WATERGY: A Water and Energy Conservation Model for Federal Facilities

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PURPOSE

Federal facility managers have more information on energy systems than they do on water usage and conservation practices. Through financial assistance and education, FEMP hopes to give these managers a clearer determination of the impact water use has on energy consumption. Although many software tools exist for the evaluation of energy conservation measures alone, WATERGY will analyze the potential of water savings, and associated energy savings associated with water conservation, at Federal facilities. This paper serves as an overview of the water-energy relationship assumptions which were used in the development of WATERGY.

INTRODUCTION

Water conservation can be defined as *any action that reduces water use of loss in which the resources used to generate the savings have a lesser value than the resources saved*. These resources include fuel oil, natural gas, coal and other energy resources in addition to water. For example, boilers and cooling systems may consume large quantities of both water and energy in commercial buildings. Similarly, domestic hot water typically represents the second largest (behind only heating and cooling) energy usage in residential facilities.[1] Reducing hot water consumption through the use of low flow shower heads, as well as efficient washers and dishwashers, will result in a reduced energy demand.

The Energy Policy Act of 1992[2] directs Federal agencies to implement all energy and water conservation projects with payback periods of less than 10 years to the maximum extent possible. Executive Order 12902, *Energy Efficiency and Water Conservation at Federal Facilities*[3], requires that U.S. Government agencies perform survey to "identify those facilities with the highest priority projects based on cost effectiveness." A June 1993 Energy and Environmental Institute study approximates Federal expenditures for water resources between $0.5 billion and $1.0 billion annually[4]. The Federal Energy Management Program (FEMP) is required to consider water as well as energy, and includes the SAVEnergy program, which conducts Federal facility energy and water surveys and prioritizes proposed water and energy conservation projects, a water component.[5]

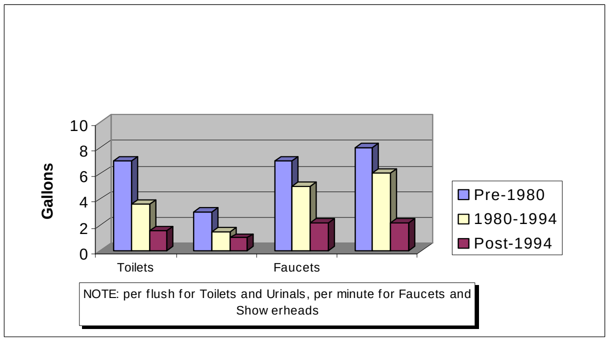
As mentioned above, this paper is meant as a general overview of the relationship between water and energy conservation and cursory attempt to provide some guidelines to generate a ballpark estimate of how much water and related energy can be saved at a given facility.

EXISTING INFORMATION

The difficulty surrounding the quantification of the relationship between water and energy conservation is primarily due to the lack of coordinated studies. A substantial amount of work has been done on both water and conservation and energy conservation, and many realize that there exists a relationship between them. Yet few efforts have attempted to quantify the synergy between the two fields. In addition, much of the water conservation work has been done not on the commercial or industrial sectors, but on the residential sector. This is partly due to the fact that commercial and industrial water use is so diverse while residential use is typically more homogeneous, making accurate studies easier to produce for the residential sector. Still, the most comprehensive study of the residential end uses of water is a HUD study from 1984.[6] The American Water Works Association Research Foundation (AWWARF) is currently in the process of developing a study to update and replace the HUD study.

Plumbing fixtures and other water using processes and devices (boilers, cooling towers, etc.) represent the best starting point when considering what method to use to reduce water consumption. In order to implement the proper method for achieving conservation, the age of the fixtures within a building must be taken into account. Plumbing fixtures are typically grouped into three age segments: pre-1980, 1980-1994, and post-1994. Exhibit 1 compares the efficiency of each of the three age segments. The pre-1980 fixtures are highly inefficient in general. The 1980 to 1994 fixtures are much more efficient that the pre-1980 ones. Moreover, the highly efficient post-1994 fixtures as mandated by the Energy Policy Act of 1992 yield approximately 62 percent less consumption than the pre-1980 fixtures and 39 percent less usage than the 1980-1994 fixtures. It is estimated that residential water demand due to toilets, faucets, and showers will be halved over the next 30 years without any additional conservation efforts as older fixtures are gradually replaced by new ones.[7]

Exhibit 1
Plumbing Fixture Efficiencies



Because water use affects energy use, it is estimated that residential water use with pre-1980 plumbing fixtures (toilet, shower head, faucets) used 57 kWh per capita per year. The post 1994 fixtures only require 22 kWh per capita per year, a savings of over 60 percent.[7] In addition, lifetime water, sewer, and energy savings with efficient washing machines may be large enough to justify a combined utility rebate of $250, according to the Seattle Water Department. In 1993 and 1994, approximately $600,000 was to have been spent on washing machine market testing by a coalition of electric, water, sewer, gas, and solid waste utilities.[8]

Energy is saved even by fixtures which do not use hot water. ULF toilets reduce energy requirements for pumping, distribution, drinking water and waste water treatment. Exhibit 2 shows EPA estimates for joint water/energy savings.[1]

Exhibit 2
Savings From Efficient Devices

Fixture	Electric (kWh/hh/yr)	Water (gal/hh/yr)
Showerhead	420-860	4,400-8,000
Faucet	31-41	1,100
Toilet	16-217	8,000-21,000
Dishwasher	935	4,750

These figures touch on the opportunities that the Federal government will have in both energy and water as it begins to implement indoor plumbing conservation at Federal facilities.

ISSUES REGARDING HOT WATER USAGE

Because hot water is such an important component in the water-energy relationship, it is important to quantify just how much energy is used to heat water. Over $15 billion was spent in the US in 1990 to heat residential water alone. The breakdown of energy sources for residential water heaters in the US is 35 percent electric, 60 percent natural gas, and five percent other (fuel oil, solar, wind, etc.).[9]

Commercial hot water heating methods vary significantly and are more difficult to segment. Some older buildings use water heated by boilers (primarily fueled by natural gas or fuel oil) and passed through a heat exchanger to cool the water to 140 degrees Fahrenheit. Other buildings utilize a central hot water heater similar to a large residential heater. Sometimes these centralized water heating systems use a looped system in order to maintain hot water throughout the building, thereby eliminating the typical wait at the faucet for the water to "warm up." Another common practice is to put individual electric hot water heaters in every bathroom to heat the water on demand, eliminating the need for storage.

The type of water heating system will have an effect on water conservation methods. For example, if a building is using a centralized system with a timer, the first person to use the hot water on a new cycle would have to wait for all the water which had cooled to flow through the pipes to get to the hot water. Putting a low flow aerator on the faucet would only prolong the wait for the hot water, not lessen the water use in this instance, because the same volume of water would have to pass through the faucet to get to the hot water, albeit at a slower rate.

In order to determine the true cost of heating water, the process must be considered from start to finish. In addition to the initial heating of water from 60 to 140 degrees Fahrenheit, the heated water usually is stored in the tank of a hot water heater, thereby requiring energy to offset the cooling that takes place over time. Therefore, an estimate of how much energy it takes to heat a gallon of water must consider both the energy required for temperature maintenance and the initial heating.

Estimates of the energy requirements for water heating vary based on the type of water heater, efficiency, usage patterns, and other assumptions. For electric water heaters, estimates generally range from about five to ten gallons of water heated per kilowatt-hour. For gas heaters, sources estimate that just over 2 gallons of hot water can be heated per cubic foot of natural gas.[9,10]

DIFFERENCES IN END USES OF WATER

In order to evaluate the effects of planned conservation measures on demand, it is important to analyze the type of facility and use through a water survey or audit. Water audits can tell you whether, and where, water is being used inefficiently; how to improve water efficiency; and the value of a water efficiency plan. A water audit will survey and document all water use processes and operations in a facility. The knowledge gained will be used to implement process modifications or installation of conserving devices where cost-effective.

Commercial water use varies widely because commercial facilities can range from a restaurant or motel to office buildings to large industrial complexes such as an electronics manufacturer. The water uses for most Federal facilities (such as office buildings and hospitals) are similar to residential uses, although in different proportions, due to fewer showers, more flushes, etc. In many office buildings, hospitals, and other facilities with large cooling and air conditioning loads, cooling towers are often the largest use of water.[11] However, on some large Federal sites (such as military bases), landscape irrigation water us is enormous due to golf courses, parade grounds, and family housing. The aggregate results of a 1991 non-residential water conservation audit in Denver are summarized in Exhibit 3.[12]

In order to dramatize the variance in the amount of water usage by different commercial customers, Exhibit 4 details some examples of water usage for a few types of commercial customers as surveyed in Phoenix in 1984 which may be applicable to Federal facilities.[13]

Exhibit 3
Commercial Water Usage in Denver, 1991

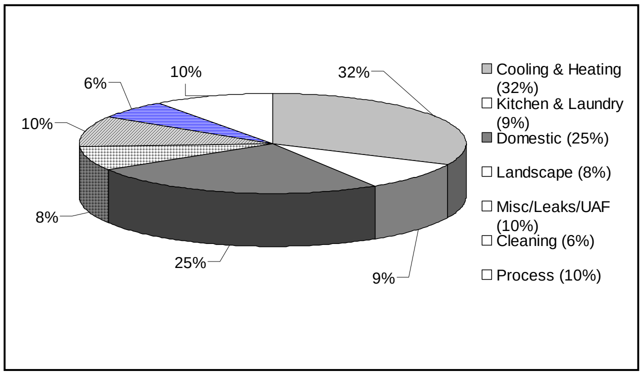


Exhibit 4
Industrial Water Use
(Gallons Per Employee Per Day)

SIC Code	Description	Phoenix (1984)
781	Landscape	107
15-17	Construction	25
7011	Hotels/Motels	414
7212-7217	Industrial Laundry	420
8062	Medical Surgery	164
8221	Universities	110
27	Printing/ Publishing	53

Water use can be defined as interior or exterior. Interior residential water use generally includes bathing, flushing, washing, (clothes and dishes), rinsing, and consumption (drinking and cooking). Exterior use encompasses lawn watering, filling swimming pools, surface washing, and car washing.

Another important point to remember when categorizing demand is that water demand is affected by both general climate and seasonal changes. Climate has a great bearing on and relation between indoor and outdoor usage. In Edmonton, landscape irrigation accounts for only five percent of residential water use. In contrast, in a climate much more arid than Edmonton's, landscape irrigation accounts for 55 percent of residential water use in Denver, an order of magnitude difference between the two cities.[12,14]
Because much of the demand, both commercially and residentially, is due to landscape irrigation, summer consumption is higher than winter (baseline) consumption. For example, in Phoenix, consumption in July is more than double January consumption.[13] In addition, it is obvious that boilers used for building heating are generally used more in the winter, and cooling loads are typically greater in the summer. It is important to realize, however, that some boilers are used year-round for humidity control and hot water, while many office buildings cool their core all year. These two examples demonstrate why a water audit is integral to any conservation plan.

IMPACT OF WATER CONSERVATION ON ENERGY USE

The conservation effects at each individual water using process should be considered in order to calculate the total energy and water savings potential in a facility. Because most Federal facilities can be characterized as either commercial or residential, industrial processes are not included in this paper. It is also important to note that the entire life cycle of energy savings has been limited in scope for this paper for simplicity. For example, if fuel oil savings meant fewer deliveries by the delivery truck, the diesel fuel saved from the reduction of truck mileage could, theoretically, be considered an energy savings, and effect not considered in this paper.

The following discussion will give general estimates for the aggregate water and related energy savings possible at a facility. The complexity of boilers, cooling towers, and irrigation systems is such that the water conservation opportunities for these systems can only be accurately assessed by a qualified professional based on site specific information. Therefore, most calculations and figures will represent possible savings at facilities with "average" or "typical" water and energy usage patterns.

DIRECT SAVINGS

Direct savings are defined as savings to the end user in the form of reduced energy usage, water usage, and sewage production, thus, lowering utility bills. Indirect savings are savings to the utilities which supply water and power, as well as wastewater utilities, which save energy from reduced pumping and treatment.

An overview of the importance of key plumbing fixtures, water using processes and the energy conservation effects for each water conserving process are described below. These methods can be reclassified into the following three classes of conservation opportunities:

- Water us that is present at all facility types (Universal Usage);
- Commercial water use; and
- Residential water use.

Universal Usage

Toilets

Toilets are among the best candidates for cost effective water consumption reduction, representing about 35 percent of residential water use, and up to 70 percent of interior water use in a typical office building.

Pre-1980 toilets typically used between 5.5 and 7 gallons per flush. Between 1980 and 1994, toilets used around 3.5 gallons per flush. The new 1994 standards will require toilets to use 1.6 gallons per flush. Based on four flushes per day per person, ULF toilets can save about 16 gallons per day (roughly 70 percent) per capita over the pre-1980 toilets and 8 gallons per day (about 55 percent) per capita over the 1980-1994 fixtures.

Gender demographics affect water consumption in commercial facilities because men have the choice of using urinals. Urinals use about half the water as toilets and have also been affected by the efficiency movement. Prior to 1980, urinals generally used between 1.5 and 3 gallons per flush. Current standards require one gallon per flush or lower.[15] High efficiency urinals, therefore, could save 4 gallons per day (50 percent) per male over older designs. There are even some urinals which use virtually no water.

Because toilets utilize cold water only, little direct energy savings exist. However, since toilets (and urinals, flush valves, etc.) represent a considerable proportion of water demand, the indirect energy savings discussed later can be important.

Faucets

As with other water fixtures, the direct energy savings are determined by the water heating efficiency multiplied by the amount of hot water conserved. Replacement of conventional faucets with metering or self-closing faucets is usually not cost effective due to high cost relative to the small amount of water savings potential.[16] However, automatic faucets incorporating infrared (IR) motion sensors have been shown to reduce water usage by 70 percent over push-down, self-closing faucets.[17] Retrofitting existing faucets with flow restrictors or aerators generally provides a low-cost and effective alternative. Assuming that a low volume aerator can reduce faucet flows from 4 gpm to 2 gpm, and that each individual uses the faucet 5 minutes per day, 10 gallons per day per person can be saved.

Estimates of the percentage of faucet water usage that is hot water range from 25 percent to 62 percent.[9,10] Therefore, at least 2.5 gallons of hot water can be saved each day per person, yielding a direct energy saving of between 0.25 and 1.2 kWh per person per day.

Outdoor Usage

Landscape irrigation can account for a sizable portion of total water use at both residential dwellings and commercial facilities. Because outdoor water usage represents the majority of summer water demand, conserving water through the use of water conserving shrubs and ground covers, often called xeriscape, is potentially very effective. In North Marin County, California, outdoor water use was 54 percent less for xeriscape than for traditional landscapes. In addition to water savings, savings of 25, 61, 44, and 22 percent were achieved for labor, fertilizer, fuel, and herbicide, respectively.[18] The fuel savings cited are from reduced mowing requirements, and should not be included in this study.

A survey of 44 non-residential facilities (16 commercial office buildings, 12 hospitals, 9 schools, and 7 hotels) was performed in Phoenix, Denver, Mesa, Ventura, and Los Angeles. The survey showed that 42 percent of the water used on landscape overall could be conserved. At the office buildings, over 50 percent could be saved.[16] Changing watering practices can account for much of the savings. By watering lawns in the morning, more of the water will reach the plants and less will evaporate than watering during the middle of the day. Evening or nighttime watering is not usually recommended as powdery mildew and other diseases may occur because the plant surfaces may not be allowed to dry completely.[19]

Recent studies have shown that commercial landscapes are typically watered at twice the rate that is necessary. An innovative approach which uses daily weather data on evapotranspiration (ET) has been shown to be cost effective. ET accounts for the amount of water lost due to evaporation from the soil and transpiration through the plant foliage. By using a programmable timer with daily ET data input, water use can be minimized. In fact, a forecasting water management system has shown water savings of between 1,550 and 4,600 gallons per day per acre and cost savings of $1,500 to $4,500 per year per acre.[20]

Because most irrigation systems do not use hot water and consist of sprinklers powered by water pressure alone, little direct energy savings exist. However, due to the magnitude of the water usage for irrigation, indirect savings are usually significant. In those instances where larger facilities utilize pumps to irrigate the landscape, energy savings can be quantified. It is estimated that between 4 Wh and 6 Wh are required to pump a gallon of water from a 1,000 feet deep well using standard irrigation pumps.[1]

Leak Detection and Metering

Between 1 and 10 percent of all water is lost due to leaks. In fact, Edmonton estimates that 6 percent of all household water is consumed by leaky toilets.[14] By metering water consumption, a user can effectively find out what processes are using the most water. If the leak is from a hot water pipe, the loss is compounded by the energy lost which heated the water. If hot water accounts for half of the total pipes and fittings in the building, one quarter of the total leakage is hot water, assuming that half of the lost water is due to leaky toilets.

Commercial Usage

Boilers

Typical water savings in boilers are not very large. The best place to look for savings is in the blowdown, or water drained to reduce impurities. Blowdown typically represents about 5 to 7 percent of water usage by boilers. Process optimization is the best way to reduce blowdown. For example, about one fifth of the boiler blowdown can be saved by changing from manually adjusted to automatically controlled continuous blowdown in an average plant.[21] If blowdown is assumed to be 7 percent, then a 20 percent reduction would yield a savings of about 1.4 percent of the total water usage. This result agrees with that of the survey of non-residential water usage mentioned above, which calculated an average water reduction of 1.2 percent.[16] While the water savings are small, the energy savings are important because every gallon of water saved will not have to be evaporated into steam.

Exhibit 5
Example of Boiler Blowdown Savings

Description	Value	Units
Evaporation	2,000,000	lb/day
Original blowdown	140,000	lb/day (7%)
Reduced blowdown	112,000	lb/day (5.6%)
Blowdown reduction	28,000	lb/day
Heat required to raise temperature from 60 to 240 F at 600 psi	447	Btu/lb
Heat reduction	12,516,000	Btu/day
Fuel (natural gas)	1,040	Btu/cf
Boiler efficiency	80%	
Available fuel heat	832	Btu/cf
Fuel reduction	15,043	cf/day
Fuel savings @ $5/MCF	$75	
Water reduction	3,357	gpd (8.34 lb/gal)
Water savings @ $1/kgal	$3	
Total daily savings	$79	
Total annual savings	$28,679	

Exhibit 5 shows a simple calculation of how both water and energy savings can be realized from boiler blowdown reduction.[21] For purposes of simplicity, steam leaks and flash steam (the amount of water that instantaneously vaporizes when hot water is removed from a pressurized system) are assumed to be negligible.

Cooling System

Cooling water demands have been estimated to account for up to 70 percent of water use in commercial buildings. Many large cooling systems discharge water after it has passed through a single cycle (called once-through cooling). Converting to a closed loop or air cooled system can reduce water usage by 20 to 95 per cent.[22] Cooling water reuse comes in many forms. Once through cooling water can often be used for landscape irrigation. In fact, one of the most prominent uses of reused water is for irrigation of golf courses and other large commercial landscapes. In addition, process optimization such as simply monitoring the efficiency of a cooling tower can reduce water consumption. Increasing the concentration ratio from 2 to 4 reduces by one-third the amount of makeup water required. The aforementioned non-residential water use survey estimates that over half of all once-through cooling (82 percent in office buildings) and one quarter of all cooling tower water can be conserved.[16]

Unfortunately, due to a variety of factor regarding the treatment of cooling tower water, cooling towers may be a difficult system to target for water conservation. One of the most commonly used chemicals over the past 50 years in cooling tower water treatment, Chromate, has been phased out of use because it is a suspected human carcinogen. Use of other effective treatment chemicals is also on the decline to environmental consequences. Zinc usage is restricted due to its toxicity to shellfish; Phosphate is suspect due to wastewater discharge requirements; and Molybdate is being regulated with other heavy metals.[23] Many experts in the cooling tower industry feel that current water treatment is "less effective and more expensive…than was the case twenty years ago".[24]

The relationship between water conservation and energy use in cooling systems is impossible to generalize due to so many site specific variables. There are only two areas where energy is used in a cooling tower system: the pump head and the fan operation.[25] In some cases a reduction in water use may reduce energy demand. In others, flow reduction may cause the cooling tower to operate inefficiently, thereby increasing energy use.

Another aspect to consider is the treatment system. One way to save water is to install treatment which may actually cost more in energy for the treatment system than the water savings will realize. Ozone systems, which are commonly used to control biological fouling, have high capital and operating costs, which may offset the water savings.[16]

Laundry and Kitchen

Another area that can save water is through industrial laundries and kitchens. Many of the savings measures used in these places are the same as those used in domestic usage and process modification. In addition, ozone washing as an alternative laundry source eliminates the need for hot water. Industrial laundries are estimated to be able to save one third of the total water consumed.[16] Because of the high volume of hard-to-clean items that commercial laundries must clean, up to75 percent of the water saved would be hot water. This assumption is also used for kitchen usage, since water usage is for dishwashing and other cleaning tasks. Studies show that industrial kitchens can achieve water reductions of approximately 15 percent.[16]

Residential Usage

Bathing (Showers and Baths)

While generally not a factor in the office environment, high efficiency shower heads are very effective in residential and recreational settings. Low flow showerheads typically save half the water used, as standard showerheads have a flow rate of 5 gpm versus the 2.5 gpm of low-flow showerheads. Assuming a 5 minute shower once per day per person, and assuming that 60% of shower water is heated, a low flow showerhead can save 7.5 gallons of hot water per day per person.[6] Thus approximately one kWh energy savings is realized per person per day for low flow showerheads.

In addition, cognitive conservation can play a substantial role in conservation from bathing water. By encouraging residents to take 5 minute showers instead of 10 minute ones, water and energy can be saved. Even more impressive are the savings that a simple behavior modification can cause. For instance, by switching from a bath with an average size of 30 gallons to a 5 minute shower with a low flow showerhead (12.5 gallons), almost 11 gallons of hot water can be conserved, yielding an energy savings of one to two kilowatt-hours per bath avoided.

Washing Machine

After toilets and shower heads, washing machines make up the next largest percentage of residential water use. Efficient washing machines use 42 gallons per load, as compared to standard machines, which use 55 gallons per load.[13] At 0.2 loads per day per person, this yields a savings of about 4 gpd per person.[6] Assuming that hot, cold, and warm wash cycles are used equally as much, and that all rinse cycles use cold water, 25 percent of washing machine water is heated. Therefore, one gallon of hot water is saved per person per day, yielding an energy savings of 0.15 kWh per person per day.

Dishwasher

Conventional dishwashers use 14 gallons per load, compared to 8.5 gallons per load for an efficient dishwasher.[13] At 0.17 loads per person per day, a savings of 1 gpd per person is realized.[6] Assuming that all dishwasher water is hot water, an efficient dishwasher saves as much hot water (and therefore energy) as an efficient washing machine: one gallon of hot water and 0.15 kWh per day per person.

INDIRECT SAVINGS

In addition to the direct energy savings due to water conservation, energy demand is also reduced at the supplier level. Based on total water use reductions (both cold water and hot water), indirect savings are incurred by water treatment and supply, wastewater collection and treatment, electricity transmission, and natural gas supply.

Water Treatment and Supply

Firstly, the quantity of water saved at the end user is not the only water saved as far as water supply is concerned. The average water utility has 10 percent of its total production as unaccounted for (UAF) water due to factors such as line leaks, breaks, and inefficient meters.[23] Therefore, if 1,000 gallons of water are saved at the end use, 1,111 gallons are saved at the water plant [1,000 divided by (100% - 10%UAF) = 1,111].

Energy is required in the treatment of water. In systems with a groundwater source, treatment may consist simply of pumping the water from an aquifer and injecting chlorine as a disinfectant. In surface water systems, chemical feed pumps, mixer, aerators, and other equipment use energy in standard filtration plants. Some water treatments use much more energy than others. Reverse osmosis, for example, uses large amounts of electricity because the system must be maintained at high pressures to be effective, thereby requiring the use of high energy consuming pumps.

Distribution systems generally require pumping the water from the treatment plant to the customer. Terrain and density have a great impact on the pumping requirements, and therefore energy consumption, of a water distribution system. Mountainous areas require extra pumping to supply water to customers at elevations higher than the water plant. Sparsely populated areas may demand a significant amount of pumping in order to send the water over long distances.

The water quality, geographic, and demographic differences throughout the country make it difficult to come up with a single national factor to estimate the energy usage by water supply. Exhibits 5 and 6 show the average electricity usage to treat and supply water and the UAF in each State. The average energy usage for water treatment and distribution presented in Exhibits 6 and 7 is 1.5 kWh per kgal produced.[26-34] However, some have estimated the average value as high as 2.5 kWh per kgal.[1]

Exhibit 6
Energy Usage For
Water Treatment and Distribution
(watt-hours used per gallon water supplied)

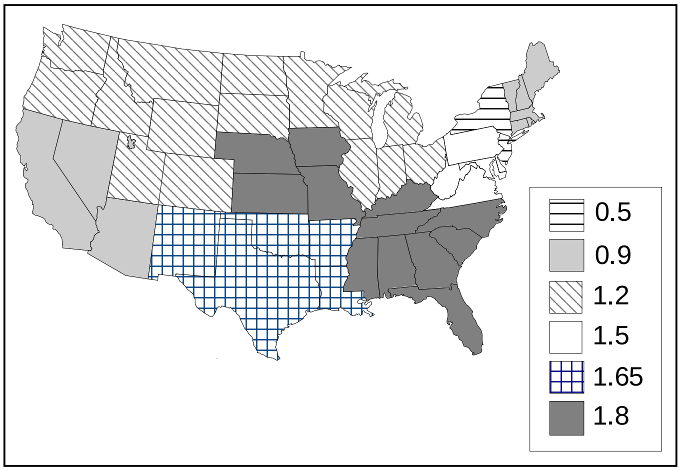


Exhibit 7
Regional Water Treatment and
Pumping Energy Costs

Region	States	Wh saved per gallon saved*	Electricity cost/kgal delivered	Avg. Electricity cost, 1992 $/kWh**	Unaccounted for water (UAF)
1	CT, ME, MA, NH, RI, VT	0.58	$0.05	$0.096	9.8%
2	NJ, NY	0.43	$0.04	$0.105	11.8%
3	DE, DC, MD, PA, VA, WV	1.44	$0.09	$0.073	14.0%
4	AL, FL, GA, KY, MS, NC, SC, TN	1.66	$0.10	$0.067	9.9%
5	IL, IN, MI, MN, MT, OH, WI	1.11	$0.07	$0.073	13.6%
6	AR, LA, NM, OK, TX	1.63	$0.10	$0.068	9.9%
7	IA, KS, MO, NE	1.73	$0.10	$0.064	9.0%
8	CO, ND, SD, UT, WY	1.10	$0.06	$0.059	7.4%
9	AZ, CA, NV, HI	0.86	$0.08	$0.099	6.1%
10	ID, OR, WA, AK	0.96	$0.04	$0.048	12.1%

* Wh saved per gallon of water saved = EXPENSE/RATE/(1-UAF)
** Commercial rates in 1992, same year as expenditure and UAF data

Wastewater Collection and Treatment

Wastewater collection and treatment can be thought of simply as analogous to water supply in reverse. Wastewater is collected and piped to the sewage treatment plant. Leakage or UAF do not typically apply to wastewater systems. While water distribution is a pressurized system in which water can leak out of the pipe, wastewater collection is not usually pressurized and actually has the reverse problem., that is, infiltration and inflow of excess water into the waste flow. Therefore, we assume that every gallon of water conserved yields one gallon of wastewater reduction.

Pumping demands for collection systems are generally subject to the same impacts as water distribution systems: terrain and density. Wastewater treatment typically consists of an activated sludge process which involves blowers for aeration, motors for skimmers and mixers, pumps, and sludge thickening equipment such as belt presses. In general, wastewater treatment and pumping consumes 2.85 kWh per kgal treated.

Electricity Production and Distribution

The difference between thermal energy input and energy content of electricity sold is generally referred to as electrical system energy loss. Most of this type of loss is due to the inefficiency of converting thermal energy into electricity. While this conversion loss typically represents approximately two thirds of the total energy input, the only losses considered in the context of this paper's intention are from in-plant use and in distribution losses.

Of all electricity generated, roughly five percent is used in-plant and nine percent is lost in distribution through line losses.[36] This 14 percent is analogous to the UAF in water supply. Similarly, approximately one kWh of indirect savings is achieved for every six kWh of direct electricity savings.

Natural Gas Supply

Prior to deregulation of the natural gas industry, accounting for UAF gas was relatively simple, as a gas company may have only a few suppliers. Now, dozens of sources may supply a gas company, making the accounting process very difficult. One industry executive stated, "You can't count molecules."[37] This fact helps to explain why a large portion of UAF is due to accounting and measurement inaccuracies.

A 1990 study by Pacific Gas and Electric Company (PG&E) showed that UAF represented on average 2.1 percent of throughput over an 11 year timeframe. However, only eight percent of the UAF was actually due to leakage or truly unaccounted for. Measurement inaccuracies due to factors such as temperature and pressure accounted for 63 percent of UAF. Accounting problems such as unmetered or poor meter accuracy and cycle billing represented 27 percent of UAF. The balance, tow percent, was found to be due to theft. Still for the purposes of this study, the total UAF figure, 2.1 percent of total deliveries should be used for calculating indirect savings.[37]

SUMMARY

Because every facility has a different set of conditions from which to work, coming up with a simple ratio of how much water can be saved and how much energy can be saved due to the water conservation is difficult. Instead, an example of the water and energy savings potential, based on the general assumptions addressed in this paper, at a hypothetical building is presented in Exhibit 8. WATERGY, a Lotus 1-2-3 v. 5.0 spreadsheet model, builds on these assumptions to help identify water and energy conservation opportunities based on site information.

Exhibit 8
Example of Annual Water And Energy Savings Possibilities

	Direct Savings								**Indirect Savings**					
	Quantity					Value (Thousands of Dollars)			Electricity Saved (Thousands of kWh)			Natural Gas	Value (Thousands of Dollars)	
Conservation Opportunity	Original Water Usage (kgal)	Water (and Waste-water)	Hot Water (kgal)	Electric (kWh x 1000)	Natural Gas (Mcf)	Water/ Waste-water	Electric	Natural Gas	Water Treat & Pump	Waste-water Treat & Pump	Electric Line Loss	Gas Distrib. (Mcf)	Electric	Natural Gas
Toilets and Urinals	3,865	2,179	0	0	0	11	0	0	3	6	2	0	1	0
Faucets	2,397	843	422	42	0	4	4	0	1	2	1	0	0	0
Showers	4,115	2,058	1,235	123	0	10	12	0	3	6	3	0	1	0
Boiler Blowdown	3,650	730	730	0	8,116	4	0	41	1	2	1	1	0	0
Landscape	14,600	7,300	0	0	0	37	0	0	11	21	5	0	4	0
Dishwasher	53	15	15	2	0	0	0	0	0	0	0	0	0	0
Washing Machine	703	166	42	4	0	1	0	0	0	0	0	0	0	0
Total	**29,383**	**13,291**	**2,444**	**171**	**8,116**	**67**	**16**	**41**	**19**	**37**	**12**	**1**	**6**	**0**

REFERENCES

1. Dyballa, Cynthia,, "Joint Energy and Water Programs: Building Cooperation and Savings." *Proceedings of American Council for an Energy Efficient Economy* Summer Study: Volume 5, Utility Programs, 1992.

2. The Energy Policy Act of 1992 (EPACT) (P.L. 102-486).

3. Executive Order (E.O.) 12902: Energy Efficiency and Water Conservation At Federal Facilities, Section 302(b) Comprehensive Facility Audits.

4. FEMP Focus, U.S. Department of Energy, Energy Efficiency and Renewable Energy, Special Water Management Edition, June 1995.

5. Federal Energy Management Program SAVEnergy Action Plan. Water Conservation Survey, Attachment 2.

6. *Residential Water Conservation Project Summary Report*, U.S. Department of Housing and Urban Development, 1984.

7. Vickers, Amy, "The Energy Policy Act: Assessing Its Impact on Utilities." *Journal American Water Works Association*, August 1993, pp. 56-62.

8. Seattle Water Department, Memorandum from Al Dietmann to Mary Ann Dickinson, June 4, 1993.

9. Heede, R., Homemade Money: How to Save Energy and Dollars in Your Home, Rocky Mountain Institute, 1995.

10. Rubin, A.R., *Water Watch: Saving Water and Saving Energy*, North Carolina Agricultural Extension Service. (N.C. State University, N.C. A&T State University, and U.S.D.A.), 1990.

11. Kobrick, J.D., "Uses of Water and Water Conservation Opportunities for Cooling Towers." Proceedings of CONSERV'93.

12. *Conservation Master Plan*, Denver Water, December 1992.

13. City of Phoenix Water Use Monitoring Program: Evaluation of Water Conservation Programs: Report of the 1989/1990 Surveys. Carbondale, IL: Planning and Management Consultants, Ltd. Prepared for Phoenix Water and Wastewater Department, Phoenix, AZ.

14. *Water Conservation Program*. 1991. City of Edmonton, Canada: Edmonton Environmental Services, Water Branch.

15. Behling, P.J., Bartilucci, N.J. "Potential Impact of Water Efficient Plumbing Fixtures on Office Water Consumption." *Journal American Water Works Association*, October 1992, pp. 74-78.

16. Ploeser, J.H., Pike, C.W., Kobrick, J.D., "Nonresidential Water Conservation: A Good Investment." *Journal American Water Works Association*, October 1992, pp. 65-73.

17. *Minneapolis - Saint Paul International Airport faucet water conservation study*, St. Paul, MN 55111, 1993.

18. Nelson, John Olaf, "Water Conserving Landscapes Show Impressive Savings." *Journal American Water Works Association*, March 1987, pp. 35-42.

19. *Save Water, Save Maintenance, Save Money: A Guide to Planning and Designing Water Conserving Landscapes*. Anne Arundel County (MD) Department of Utilities, 1989.

20. Gelinas, G., and Brant, B., *A Systems Approach To Saving Water and Energy*, Presented at 18th World Engineering Congress, Atlanta, GA, November, 1995.

21. Betz Handbook of Industrial Water Conditioning, Betz Laboratories, 1991.

22. Maddous, William O., *Water Conservation*, American Water Works Association, 1987.

23. Khambatta, B., Meier, D., and Kamrath, M. (Nalco Chemical Company), *Development of High Cycle Cooling Water Treatment Program*, Presented at the 1994 Cooling Tower Institute Annual Meeting.

24. Cunningham, R.J. (Chemisis, Inc.), *Maximizing Cooling Tower Cycles of Concentration*, Presented at the 1995 Cooling Tower Institute Annual Meeting.

25. Hunt-Atwater, K.M. (B.A.C. Pritchard, Inc.), *The Manufacturer and Energy-Efficient Cooling Towers*, Presented at the 1981 Cooling Tower Institute Annual Meeting.

26. Water Industry Data Base (WIDB), American Water Works Association, 1992.

27. Annual Report 1993, City of Akron (OH), Department of Public Service, Public Utilities Bureau.

28. Component Unit Financial Report of the Las Vegas Valley Water District for the Fiscal Year Ended June 30, 1993.

29. 90 year of Tucson Water: Annual Report 1990, Tucson Water Department.

30. Annual Report of Providence (RI) Water Supply Board for the year ending June 30, 1993.

31. Annual Report of The Mount Holly (NJ) Water Company for the year ending December 31, 1993.

32. Annual Report of Elizabethtown (NJ) Water Company for the year ending December 31, 1993.

33. 1993 Annual Report of The Cleveland Division of Water.

34. Audit Report of Water Utility, City of Evansville (IN). January 1, 1993 to December 31, 1993.

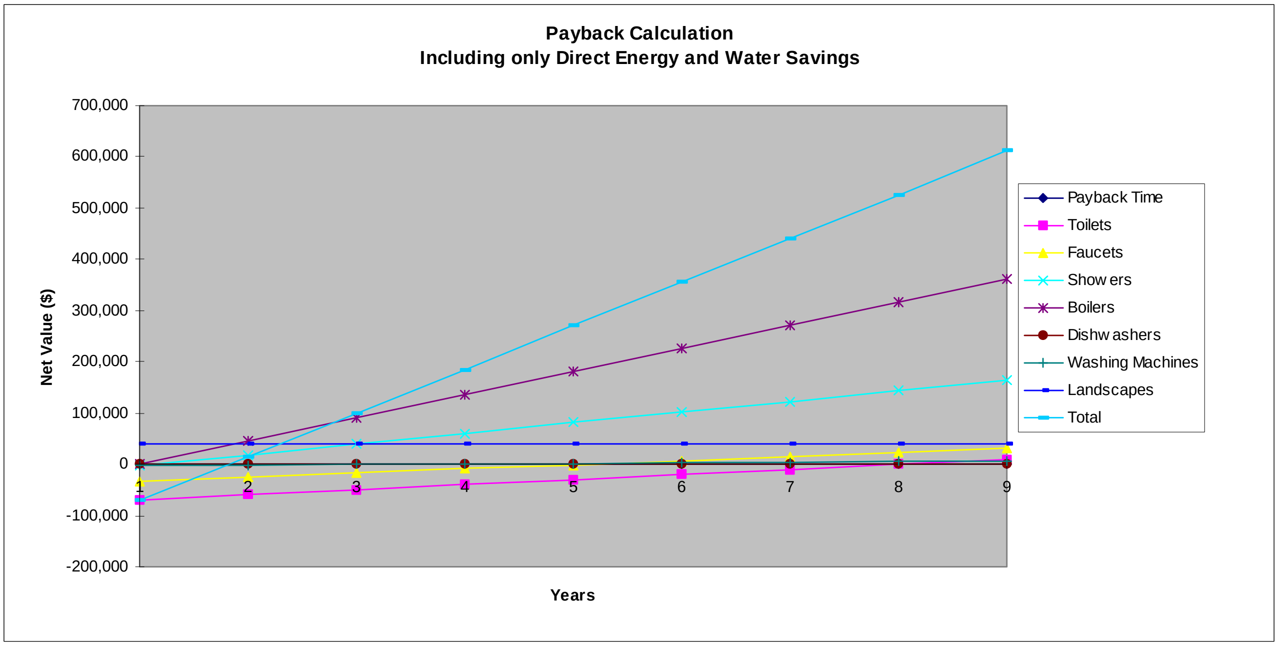
35. 1993 Operational Report, Columbus Division of Sewerage & Drainage.

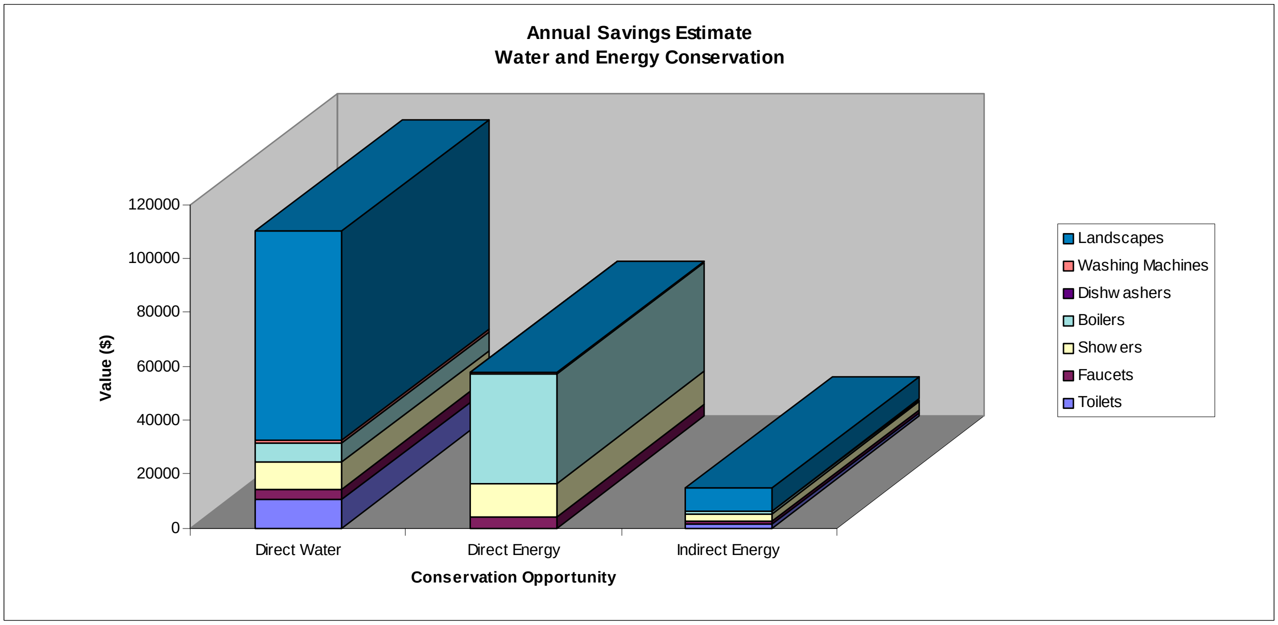
36. *Electric Sales and Revenue 1992*. Energy Information Administration, U.S. Department of Energy, April 1994.

37. Ahrens, Frank, "Finders of Lost Gas", *American Gas*, May, 1991, pp. 32-35.

Potential Conservation Opportunities

Conservation Method	Number of Installations	Total Cost	Annual Savings ($)			Payback Time Direct Only
			Direct Water	Direct Energy	Indirect Energy	
Installation of ULF toilets and urinals	238	$70,210	$10,423	$0	$1,143	6.74
Installation of automatic faucets	110	$32,450	$4,033	$4,216	$1,128	3.93
Installation of faucet aerators	0	$0	$0	$0	$0	#N/A
Low Flow showerhead	11	$3,245	$9,843	$12,346	$3,089	0.15
Boiler blowdown optimization	1	$0	$7,134	$40,581	$786	0.00
Efficient dishwashers	3	$975	$73	$153	$33	4.30
Efficient washing machines	7	$2,975	$794	$415	$155	2.46
Landscape irrigation optimization	#N/A	$38,984	$77,968	$0	$8,547	Annual
Total (excluding Landscape)		**$109,855**	**$32,301**	**$57,712**	**$6,334**	**1.22**


Payback Calculation
Including only Direct Energy and Water Savings


Annual Savings Estimate
Water and Energy Conservation