |
| | $315 | Yes | 4.9 | No | Yes | CIFAR (1995b), without wastewater charges. |
| Byproduct Recovery from Dilute Rinses Using Reverse Osmosis. | -19,173 | Yes | 0.5 | Yes | No | CIFAR (1995a), with wastewater charges. |
| | -15,453 | Yes | 0.6 | Yes | No | CIFAR (1995a), without wastewater charges. |
| Caustic Recovery from Dilute Rinses Using Reverse Osmosis (Byproduct-caustic) | $3 | Yes | 4.8 | No | Yes | CIFAR (1995a), with wastewater charges. |
| | $374 | Yes | 6.1 | No | Yes | CIFAR (1995a), without wastewater charges. |
| **Proxies for Cost of Conserved Water** | | | | | | |
| **Refineries** | | | | | | |
| Refinery Cooling Towers – Reclaimed Water | $483 | Yes | – | N/A | N/A | Carson (City of El Segundo, personal communication, 2002). |
| Refinery Low Pressure Boilers – Reclaimed Water | $388 | Yes | – | N/A | N/A | Carson (City of El Segundo, personal communication, 2002). |
| Refinery High Pressure Boilers – Reclaimed Water | $845[D] | Yes | – | N/A | N/A | Carson (City of El Segundo, personal communication, 2002). |
| **Technologies for Which Only Payback Period Data Was Available** | | | | | | |
| **Dairies** | | | | | | |
| Recover Steam Condensate from Milk Pasteurizer and Heated Cooling Water from Steam Sterilization | – | | 0.7 | | | Carson (City of El Segundo, personal communication, 2002). |
| Membrane Filtration System to Recover Milk Solids from Dilute Rinses | – | | 3.2 | | | Ontario Ministry of the Environment (2002). |
| Recover and Recycle Phosphate Cleaning Solution for Clean-In-Place at Dairies | – | | 0.8 | | | Ontario Ministry of the Environment (2002). |
| **Commercial Laundries** | | | | | | |
| VSEP System: 100 Percent Recycling | | | 5 to 10 | | | Johnson (New Logic, personal communication, 2002). |

D These are actual prices paid by the refineries. High-pressure boiler water is expensive because it is of high purity. In this case the water utility supplies high-purity water to the refinery. These prices are cost-effective for the refinery as well as for the water agency.

The quantities of water that can be conserved statewide by the measures in Table 5-15 are presented in Table 5-16. Unfortunately, it was not feasible to estimate the cost-effectiveness of all CII conservation measures. As the table shows, we found that at least about 650,000 AF of the 974,000 AF of potential CII conservation were cost-effective to conserve (67% of the CII potential we identified) if the cost of water supply displaced by conservation is about $600 per AF or more. This is why our conclusions refer to the "minimum cost-effective level of CII conservation." The lack of information does not mean a measure is too costly. In fact, some of the measures that we did not evaluate economically have been installed in a variety of settings, suggesting that they are in fact cost-effective.

**Table 5-16**
Quantities of Water That Can Be Conserved in CII Sectors with Cost-Effective Approaches

| Conservation Measure | Potential Savings (AF/yr) | Cost of Conserved Water ($/AF) |
|---|---|---|
| Commercial Dishwashers | 9,000 | -4,739 |
| Restaurant Dishware Sensing | 6,500 | -3,575 |
| Fruit/Veg RO Wastewater Recovery | 6,700 | -1,548 |
| Restaurant Pre-Rinse Nozzles | 5,400 | -808 |
| CII Toilets: Hotel Showers | 10,400 | -803 |
| Coin Laundry H-Axis | 1,500 | -632 |
| Meat Processing: Good Housekeeping | 3,500 | -595 |
| Dairy Cow Water Resale | 460 | 1 |
| Hospital Sterilizers | 1,200 | 26 |
| CII Toilets: 30 flushes Per Day | 102,700 | 103 |
| Landscaping | 407,000 | 106 |
| Hospitals X-Ray | 1,600 | 249 |
| Textile Dye Bath Reuse | 7,700 | 322 |
| Textile Prep Water Reuse | 1,300 | 322 |
| Commercial Laundry VSEP | 16,554 | 325 |
| Refinery Boilers | 22,900 | 388 |
| Refinery Cooling | 38,400 | 483 |
| CII Toilets: 15 Flushes Per Day | 6,160 | 598 |
| **Total Cost-Effective (Minimum)** | **650,000 AF (rounded)** | |

The cost data used in this study were developed from case studies of facilities all over the United States. The calculations were based on different energy, water, and wastewater prices. In order to make the measures comparable, the assumptions had to be normalized. Normalization assumptions were:

- All capital costs were normalized to the year 2000, by using the producer price index for capital goods published by the Bureau of Labor Statistics.
- All operating costs (material and labor) were normalized to the year 2000 using the Consumer Price Index published by the Bureau of Labor Statistics.
- Average commercial energy prices (natural gas and electricity) for 2000 in California were obtained from the Energy Information Administration.

- Average Water and Sewer Rates for California were obtained from Bulletin 166-4 (CDWR 1994b). However, since these were not volumetric charges, these rates were adjusted to obtain only the volumetric component.

- No survey on BOD, COD, or TSS surcharges for industrial customers has been completed to date. Average rates in the EPRI studies were chosen.

Sometimes the information required to calculate the customer's cost of conserved water in $/AF was not available or we could not "normalize" the reported data to California average water and wastewater rates. In these cases the payback period estimated in the case study is reported as is.

Specifically, the following assumptions were used in our calculations:

- Price of Water: $1.95/kGal for commercial, 1.70$/kGal for industrial customers (Average Rates from CDWR 1994b).

- Price of Wastewater based on water usage: $1.20/kGal for commercial, $1.00/kGal for industrial customers (assumed).

- BOD Charges-$100/thousand pounds, SS Charges-$50/thousand pounds (assumed only where specified from data).

- Price of Electricity: $0.10/kWh for commercial, $0.075/kWh for industrial customers (USEIA 2002).

- Price of Natural Gas: $0.75/Therm for commercial, $0.55/Therm for industrial customers (USEIA 2002).

- Seven therms of natural gas were required to heat one kGal of hot water when computing energy savings for low-flow nozzles, dishwashers, and clothes washers. See also Sezgen and Koomey (1995) for general information on energy used to heat water in commercial buildings in the U.S.

- If hot water use was not specified (e.g., pre-rinse nozzles and dishwashers), 50 percent of the water was assumed to be hot water.

- Lifetime of equipment was assumed to be 10 years except where otherwise specified.

Finally, in the case of reclaimed water use at refineries, we were unable to obtain information on capital costs and operating costs of the reverse osmosis and de-nitrification facilities used to treat the reclaimed water to boiler and cooling tower quality. We could not, therefore, directly estimate either costs of conserved water or payback periods.

However, we were able to get the prices charged for reclaimed water by the West Basin Municipal Water District. When the costs for treating water are simply being passed through to the refinery, the price of reclaimed water can be used as a proxy for the cost of conserved water. These dollar per acre-foot values are included in Table 5-15 for comparison with the costs of conserved water that we estimated directly.

An important point to note is that the price of high-pressure boiler water cannot be compared with the price of potable city water. The refinery would spend a significant amount of money to treat potable city water to "boiler spec" quality. This suggests that the $845/AF cost of conserved water reported for high-pressure boiler water is reasonable.

## Discussion of Results

Tables 5-15 and 5-16 show that most of the measures we have looked at are cost-effective. Fewer have attractive payback periods using the three-year-or-less payback criterion. As we mentioned earlier, measures that are cost-effective but have longer payback periods usually require and are worthy of policy support.

### Commercial

- Accelerated commercial ULFT retrofits are cost-efficient at all establishments with more than 15 flushes/day/toilet. At establishments with less than this number of flushes, toilet dams are recommended during the remaining useful life of the toilet. (Note that for office buildings, schools, etc. the number of working days is less than 365, so the average flushes/toilet/day must be adjusted accordingly.) Natural replacement of ULFTs is cost-effective for all establishments.

- Low-flow showerheads, nozzles, and faucet aerators are highly cost-effective. Free replacements/outreach programs by the water agencies are recommended.

- Efficient dishwashers and clothes washers are cost-effective and have paybacks of less than two years. Replacement of clothes washers is cost-efficient at usages of over 1.5-turns/machine/day, and replacement of dishwashers is cost-effective at over 20 racks of dishes per day.

- Recycling of 80 percent of the water in industrial and commercial laundries is highly cost-effective.

### Industrial

- Preliminary trials by EPRI have showed that several of the membrane filtration trials, especially where valuable by-products can be recovered, are cost-effective. There is plenty of potential in the food-processing sector for this.

- Using reclaimed water in refinery cooling towers and boilers is cost-effective.

- Dye-bath reuse is cost-effective in the textile industry (but very little headway has been made).

- Acid recovery systems in the metal finishing industry are cost-effective and have a payback of less than two years.

## Sources of Error and Uncertainty in the CII Results

These results represent best estimates with the information available at this time. They are somewhat uncertain and subject to error based on the following:

- Increases in the real (inflation-adjusted) cost of delivered water during the lifetime of the conservation device, if any, will make the conservation and efficiency investment even more attractive financially.

- Reductions in the costs of the conservation and efficiency improvements analyzed here would also make investments more attractive financially.

- Higher interest rates and shorter useful lifetimes for conservation measures would make our estimate of the cost of conserved water from any measure "s" ($C_s$) higher, and water conservation from that measure less attractive.

- Increases in customer expenses (other than water purchase) also make conservation more expensive and less attractive; but decreases in customer expenses (such as avoided energy expenditures when hot water is conserved) have the opposite effect.

The water and sewer rates assumed are average rates for California. Since most agencies have higher or lower sewer rates than average, the cost of conserved water will be higher or lower depending on region. Similarly, payback periods will differ between regions due to variation in water rates.

## A Tale of Two Margins: Optimal[24] Prices and Conservation Rebates

Saving water usually saves money. Water users can reduce their bills; water suppliers can reduce delivery costs and treatment costs; wastewater treatment utilities can reduce operations costs; and costs of new supply and equipment can be deferred or eliminated. Customers' savings, however, may differ from costs the water supplier can avoid, because suppliers no longer need to deliver as much water to that customer. Customers of that water supplier, in aggregate, will be affected through changes in their water bills unless the water supplier is permitted to earn higher profits or is subsidized with general tax dollars. This is why many economists recommend marginal cost pricing: It rewards individual customers for short-term conservation and water-use decisions in a way that does not burden or benefit other customers.

Most economists refer to the marginal cost of supplying an acre-foot of water as the short-run marginal cost (SRMC). Volumetric water prices, ideally, would match SRMCs in each year.[25] A customer saves water, the supplier avoids some costs of supplying that water, the customer doesn't have to pay those costs, other customers are not burdened because the conserving customer avoids paying the water supplier exactly the amount that the water supplier avoids paying its suppliers and workers (e.g., by reducing overtime), and the conserving customer is encouraged to conserve just the right amount – no more or less. Everyone is happy,

24 We define "optimal" prices and rebates as those that charge and reward all customers of a water supplier for the costs and benefits of the conservation decisions they make, excluding costs and benefits that are not usually included in water prices (e.g., wastewater and energy costs or benefits, or environmental damages).

25 In addition to SRMC at the time of the conservation investment, customers base their decisions on expectations of future volumetric water prices/SRMC. For example, suppose a customer is considering a water-conservation measure that will save water for two years. Even if the volumetric water prices established at the beginning of each year were identical to the actual SRMC in that year, customers don't know during year one how much they will probably save on their water bill in year two. Of course no one knows the future, and uninformed guesses about next year's water price/SRMC are probably a trivial problem; but water-conservation measures often have time horizons between 5 and 15 years, and customers' guesses over longer time frames will probably be biased compared with the best estimates that informed persons would make. Because expectations of future prices as well as current prices are used by customers to make conservation decisions, ideal marginal cost-pricing systems require that water suppliers inform customers of their best estimate of future volumetric prices.

including economists who applaud the efficiency of this scenario, until complications arise.

An important complication occurs when conservation measures create savings for long enough that capital facility investments by the water supplier could be delayed or avoided entirely as a result of conservation. This causes the long-run marginal cost (LRMC) to be relevant to the conservation decision. LRMC is defined as the marginal cost of supplying an acre-foot of water when currently avoidable capital expenses are included.[26] LRMC is the sum of SRMC and the marginal cost of currently avoidable capacity investments (MCC).

The complication for marginal cost pricing is that MCC and LRMC should not be used to determine the optimal volumetric price of water. Suppose SRMC is $250 per acre-foot and MCC is $500 per acre-foot.[27] Charging customers $750 per acre-foot may be too large an incentive for water conservation. First, conservation measures that will complete their useful lives prior to the expansion don't help to defer or avoid the expansion, so $750 per acre-foot is too high a reward for such conservation. Second, $750 per acre-foot is not avoidable after new capacity has been installed (i.e., after the $500 per acre-foot has become a "sunk" cost), so $750 per acre-foot is too high a reward for conservation investments that take place too late to affect the timing of the expansion.

On the other hand, a volumetric charge of only $250 per acre-foot before the expansion takes place fails to "tell" customers that conservation investments costing less than $750 per acre-foot may be cost-effective if they are sufficiently long-lived. Finally, a volumetric charge of $750 per acre-foot prior to the expansion and $250 per acre-foot after it would short-change customers who invested in conservation prior to the expansion, because water was costly ($750 per acre-foot).

One can address this problem through a properly designed rebate. Such a rebate is consistent with marginal cost pricing, but explicitly recognizes that two marginal costs are involved for conservation investments that are sufficiently long-lived. The first is the marginal cost of water itself; the second is the marginal cost of avoidable future capital facilities (MCC). Volumetric water rates based on SRMC address the first marginal cost issue; rebates (or equivalent financial incentives) address the second marginal cost issue.

Suppose a water supplier anticipates that capacity expansions will be needed in five and fifteen years to satisfy rising demand for water. Volumetric water prices equal to SRMC in each year will efficiently reward customers for water-conservation measures that save water for less than five years, or for water-conservation measures in year six that save water for less than nine years, and so forth. But a water-conservation measure implemented today that saves water for 12 years will not be rewarded efficiently because avoidable, future capital costs have been neglected. A rebate based on anticipated annual water conservation from that measure times the appropriate MCC during years five through twelve, however, would reward the customer efficiently for the capacity portion of their conservation decision.

A sample calculation of the ideal rebate is presented below. It includes estimates of MCC by the method we felt was most appropriate for our

26 There are at least three categories of future capital expenditures: First, existing capital facilities may require replacement. Second, new capital facilities may be needed to accommodate growth in demand. Third, new capital facilities may be needed or desirable to enhance performance of the system (e.g., new water-quality regulations or reliability improvements). The second category is always relevant to estimates of MCC and LRMC, because system expansions can always be deferred a bit (temporary avoidance). The first and third categories may or may not be relevant to estimates of MCC and LRMC, because they may or may not be avoidable. Future capital costs that are not avoidable even if water purchases were to fall dramatically (e.g., seismic retrofit of an essential pipeline) are irrelevant to both SMRC and LRMC.

27 CalFed (October 1999) reports current marginal costs of $209 and $300 per acre-foot in the San Francisco Bay and South Coast Regions, respectively. See the previous discussion of this issue.

study. There are a variety of ways of estimating MCC; we illustrate two that are based on Appendix C of CUWCC (1997).

Our example involves two capacity expansions: one in five years and a second in ten years. The first expansion increases average annual capacity to deliver water by 3,000 acre-feet;[28] the second expansion increases average annual capacity by 7,000 acre-feet. All dollars are year 2000 dollars. MCC is estimated for each expansion by amortizing capital cost over the useful life of the expansion at a fixed cost of capital and dividing by the capacity increase. This yields the cost per acre-foot of additional capacity from each project.

A conservation investment creates capacity as well. That capacity is redundant, however, before the year in which the first avoidable capacity investment is required. In our example, a residential washing machine with a useful life of 12 years, installed in year 2000, creates redundant capacity for five years. We treat redundant capacity as having no value in our sample calculation, below, but there may be substantial benefits from redundancy (e.g., reliability during drought).

The washing machine would also create capacity for seven years that might replace a small part of the first expansion, and for two years that might replace a small part of the second expansion. Multiplying the MCC for each project by the number of years of overlap with that project by the annual water savings from the conservation measure yields an approximation of the potentially avoidable capital expenditures for each project. Discounting these to the year in which the rebate would be paid at the real cost of capital to the water supplier (four percent assumed), and then adding, gives an estimate of the optimal rebate.

The sample calculation is as follows:

| | |
|---|---|
| Annual MCC of Expansion Project 1 (3,000 AF/yr):<br>($8.8 million borrowed at 6 percent interest for 10 years) | $400/AF |
| Annual MCC of Expansion Project 2 (7,000 AF/yr):<br>($60.5 million borrowed at 7 percent interest for 30 years) | $700/AF |
| Annual Capacity of the Conservation Measure: | 0.01 AF/yr |
| Duration of Overlap of Conservation Measure with Project 1: | 7 yrs. |
| Duration of Overlap of Conservation Measure with Project 2: | 2 yrs. |
| Potentially Avoidable Capital Cost for Project 1 in 2005: | $28 |
| Potentially Avoidable Capital Cost for Project 2 in 2010: | $14 |
| Real Discount Rate: | 4% |
| Year 2000 Value of the Avoidable Capital Cost for Project 1: | $23 |
| Year 2000 Value of the Avoidable Capital Cost for Project 2: | $9 |
| One Estimate of the Ideal Rebate for This Measure: | $32 |

28 Capacity can be expressed in various ways; e.g., acre-feet per peak hour, day, or season, or acre-feet per average day or year. In most conservation analyses, capacity in acre-feet per year is probably appropriate.

In practice, the expansion projects would probably be deferred rather than (slightly) reduced in size. The length of the deferral depends on how fast demand is anticipated to grow. This is embedded in the assumption that expansions are required in five and ten years. Because the 3,000 acre-foot per year capacity expansion is fully utilized after five years, demand is growing by about 600 acre-feet per year each year (or about 50 acre-feet per year each month, and so forth). This rate of demand growth implies that the efficient washing machine could defer both expansion projects by a bit less than 9 minutes.

The value of any deferral is the reduced expenditure for borrowed monies with which to fund the capital expansions. Calculating the cost of borrowed funds at the real rate of return of four percent and multiplying by a bit less than 9 minutes gives exactly the same optimal rebate as above.[29]

The alternative, confirming estimate for the optimal rebate is:

| | |
|---|---|
| Year 2000 Value of $8.8 million in Year 2005: | $7.2 million |
| Year 2000 Value of $60.5 million in Year 2010 | $40.9 million |
| Total Year 2000 Value of Capital Required for Projects 1 and 2: | $48.1 million |
| Cost of Borrowing $48.1 million for one minute: | $3.66 |
| Duration of Deferral Made Possible by This Conservation Measure: | 8.75 minutes |
| Capital Financing Savings from This Single Measure: | $32 |

The second method shows why ratepayers should pay a rebate to the purchaser of a water-efficient clothes washer (or any other conservation measure). They can pay $32 to the bank for financing expansion projects on the original schedule or they can pay $32 to the customer who invests in conservation, and then finance the expansion projects a little later.[30]

A related topic is that customer rebates will sometimes create an "extra" benefit for the customer receiving it. For example, customers who would purchase a water-efficient washing machine with a $20 rebate (but not with a $19 rebate) gain $12. On the other hand, this gain could be captured by the water supplier in a world without secrets. The water supplier would need to known the minimum (customer-specific) rebate required to induce each customer to invest in conservation. In that miraculous scenario, the part of the $32 of financing savings not needed as an incentive (e.g., $12) would accrue to the water supplier, who in theory would use it to reduce water rates for other customers.

Some water-conservation studies have incorrectly claimed that rebates made to customers who would make the investment anyway (an extreme case of the above example) are economically inefficient. Efficiency requires that the rebate to each customer be at least as large as the minimum needed

29 As it must if the anticipated rate of growth is consistent with the series of capital projects in the long-term water plan, and data and assumptions are identical for the two methods.

30 The cost of administration can and should be factored into this "balance" during design of rebate programs. If the cost of administering a rebate program amounted to $2 per rebate paid, the rebate itself should be $30 rather than $32. On the other hand, if the cost of funds and associated negotiation and administrative expenses (e.g., "points" paid on a loan) were reduced by a significant water conservation program, avoided financing expenses might be greater than $3.66 per minute of deferral.

for them to invest in efficient water conservation ($0 in some cases), and no higher than the savings from avoided capital-related expenses ($32 in our example). Any rebate(s) between $0 and $32 is efficient.

The distribution of the efficiency gain of $32 per water-saving washing machine installed is another issue entirely. Although it is correct that ratepayers in aggregate could pocket $32 if a customer were going to purchase a water-saving clothes washer without a rebate, doing so is just one way of sharing the efficiency gain of $32. None of these ways of sharing is necessarily more or less efficient.[31]

31 However, rebates lower than the amount saved ($32 in our example) may create inefficiency because, for example, a $20 rebate would lead customers who would only purchase a water-saving washing machine with a rebate greater than $20 to not do so.

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# Appendices

Note: The following appendices are available online at
**http://www.pacinst.org/reports/waste_not**

**Appendix A**
Indoor Residential Water Use and the Potential for Conservation

**Appendix B**
Outdoor Residential Water Use and the Potential for Conservation

**Appendix C**
Industrial and Commercial Water Use: Glossary, Data, and Methods of Analysis

**Appendix D**
Details of Commercial and Industrial Assumptions, by End Use

**Appendix E**
Details of Commercial Water Use and Potential Savings, by Sector

**Appendix F**
Details of Industrial Water Use and Potential Savings, by Sector

**Appendix G**
CII Conservation Potential by Region: Discussion