Saving Water Saves Energy

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Abstract

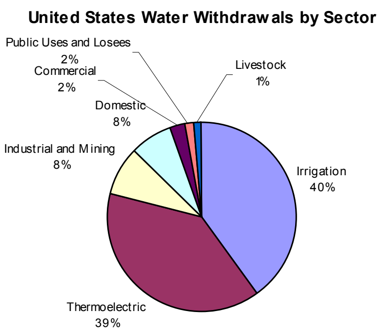
Hot water use in households, for showers and baths as well as for washing clothes and dishes, is a major driver of household energy consumption. Other household uses of water (such as irrigating landscaping) require additional energy in other sectors to transport and treat the water before use, and to treat wastewater. In California, 19 percent of total electricity for all sectors combined and 32 percent of natural gas consumption is related to water. There is a critical interdependence between energy and water systems: thermal power plants require cooling water, and water pumping and treatment require energy.

Energy efficiency can be increased by a number of means, including more-efficient appliances (e.g., clothes washers or dishwashers that use less total water and less heated water), water-conserving plumbing fixtures and fittings (e.g., showerheads, faucets, toilets) and changes in consumer behavior (e.g., lower temperature set points for storage water heaters, shorter showers). Water- and energy-conserving activities can help offset the stress imposed on limited water (and energy) supplies from increasing population in some areas, particularly in drought years, or increased consumption (e.g., some new shower systems) as a result of increased wealth.

This paper explores the connections between household water use and energy, and suggests options for increased efficiencies in both individual technologies and systems. Studies indicate that urban water use can be reduced cost-effectively by up to 30 percent with commercially available products. The energy savings associated with water savings may represent a large additional—and largely untapped—cost-effective opportunity.

Water Withdrawal and Consumption

Unlike energy, water can be reused. That is, after water is used for one purpose, it may be returned to a water source (such as a river or lake) and then taken again for another use. Removing water from a water source is known as “withdrawal.” Withdrawn water may be consumed or returned. “Consumed” water—e.g., water evaporated in cooling towers or evapotranspired from plants—is not immediately available in liquid phase to be used again. Figure 1 shows the uses for which fresh water is withdrawn and consumed in the United States; domestic (household) uses account for 8 percent of withdrawals and 5 percent of consumption. Withdrawals are dominated by cooling water for thermoelectric power plants and by irrigation for agriculture. (These do not include hydropower or environmental water such as in-stream flows, wild and scenic flows, required outflows, and managed wetlands water use.)



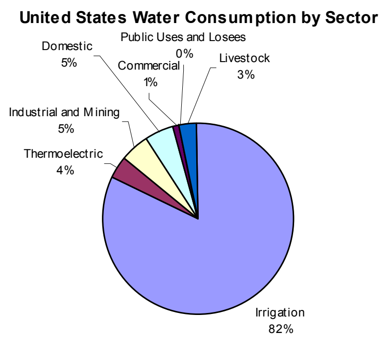


Figure 1. Water Withdrawal and Consumption by Sector, United States, 2000. [1]

Water consumption is dominated by agricultural applications (82 percent), followed by residential and industrial uses (5 percent each). Commercial applications account for another 1 percent. Increasing system efficiencies in industrial and commercial facilities and increasing end-use efficiencies in all applications have the potential to reduce water consumption, which in turn reduces energy consumption. In addition, water—with appropriate attention to quality—can be recycled or reused. The demand for water, and related energy demands, can be reduced through more efficient processes, adoption of water- and energy-efficient technologies, and changes in behavior toward sustainable practices.

Water Consumption in Households

The average household in the United States directly consumes 74 gallons (280 liters) of water per person per day. [2] Major indoor end uses include toilets, clothes washers, showers, faucets, and leaks. Outdoor uses—e.g., irrigating the landscape—account for even more water, but are not discussed further here.

Figure 2a shows a pie chart of household water consumption by end use in the United States. [2] Figure 2b shows household natural gas consumption by end use and Figure 2c shows household electricity consumption by end use. [3]

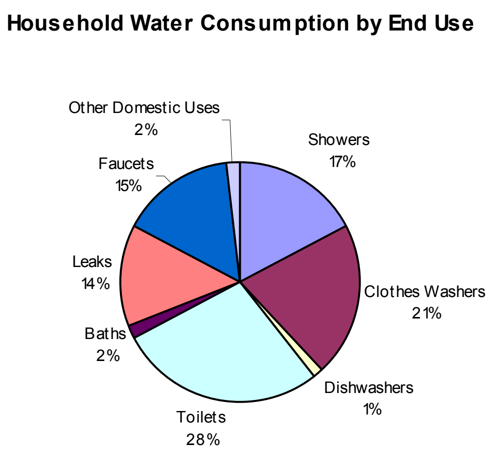
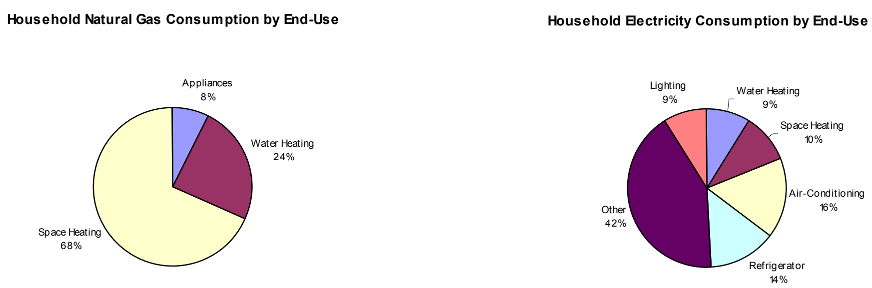


Figure 2a. Household Water Consumption by End Use, United States. [2]



Figures 2b and 2c. Household Site Energy Consumption by End Use for Natural Gas and Electricity. [3]

As these figures show, a significant share of household energy consumption is associated with water. Water heating comprises 9 percent of household electricity consumption and 24 percent of household consumption of natural gas in the United States. The heated water is used by appliances such as clothes washers and dishwashers, as well as for showers and baths.

In addition to the water directly consumed in households, energy consumption in households increases the need for water in the energy sector. Since households are responsible for 35 percent of U.S. electricity consumption, they account for about 14 percent of freshwater withdrawals for thermoelectric cooling, in addition to the 8 percent of withdrawals consumed for household water uses, for a total of 22 percent of freshwater withdrawals. Therefore, there is potential for reducing the stress on water systems by reducing electricity consumption in households.

Efficient Technologies

In the United States, efforts to increase energy efficiency have, in parallel, increased water efficiency, most notably for clothes washers and toilets. Technologies having a range of efficiencies are commercially available. Studies in California, where significant efficiency gains already have been made, indicate that urban water consumption could be reduced by at least an additional 30 percent, using technologies that are already commercially available and cost-effective. [4]

Clothes Washers

The National Appliance Energy Conservation Act of 1987 (NAECA) established mandatory energy performance standards for clothes washers in the United States, effective in 1988. [5] Subsequent updates established progressively more stringent standards, effective in 1994, 2004, and 2007. [6] The mandatory standards are expressed as a modified energy factor (MEF) in cycles per kWh per cubic foot of tub volume. MEF includes both washer and dryer energy, to account for the spin speed of the washer. In 2004, the mandatory MEF was 1.04, while the voluntary Energy Star level was 1.42. Clothes washers commercially available in the United States have MEFs ranging from 1.04 to 2.79 and water factors ranging from 12.9 to 3.5. [7] In 2007, the mandatory MEF will be 1.26, while the voluntary Energy Star level will be 1.72, with a water factor of 8.0 gallons per cubic foot.

Figure 3 shows the relationship between increased energy efficiency and energy and water savings. [8] Most of the energy savings are achieved by reducing the amount of hot water used. Clothes washers with both a high energy efficiency and high water efficiency (low water factor) use less hot water and less total water. However, there is not a direct correlation of energy efficiency to water efficiency; some clothes washers with higher energy efficiency may have lower water efficiency (i.e., a higher water factor), saving energy by using larger quantities of cold water.

The State of California originally established energy performance standards for clothes washers, which were superseded by the national standards. In 2006, California proposed water efficiency standards for clothes washers and has petitioned the U.S. Department of Energy (DOE) to allow the state to adopt them.[9] Pending DOE’s approval, the State of California adopted water efficiency standards, effective in 2007, with a maximum water factor of 8.5 gallons per cubic foot (of tub volume); effective in 2010, the maximum water factor will be 6.0 gallons per cubic foot.[10]

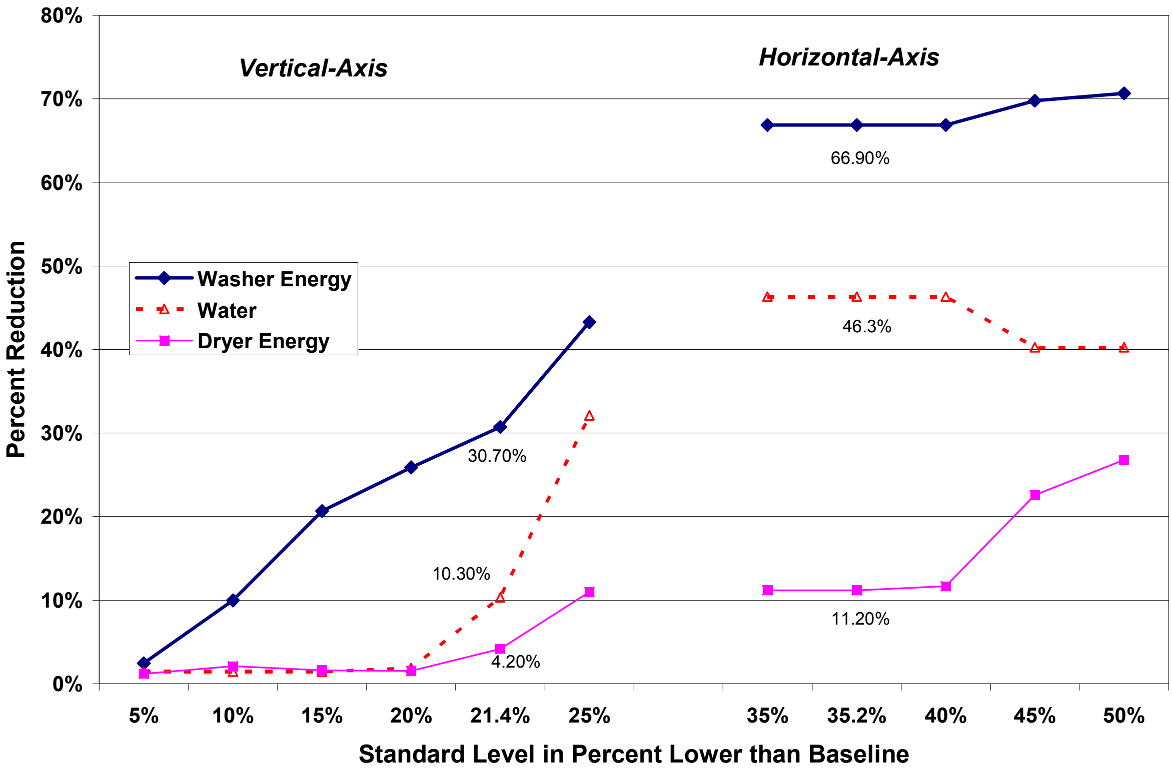


Figure 3: Energy and Water Savings for Clothes Washers for Various Changes in Modified Energy Factor [8]

Dishwashers

NAECA established mandatory energy performance standards for dishwashers, effective in 1988, for the United States.[5] Subsequent updates established more stringent standards, effective in 1994, with an energy factor (EF) of 0.62 and 0.46 cycles per kWh for compact and standard dishwashers, respectively.[11] In 2004, the voluntary Energy Star level was 0.58 cycles/kWh for standard dishwashers; no level has been established for compacts. Dishwashers commercially available in the United States have EFs ranging from 0.46 (the minimum required) to 1.11.

In 2003, the DOE test procedure for dishwashers was updated to account for soil-sensing models and changes in the number of cycles per year, and to require the measurement of standby power consumption in annual energy use or operating cost calculations. [12]

Showerheads

The Energy Policy Act of 1992 established mandatory performance standards for showerheads, faucets, water closets (toilets), and urinals, effective in 1994 for the United States. The mandatory standards require showerheads to have water flow no greater than 2.5 gallons per minute (gpm) at 80 psig. Prior to 1992, some showerheads had flow rates of 5.5 gpm.

Showerheads commercially available in the United States have flow rates ranging from 0.94 to 2.5 gpm [13] or more. California called attention to the issue of whether some current products are above the standard. Recent testing by the California Energy Commission found showerheads that had flow rates of up to 13 gpm.[14] Recent trends include installations of multiple showerheads in new construction—an estimated 3–6 percent of new households [15]—as well as in existing showers. Some of these shower systems with multiple sprays from different directions are designed to provide a therapeutic function, rather than a cleaning function, and may thus increase the duration of a shower.

Toilets

The mandatory standards established by the Energy Policy Act of 1992 require toilets (termed “water closets” in the Act) to have flow rates no greater than 1.6 gallons (6.0 liters) per flush, compared to previous designs using 3.5 gallons. Toilets commercially available in the United States have flow rates ranging from 0.8 gallons (“short flush” in dual flush models) to 1.6 gallons. The California Urban Water Conservation Council reports maximum performance testing by model to identify the best performing designs.[16]

Energy Used to Supply, Treat, and Dispose of Water

Water consumption requires large amounts of energy for three main purposes: water supply, water heating, and wastewater disposal. As an illustration, the California Energy Commission conducted a preliminary analysis of energy consumption by the water and wastewater sector and found that 19 percent of statewide electricity and 32 percent of natural gas consumption was related to water.[17] These estimates included water conveyance, treatment, distribution, and water heating (in residential, commercial, and industrial sectors); wastewater treatment, collection, and discharge; and treatment and distribution of recycled water. The amount of energy varied significantly, depending on the amount of pumping required in conveyance and the amount of treatment required as a function of water quality. Conveyance is a major component of water-related energy use in California, since two-thirds of the annual precipitation occurs in the northern portion of the state, while two-thirds of the water demand is in the southern portion. The amount of energy required to provide water to Southern California is high because the water must be transported over 1000 km via canal and pumped over the Tehachapi Mountains (a vertical lift of 610 meters).[18]

Reductions in water consumption at the end-use level directly reduce energy consumption required for supplying and heating water, and for disposing of wastewater. An important recent finding is that large energy savings are not only available but may be more cost-effective from water efficiency measures than had been identified in California’s electricity savings plans. Table 1 shows a comparison of three estimates of savings in California: a) electricity savings achieved in 2004–2005; b) planned electricity savings in 2006–2008; and c) potential electricity savings from newly identified water savings opportunities. Preliminary calculations suggest that the goals that are being pursued in current electricity-savings plans could have been achieved at lower cost by saving water instead. This suggestion does not imply that the electricity savings programs are deficient, but rather that an additional, large, untapped potential for energy savings exists by saving water.

Table 1. Water Use Efficiency Potential Compared to Energy Efficiency Programs in California

	Energy Efficiency Procurement by Investor-Owned Utilities		**Water Use Efficiency Potential**
	2004-2005	**2006-2008 (projected)**	
GWh (Annualized)	2 745	6 812	6 500
Peak MW	690	1 417	850
Funding ($ Million)	$762	$1 500	$826
$/Annual KWh	$0.28	$0.22	$0.13
Cost of Electricity Saved from Water Efficiency as percent of Cost of Procurement of Electricity Efficiency (Ratio of respective $/Annual KWh)	46%	58%	100%

California Energy Commission (CEC-700-2005-011-SF), Table 4-2 [19]

Future Trends

Supplies of potable freshwater are a finite resource. Future trends in water (and related energy use) may depend on such factors as population growth and demographic trends, climate change, technological changes, and policies.

Population Growth and Demographic Shifts

Demand for potable water is expected to increase as a result of population growth. In addition, the demographic trend in the United States is toward the south and west—toward warmer regions with more restricted freshwater supplies.

Climate Change

Historical records over the last few centuries provide sufficient basis for planning for periodic droughts. Climate change has the potential to make future precipitation patterns depart from the recent historical record, and perhaps to increase the frequency and severity of droughts.

Technological Change

Since most freshwater supplies have already been identified, technologies are focused in two directions: a) more efficient use of water; and b) treatment of brackish water, seawater, or other impaired water to make it useable. For those end uses that use both energy and water, such as clothes washers, dishwashers, and showerheads, new technologies that reduce hot water consumption will save both water and energy. For those end uses that use cold water, such as toilets, increases in water efficiency will directly save water and indirectly save the energy used to supply and dispose of water.

Some proposed technological solutions to increase the supply of potable water have the potential to significantly increase energy consumption. Current methods for removing salt from brackish water or seawater increase the energy required for water supply by factors of two to five. In such situations, joint planning of both energy and water systems will be essential to avoid unintended and possibly unacceptable consequences.

In addition to attention to specific technologies, such as those used for end uses such as clothes washers, systems analyses will be needed, with particular attention to recycling or reusing water. Possibilities include dual systems and distributed treatment. A dual system would involve providing a household or business with two water systems—one for potable water and one for “gray” water for uses that do not require potable water, such as irrigation of the landscape. Depending on the scale of the technology developed, distributed treatment may involve treating wastewater at the household or neighborhood level, rather than at central municipal facilities.

Policies and Programs

Water is essential to life and health and is also, in some applications, a commodity. Establishing an economic value for water is complex, and includes long-term considerations of sustainability as well as short-term desires by some to establish markets. Laws about ownership of and rights to water are complex and vary among jurisdictions. Responsibilities for various aspects of water supply, water quality, and wastewater reside in a large number of government agencies and institutions. For example, agencies dealing with health, agriculture, and environmental issues are involved at several levels of government, from national to local. In the United States, the number of utilities is much greater for water than for electricity.

Information about water consumption by end uses is not always available. Efforts similar to those expended over the last thirty years to understand and reduce energy consumption are necessary for water. Voluntary programs to improve efficiency and reduce consumption need reliable information in order to establish goals and track progress. Incentive programs, whether tax credits to manufacturers or rebates to consumers, can in some ways be modeled after experiences in the energy sector. In some cases, as with clothes washers, considering the combined energy and water savings rather than considering each resource separately will justify greater efficiency improvements. For example, both energy and water utilities offer rebates for clothes washers, and some voluntary and mandatory standards for these products have considered both energy and water efficiency.

Conclusions

Households account for about 8 percent of freshwater withdrawals and 5 percent of water consumption in the United States. Household uses of water include bathing or showering, washing clothes or dishes, irrigating landscape, cooking, and drinking. Energy use and water use are related, since energy is required to supply potable water and to heat water for washing and other applications. Conserving water or using water more efficiently reduces energy consumption. Since freshwater withdrawals to cool thermal electricity generating plants represent about 39 percent of total withdrawals, and household electricity consumption is 35 percent of the U.S. total, about 14 percent of freshwater withdrawals can be attributed to household electricity consumption. Combining direct water uses with electricity use, households account for 22 percent of freshwater withdrawals and about 6 percent of freshwater consumption.

Opportunities for reducing water consumption include efficient technologies for clothes washers, dishwashers, toilets, and showerheads. For clothes washers, energy-efficient designs tend to reduce consumption of hot water as a primary strategy for saving energy. However, some energy-efficient clothes washers reduce energy consumption by using more cold water. Both voluntary and mandatory energy-efficiency standards can be complemented by water efficiency requirements in the form of water factors. Some studies indicate that, in California, where a number of efficiency measures are already in place, an additional 30 percent reduction in household water consumption is cost-effective and available now from commercially available products.

A preliminary estimate of the cost of energy saved from more-efficient water use indicates that a significant reservoir of energy savings may be available at a lower cost per kWh than current energy efficiency procurement programs in California.

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