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Division of Statewide Integrated Water Management

Water Use and Efficiency Branch

DRAFT

Commercial, Institutional and Industrial Task Force Best Management Practices Report to the Legislature

A report to the Legislature pursuant to Section 10608.64 of the California Water Code

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This Draft Report was prepared by

California Department of Water Resources

And

Commercial, Institutional and Industrial Task Force

in

Consultation with the California Urban Water Conservation Council

The Task Force members and alternates who participated in the development of this report are as follows:

Mr. David Arrieta	DNA Associates	Sacramento, CA
Mr. Dave Bolland	Association of California Water Agencies	Sacramento, CA
Alt: Mark Rentz	Association of California Water Agencies	Sacramento, CA
Mr. Ray Cardwell	Contra Costa Water District	Concord, CA
Alt: Mr. Chris Dundon	Contra Costa Water District	Concord, CA
Ms. Heather Cooley	Pacific Institute	Oakland, CA
Alt: Ms. Lucy Allen	Pacific Institute	Oakland, CA
Mr. Dan Cunningham	Metal Finishing Association of CA	Torrance, CA
Ms. Jan Marie Ennenga	Manufacturers Council of the Central Valley	Modesto, CA
Alt: Tim Ruby	Del Monte Foods	Walnut Creek, CA
Mr. Don Fisher	Fisher Nickel Inc., Food Service Tech.	San Ramon, CA
Alt: Mr. Amin Delagah	Fisher Nickel Inc.	Ramon, CA
Ms. Jenny Gain, P.E., QSD	California Urban Water Agencies	Walnut Creek, CA
Alt: Ms. Penny Falcon	Los Angeles Dept. of Water and Power	Los Angeles, CA
Mr. Mark Gentili	Los Angeles Dept. of Water and Power	Los Angeles, CA

Alt: Mr. Enrique Silva	Los Angeles Dept. of Water and Power	Los Angeles, CA
Mr. Richard Harris	East Bay Municipal Utility District	Oakland, CA
Alt: Mr. Charles Bohlig	East Bay Municipal Utility District	Oakland, CA
Mr. Jack Hawks	California Water Association	San Francisco, CA
Mr. Jerry Desmond, Jr.	Plumbing Manufacturers International	Sacramento, CA
Alt: Len Swatkowski	Plumbing Manufacturers International	Rolling Meadow, Il
Ms. Trudi Hughes	California League of Food Processors	Sacramento, CA
Alt: Mr. Rob Neenan	California League of Food Processors	Sacramento, CA
Lt Col Jeremy N. Jungreis	USMCR	Camp Pendleton, CA
Alt: Mr. Paul Boughman	USMC Western Area Counsel Office	Camp Pendleton, CA
Ms. Randi Knott	California Hotel and Lodging Association	Sacramento, CA
Alt: Mr. Lynn Mohrfeld	California Hotel and Lodging Association	Sacramento, CA
Ms. Patti Krebs (dec.)	Industrial Environment Association	San Diego, CA
Mr. Joe Hess	Genentech	Oceanside, CA
Mr. Ken Letwin	BP America	Carson, CA
Alt: Mr. Scott Hawley	BP America	Carson, CA
Mr. Mike McCullough	Northern California Golf Association	Pebble Beach, CA
Mr. Bill McDonnell	Metropolitan Water District of Southern CA	Los Angeles, CA
Mr. Jim Metropulos	Sierra Club	Sacramento, CA
Mr. Mike Mielke	Silicon Valley Leadership Group	San Jose, CA
Mr. Mike Pimentel	Rain Bird Corporation	Tucson, AZ
Ms. Tracy Quinn	Natural Resources Defense Council	Santa Monica, CA
Alt: Mr. Ed Osann	Natural Resources Defense Council	Santa Monica, CA
Ms. Toby Roy (Task Force Chair)	San Diego County Water Authority	San Diego, CA
Alt: Ms. Maria Mariscal	San Diego County Water Authority	San Diego, CA
Mr. Tat-Yuen (Jacky) Sang	Bayer Health Care	Berkeley, CA

Mr. Patrick Silvestri	CA Soc. for Healthcare Engineering, Inc	Ontario, CA
Mr. Dave Smith	WateReuse California	Sacramento, CA
Alt: Ms. Elise Goldman	West Basin Municipal Water District	Carson, CA
Mr. Carlo Tarantola	California School Employees Association	Citrus Heights, CA
Alt: Ms. Sharon Furlong	California School Employees Association	Citrus Heights, CA

DWR-Task Force Project Team

Division of Statewide Integrated Water Management,
Water Use and Efficiency Branch staff;

Manucher Alemi, Chief
Kent Frame, Program Manager II
Rich Mills, Senior Engineer, WR
Michael Ross, Engineer, WR
Toni Pezzetti, Engineering Geologist
Jim Lin, Senior Water Resources Engineer
Martin Berbach, Staff Land and Water Use Scientist
Spencer Kenner, Staff Counsel
Andria Avila, Office Technician

and

Members of the CA Urban Water Conservation Council staff;
Chris Brown, Executive Director

Angelina Anderson, Project Manager

Keir Keightley, Project Manager

Elizabeth Bettencourt, Project Manager

Marci Flores, Administrative Assistant

With the assistance from the following consultants:

Bill Jacoby, Consultant

Bill Hoffman, Consultant

Richard Bennet, Consultant

John Koeller, Consultant

Ken Mirvas, Technical Writer

Dave Ceppos, Center for Collaborative Policy, California State University Sacramento who facilitated stakeholder and public meetings.

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2 Executive Summary

(To be added later)

3.0 Preliminary Working Draft – Introduction

This section has not yet been reviewed by the members of the Task Force.

Senate Bill X7-7 was enacted in November 2009 mandating water conservation, measurement, and reporting activities for urban and agricultural water suppliers. There are 18 actions in this legislation for which the Department of Water Resources (DWR) is assigned as the lead agency. These actions have been designated by DWR as "projects" for implementation of the legislation.

Specifically, SB X7-7 states;" DWR shall in conjunction with the CA Urban Water Conservation Council (CUWCC) convene a task force consisting of academic experts, urban retail water suppliers, environmental organizations, commercial, industrial, and institutional water users to develop alternative best management practices for commercial, industrial, & institutional (CII) water sector. (10608.43)".

The CII Task Force (CII TF) was also directed to assess the potential statewide water use efficiency improvements in CII sectors that would result from implementation of the alternative BMPs. The CII TF, in conjunction with DWR, will submit a report to the legislature by April 1, 2012.

Public and Report Development Process:

DWR and the CUWCC has formed the CII TF to seek technical and policy input from stakeholder representatives and the public as it plans and implements the requirements of the law. Sub committees were formed to address technical components specific tasks. The CII TF is chartered to review technical material and documents, and to provide comments, data and supporting information to DWR's project management team in implementing SBX7-7 requirements as pertains to section 10608.43 of the legislation, and as the TF and DWR prepares the legislatively mandated report.

The CII TF convened March 1, 2011 and will hold monthly meetings until the report to the Legislature is complete. Meetings of the CII TF are open to the public. Agendas are out ten days in advance of the meetings and posted on the CUWCC CII TF website dedicated to this project, as well as referenced on the DWR Water Use Efficiency web site, www.wateruseefficiency/sb7. At each meeting, the public will be given an opportunity to comment as well as submit written comments at any time during the process.

TF Scope:

The CII TF scope was defined by the stature as outlined below:

Development alternative best management practices for commercial, industrial, and institutional users and an assessment of the potential statewide water use efficiency improvement in the commercial, industrial, and institutional sectors that would results from implementation of these best management practices.

- a review of multiple sectors within commercial, industrial, and institutional users and recommended water use efficiency standards for commercial, industrial, and institutional users among the various sectors of water use;
- appropriate metrics for evaluating commercial, industrial, and institutional water use;
- evaluation of water demands for manufacturing processes, goods, and cooling
- evaluation of public infrastructure necessary for delivery of recycled water to the commercial, industrial, and institutional sectors;
- evaluation of institutional and economic barriers to increased recycled water use within the commercial, industrial, and institutional sectors;
- identification of the technical feasibility and cost of the best management practices to achieve more efficient water use statewide in the commercial, industrial, and institutional sectors that is consistent with the public interest and reflects past investments in water use efficiency.

Report Contents:

In the report the reader will find disparate section related to the various tasks outlined in the scope. The content is organized in such a way that the projects unrelated to the BMP's themselves were discussed first followed by the reporting of the various CII sectors and recommended BMP's. The report therefore, begins with a discussion of appropriate metrics, standards, an evaluation of CII water demand and the technical feasibility and the potential savings of BMP implementation. This is followed by a technical discussion of the various CII sectors and their water use, technologies and recommended BMP's. The final segment of this report discusses the role of recycled water.

In each of the sections detailing the various sectors the content format began with a discussion of the background and overview of that particular sector. This was followed by describing how water is used and in the case of industry its NAICCS code of Operations and the availability or lack of data. There is then a description of specific BMP's, savings, metrics and any other influencing factors such as regulatory issues, water quality issues and any other factors that would influence the feasibility of implementing that BMP. Case studies are also inserted with the appropriate BMP's when they are available.

In the Commercial and Institutional sections you will find descriptions of processes that carry over to many of the industrial sectors such as thermodynamics. In order to reduce redundancy these shared similar processes that were detailed in the commercial section and are then referenced back to the discussion of that process in the commercial section when they are applied to an industrial sector.

The recycling section in order incorporated discussions and assessments of status of recycled water use, the Recycled water TF findings, identifying barriers to reuse, recommendation to increasing water reuse, infrastructure requirements for reuse, and the evaluation of institutional and economic barriers to recycled water use.

The Draft Report (in pdf) as well as the supporting materials can be found at: http://dnn.cuwcc.org/CIITaskForceMaterials.aspx

http://www.water.ca.gov/calendar/index.cfm?meeting=18282

4.0 Preliminary Working Draft - Water Use and Demand In the Commercial, Institutional and Industrial Sectors

This section has not yet been reviewed by the members of the Task Force.

Current CII Water Use Estimates:

The California Department of Water Resources (CDWR) estimates that, based on the xx year data,public water purveyors for which water use data are available in the state provided approximately 1.89 million acre feet of water per year to CII sectors. It is also estimated that an additional 418,000 acre feet of self-supplied water is used by the CII sectors. These estimates do not include power plants water use. The U. S. Geological Survey (USGS) report *Estimated Use of Water in the United States in 2005,* estimates that thermoelectric power plants in California use about 55,500 acre feet of fresh water each year. Table X summarizes freshwater use by sector from self-supplied and public sources in California.

Table X. Freshwater Use from Self Supplied and Public Sources for the CII Sectors in California	
Commercial/Institutional	1,401,600
Industrial	312,300
Landscape Irrigation	594,100
Thermoelectric Power Plants	55,500
Total	**2,363,500**

Based on the recycled water survey conducted by the SWRCB*2009 Municipal Wastewater Recycling Survey,* recycled water provides an additional 209,500 acre foot of fresh water a year to CII sectors including power plants. Saline water use from coastal sources also provides additional water primarily to the mining and steam electric power plants, estimated to be 14.5 MAF per year. Table Y summarizes recycled water use for the same sectors.

Table Y. Recycled Freshwater Use for CII Sectors in California	
Type of Use	Acre feet per Year
Landscape	112,600
Golf Course	43,600
Total Irrigation Use	156,200
Industrial	47,100
Commercial	6,400
TOTAL RECYCLED WATER USE	**209,700**

Total freshwater use from all sources for the CII sectors is therefore estimated to be 2.57 million acre feet a year.

Section 5A: Preliminary Working Draft - Technical Feasibility and Potential Water Savings of Best Management Practices on Water Use in the Commercial, Institutional and Industrial Sectors

This section has not yet been reviewed by the Task Force.

Purpose: To examine the technical feasibility and the potential for water reduction by implementing the Best Management Practices (BMP's) described in this document.

Technical Feasibility of Implementing the BMP's

All BMP's described in this document are technically feasible and have been used in the past. However, it does not mean that each BMP is applicable in all cases. In developing best management practices (BMP's) three guiding principles should be kept in mind.

1. One size does not fit all – For any given industry, there may be a dozen potential BMP's. Not all will be applicable. In many cases establishing one BMP could mean that another will not be applicable because they will "be saving the same water."

2. Every facility is unique - Analysis of potential payback is unique to each facility and situation. Facilities, even in the same industry, vary in their process, equipment selection and design. This means that what may work at one vegetable processing plant may not be applicable at another; what works in one research laboratory or hotel may not be applicable in another.

3. The list should be used only as a guide - The intent of the manufacturing BMP's is to provide a list of possible measures that plants can adopt for their specific situation.

Potential Savings by Implementation of the BMP's

First and foremost, many commercial, institutional, and industrial (CII) facilities in California are already practicing up-to-date water efficiency techniques. The selection and implementation of these BMP's is determined by their local economics and design. Others have real opportunity to reduce water use further in an economic manner. The State does not currently have the data necessary to establish the baseline of use in each CII sector. One of the major objectives of the section on metrics is to begin to gather the information needed to make this evaluation on a State wide basis.

This document contains numerous examples of water saving. These are found in the text of the BMP's themselves and as examples along with the text which contains a number of case studies to illustrate potential savings. In most cases, the information needed to estimate statewide savings must await the development of the baselines and metrics recommended in this report. However, there are two examples of Statewide achievement that illustrate what such analysis has to offer. The first Statewide example is in section 7 the California Department of Corrections and Rehabilitation of this report which has already realized a 21 percent reduction totaling over 2.4 billion gallons of water annually (7,365 acre-feet annually).

The second example is found in the Water Recycle section. Based on a 2009 survey, almost 670,000 acre feet of water are being recycled annually (218 billion gallons of water annually).

The BMP's and the examples cited from the case studies describe many ways to reduce freshwater use can be summarized into the following five categories:

1. **Adjust equipment and fix leaks** - Making adjustments and repairs to existing equipment and processes so that it operates more efficiently. For example, in the General Building Sanitation Section, an example is given of the Park 55 Wyndham Hotel in downtown San Francisco. The toilet retrofit resulted in a larger than expected savings based on "engineering" estimates because leaks and faulty equipment was fixed. In another example, Eagle Food in Sun Valley, California audited their facility and implemented the following measures:

    - Restrict water flow at hose stands – Eagle Foods installed flow control valves to reduce water flow from 7.5 gallons per minute (gpm) to 3.5 gpm.
    - Use water brooms instead of hoses to wash down for sanitary purposes
    - *Install hose bib connectors to reduce leakage at water tanks*
    - *Replace cracked hoses as needed to reduce leakage*

    Although the first two measures were examples of modifying or installing more efficient equipment, the last two measures reduced leaks. The combination of measures resulted in a savings of nearly 230 gallon a day.

2. **Modify equipment or install water saving devices and controls** - Adding devices, automated systems, or equipment to existing water using equipment and processes. For example, the Los Angeles County, Department of Parks and Recreation (LACDPR) installed weather based controllers, rain sensors and monitoring system at its El Cariso Park & Golf Course and Veterans Park. This resulted in a 27 percent reduction in water use of 198 acre feet (64.5 million gallons a year.

    Artistic Plating and Metal Finishing, Inc. of Anaheim, California installed electrode less conductivity controllers on nine tanks on the plating line. This reduced water use by 49%. This also reduced chemical costs by 20%. The total cost was $14,500 but it saves $13,800 per year, a pay back of 13 months.

3. **Replacement with more efficient equipment** - Replacing older inefficient water using equipment and fixtures with water saving types of equipment is one of the most recognized ways to reduce water use. For example, in the General Building Sanitation Section, an estimate of total potential statewide water savings that could result from the replacement of existing CII toilets with high-efficiency toilets was made in 2005. That analysis estimated the savings potential as being between 26,000 and 38,000 acre-feet per year (AFY) of water. Another 3,000 to 5,000 AFY could be saved through legislation, codes, and standards applied to new construction. In a similar manner, installing a clean in place system in a food processing plant can cut the water use by half for washing pipes and vessels.

4. **Water reuse/recycle** - The many case examples of water recycling in California show the potential for using this source of fresh, non-potable water. On-site sources of water are also being used. Examples range from the low impact stormwater management options used in San Diego County, California to rainwater harvesting and air conditioning condensate recovery in many places in the United States. The food processing industry provides many examples of the reuse of their effluent for crop production.

5. **Change to waterless process** - There are a number of examples of replacing water using equipment with equipment that does not use water in the actual BMP's. From the section on Thermodynamics using air cooling and ground effect (geothermal) air conditioning systems eliminates cooling tower water use entirely. In conventional cooling towers, approximately 2.5 gallons of water is used per ton hour of cooling. This means that a large office building can require 20,000 to 30,000 gallons of water a day during the hottest part of the summer just for the cooling towers.

   The use of dry vacuum pumps in laboratories and medical facilities offers another example. In recent years, most major radiology departments in hospitals have converted to digital imaging because of its superior medical diagnostic capabilities. This has resulted in the elimination of water for large plate X-ray film development. This can save as much as 500,000 gallons of water per year per film developer.

The reader is urged to read the many examples in the text of this document and in the case studies.

Calculation of Water Saving Potentials

Pacific Institute (2003) provided the following method to estimate the Percentage Water Conservation Potential (S):

S = [(1-p)c]/(1-pc)
Where p is the Penetration Potential (%); and
C is the Technical Saving (%).

Let's use water saving for toilets as an example to illustrate the above formula. Suppose a small community has totally 50 toilets with 10 toilets at 1.6 gallons per flush and 40 of them at 3.5 gallons per flush. Also suppose that the lower flush rate above (1.6 gallons) meets the best management practice. The Technical Saving, c, is calculated as (3.5-1.6)/3.5 = 0.543, and the Penetration Rate, p, is calculated as 10/50 = 20%. We can thus calculate the Percentage Water Conservation Potential,

S = [(1 - 20%) x 0.543]/(1 - 20% x 0.543) = 48.7%.

After obtaining S, we can calculate the Annual Water Saving of the community by multiplying S by the Current Annual Water Use. Now assuming the Current Annual Water Use is 0.5 million gallons (MG), we get

The Annual Water Saving Potential = 0.5 MG x 48.7% = 0.2435 MG or 243,500 gallons per year.

In order to calculate the Percent Water Conservation Potential S and the Annual Water Saving Potential in 2010 statewide in CII sectors, we need the current Penetration Rate p and Technical potential c as well as the current water use in each NAICS sector. To collect such data and much other information, a new CII statewide water survey similar to the one that DWR conducted in 1994 is needed as well as the development of metrics standard.

Section 5B: Cost Analysis Approach

Legislative Mandate: Section 10608.23 of the California Water Code (CWC) mandated the formation of the CII Task Force and the creation of a final report to the legislature creation by that TF in collaboration with the CA Department of Water Resources and the CA Urban Water Conservation Council (CUWCC). This final report should contain “identification of technical feasibility and cost effectiveness of the best management practices to achieve more efficient water use statewide in the commercial, industrial and institutional section…”

Purpose: This white paper is to discuss variables involved in cost analysis and propose an approach for the final report for assessing cost effectiveness of a Best Management Practice (BMP).

Economic Analysis Approach: Economic analyses may be conducted from a number of perspectives, including the utility, customer, and community/society. The perspective determines which costs and benefits to include in the analysis. The utility perspective is based on costs and benefits to the water utility. The customer/business perspective is based on costs and benefits to the customer or business. The societal perspective is based on costs and benefits to the water utility and its customers, and it may also include external costs and benefits, such as recreational benefits that may accrue to downstream communities by leaving more water in streams and rivers. The approach in this chapter focused on the customer/business perspective.

Varying degrees of complexity, size, technical needs, and inherent barriers to analyzing BMP costs for industrial equipment, processes, and plants, make a one-size-fits-all statewide assessment of costs to implement BMPs impossible. Therefore, this report outlines an approach that businesses may use to evaluate the costs and benefits of a particular BMP. Variability in business size, type of water use, and other related costs support this approach.

Geographical Variability: Water, wastewater, and energy costs have significant variations across the State (Figure 5.2.1). How that water is used at a specific location, variations in plant design in similar types of facilities, and past conservation efforts all further affect the cost effectiveness calculations for any given BMP. In all parts of the State, however, water, wastewater, and energy rates are continually increasing, and they are becoming a larger component of businesses' bottom line. Figure A shows that national water and wastewater rates are increasing faster than the consumer price index and other utility rates. In fact, water and wastewater rates have risen even faster than fuel prices over the same period, according information from the US Department of Commerce. A number of factors are driving this trend, including limits on the availability of conventional fresh water resources, needed investment in aging water and wastewater infrastructure, increases in water quality and compliance costs, and climate impacts.

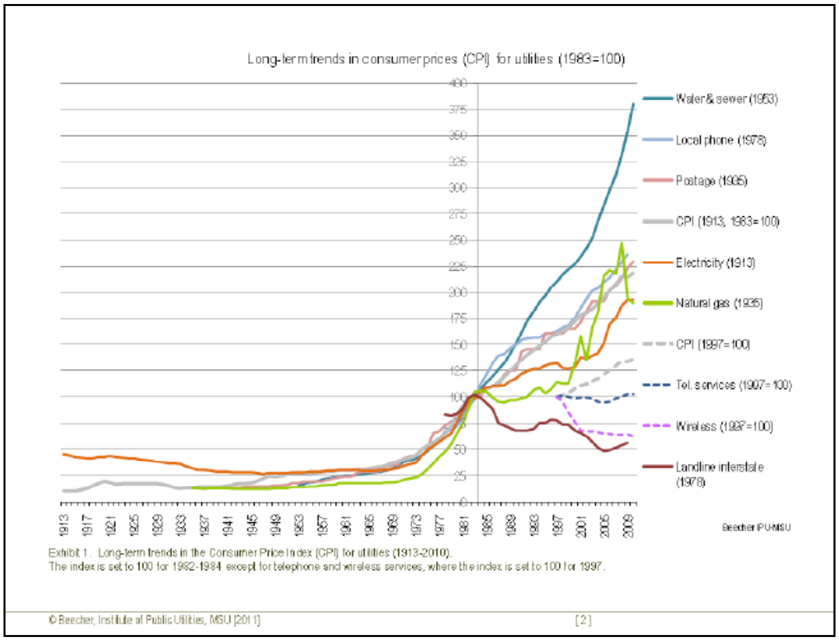
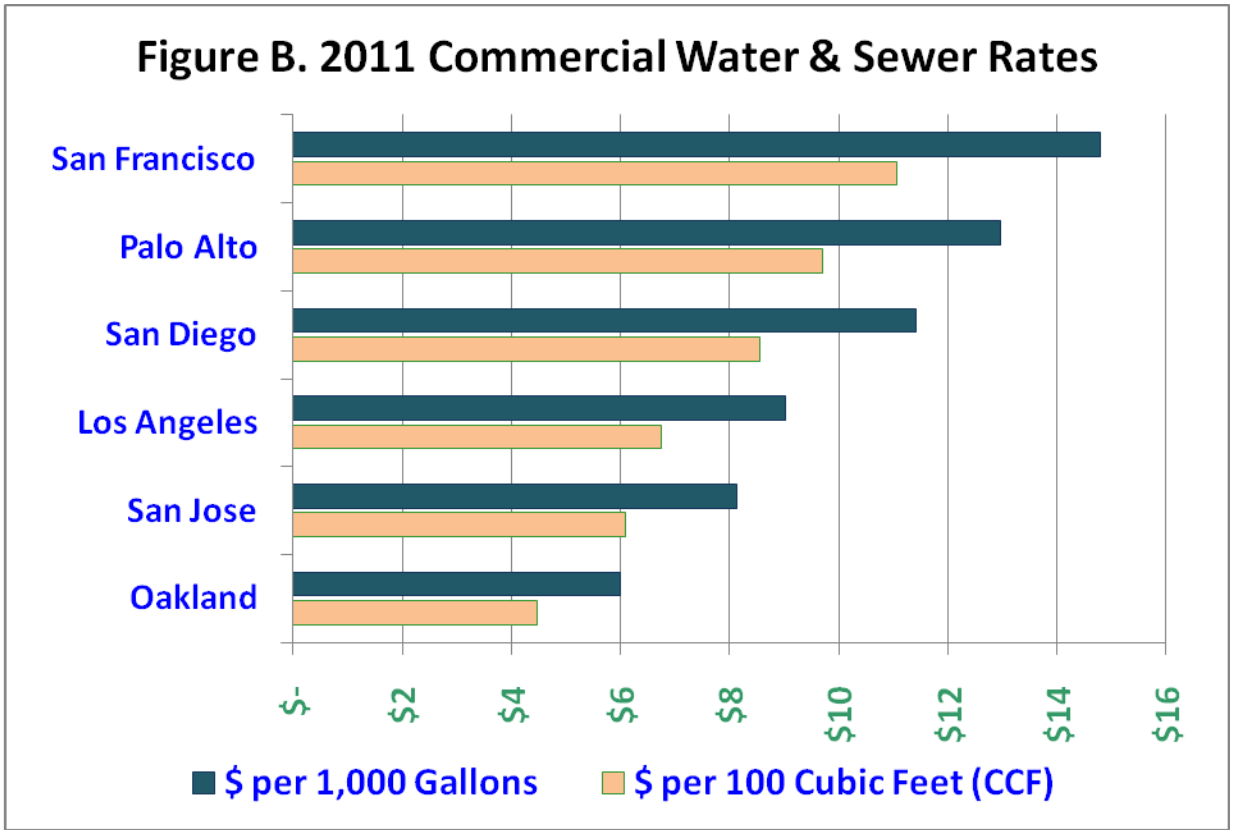


Figure 5.2.1 Consumer Price Index for Utilities

As shown in Figure 5.2.1, rates also vary significantly from one utility to another in California, meaning that a measure that may be cost effective in one area may not be in another.



Overall Cost Effectiveness Approach: There are many ways to look at the issues of cost, benefit, technical feasibility, and payback to the individual end user. Additionally, there are costs and benefits that accrue to the society at large. The purpose of this section is to provide an overview of how these two different objectives can be addressed. It provides example of how businesses water and wastewater utilities, and society might perceive issues related to costs and benefits.

This section further considers how to determine the true cost of water to a business or industry and how to compare that to the cost of a BMP to reduce the associated water costs. This analysis entails looking at the true cost of water, examining the costs of implementing the BMP, and focusing on the balance of costs to benefits. The true cost of water will consider all costs to the customer that are associated with use and disposal of the water as it flows through the system.

When determining whether a BMP is cost effective, the customer will need to assess the financial costs and benefits of implementing the BMP. There are a variety of financial metrics that can be used to determine whether a particular BMP makes economic sense. No single metric is perfect; rather each has strengths and weaknesses, and some combination of these indicators can be useful for financial planning.

A sample of applicable costs, benefits and factors typically included in an economic analysis includes:

a. Capital Costs of installing the BMP (if it includes equipment)

b. Changes in operation and maintenance costs including changes in water, wastewater, energy, waste disposal, pre-treatment, chemical, and labor costs

c. Expected usable life of the measure

d. Reduced Risk Factors.

In addition, all rebates, tax liabilities (or benefits), and other related incentives and costs must be taken into account. Specifics of individual BMP cost calculations and examples are discussed in Section 8. Calculating the Cost of Individual BMPs.

Section 5C: Developing the Benefit/Cost Estimate

While there are several ways to complete benefit/cost (B/C) analyses, the basic concept is to determine if benefits to a specific industry or business outweigh the costs. When discussing benefit/cost analyses, some commonly terms are "payback," return on investment (ROI), and internal rate of return (IRR). These analyses provide guidance on a short time scale, helping to determine if a proposed modification is worth the investment. Longer-term analyses look most only at the costs and benefit, but also at lifecycle factors, such as net present value, inflation, and amortization.

Payback Period

The payback period is the time required for an investment in efficiency to pay for itself. The simple payback is calculated by dividing the total costs (including installation, capital, permitting, and equipment costs) by the annual benefits, giving a simple payback in terms of years. Many firms set a simple payback criterion of two years or less unless the life of the device is shorter. Depending on the Business Plan, many companies use 3-4 year paybacks as cost effective, which is a return of 25-33% on investment. A two-year payback is generally considered to be extremely cost effective. If a business using a more efficient device does not own the building or the equipment, some issues with the economics of payback become more challenging.
The payback period is a straightforward metric that is easy for most people to understand. It is the time required to recoup the cost of an investment. While the payback method is relatively easy to calculate, it does not account for the life of the device. Device A, for example, may have an incremental capital cost of $100, annual water and energy savings of $50, and a lifetime of three years. Device B, in comparison, may have the same incremental capital cost and annual water and energy savings, but have a lifetime of 20 years. Thus, while both devices may have a simple payback of two years, Device B will provide benefits for 17 years beyond that of Device A. Additionally, the payback does not include the rate of interest that an investor must pay (or forgo) when making the initial investment.

Installed cost of BMP / (annual Savings of BMP to business) = payback in years)

Return on Investment (ROI)

The return on investment (ROI) is the percent of payback the BMP produces per year. In the case of a one-year payback, the ROI is 100%. If the payback is in 1.6 years as shown in the example below, the ROI equal to ($100%/1.6) or 62.6% a year.
If energy, chemicals, labor, and other savings or costs are involved, they must be included in the denominator.

<u>EXAMPLE</u>

In a school gymnasium, what is the Payback and Return on Investment (ROI) if a showerhead is replaced from 2.5 gallons per minute device to 2.0 gallons per minute device and heated with natural gas? What is the total cost of the water savings, if replacing all the showerheads?

Water cost	*$3.50 per CCF*
Wastewater cost	*$4.00 per CCF*
Natural gas cost	*$8.50 per MCF (0.85 cents per therm)*
One MCF of gas	*Equals one million British Thermal Units (BTUs)*
Cold water temperature	*60^{o} F*
Water for showering	*100^{o}F*
Showerhead cost including labor	*$25*
Average shower time	*8 minutes*
Shower frequency	*an average of four times a day*
Gym usage	*180 days a year and has 5 shower heads*

Water and wastewater cost	*$7.50 per CCF*
Per thousand gallons	*$10.03* *($7.50 / 0.748 = $10.03)*
Per gallon	*1.003 cents*
Water used by the old shower	*$14.41 per yr for water alone (8 mins X 2.5 gals per mine X 4 times a day X 180 days a yr = 14,400 gals a yr)*

Assuming a water heater efficiency of 75%, and a change in temperature of 40^{o}F (hot and cold water mixed). The energy used is 2.5 gallons per minute.

Energy used to heat 14,400 gallons of water a year to 100^{o}F	*4.804 million BTUs* *(14,400 gals X 8.34 pounds per gal X 1 BTU/pound/degree F X 40^{o}F)*
Gas needed to heat the water	*6.405 million BTUs*

	(4.804 / 0.75)
At $8.50 per MCF	*$54.44 per year to heat the water*
Total water costs include energy costs plus water and wastewater costs	*$64.47 per year* *($10.03 + $54.44)*
Installing a new shower head	*0.5 gallons per minute will be saved*
The amount saved (water, wastewater and energy combined)	*$20.92*
Payback	*1.2 years* *($25.00/$20.92)*
The savings for five shower heads	*$104.59 per year* *($20.94 X 5)*

Internal Rate of Return (IRR)

The internal rate of return, or IRR, provides an indication of the efficiency of an investment. It is defined as the effective annual interest rate at which an investment accrues income. The IRR of the net spending column for a water conservation measure can be compared to the interest rate on borrowed funds or the rate of return that is possible from other investments. If IRR is higher than the agency's rate of return, then the investment is deemed to be worthwhile.[1] While the IRR is useful for determining whether a single project is worth investing in, it cannot be used to compare mutually exclusive projects. The IRR can only be used under certain conditions. With a complex series of cash flows that change signs more than once, there is more than one mathematically feasible solution. In other words, the information from an IRR is not always meaningful.

Net Present Value Analysis Approach

A business may also want to analyze the costs and benefits over the economic life of the device, particularly for large investments that may have longer payback periods. This analysis may be appropriate if the time for return on investments does not justify making the improvements in the short term and there is a long-term investment involved.   A lifecycle analysis will take into consideration the costs and savings over the full life of the BMP being installed. In this type of analysis the business would consider the time value of money, savings

[1] Note that the model calculates the IRR based on the undiscounted net cash flows. Therefore the resulting rate of return should be compared to the agency's undiscounted rate of return.

through the life of the equipment, and the increasing costs of water, energy or sewage disposal over the life of the equipment. This analysis may also include labor, tax, and insurance savings.

NPV is among the most common financial metrics used in capital budgeting. It sums all of the costs and benefits over the lifetime of the device and reports their value at the beginning of the project. The costs include initial start-up costs plus those needed to operate the conservation program, such as the cost of the rebate and program administration. While the costs typically accrue only during the duration of the conservation program, the benefits accrue over the life of the device. A positive NPV indicates that the benefits of the project exceed the costs over the life of the device. This approach has not been as commonly used by business as the ROI or payback approach, but may become more applicable in the future

Increased Water Rates

Water shortages and development of costly water supplies will result in increased water rates. Implementing water use efficiency measures will reduce the demand on the local water supply and the need to develop costly future water supplies, which may reduce the long-term costs of water to the business. Large water users are likely to feel the greatest impacts of increased water rates. Predicting water rates is not a exact science since water agencies have so many factors influencing rates, such as supply, conservation pricing, operational costs, capital costs, bonds, employee salaries and benefits to name a few. In addition, water is priced differently throughout the state, because water sources, infrastructure, and reliability vary. However, water and garbage rates are increasing by percentage faster than all other utilities, and as such, decreasing water demand will have a greater effect over time. These increases should be factored in to the lifetime cost analyses

The National Utility Service, *Inc*. (*NUS Consulting Group)* annual survey shows that between 2004 and 2008, water and wastewater costs nationwide increased by an average of 6.5 percent a year, far more than consumer price index inflation. To take these increased water costs into account, all costs should be converted to present value.

In this situation, the cost of the retrofit will remain the same, but the actual savings will include expected increases in water and wastewater costs over the anticipated useful life of the BMP. Where energy, chemical, labor, tax, insurance and other savings are costs are involved, they would also have to be included. With many measures, the costs are incurred in year one while the benefits accrue in subsequent years. For this reason, the discount rate is used. Rising water and wastewater rates would be taken into account as escalation factors.

The general formula for calculating present value is:

$$\text{PV Costs} = \sum \text{Costs}_t/(1 + \text{discount rate})^t$$

Consideration of Risk Factors by Businesses

Note: There was agreement that this concept will be included in the report, but no decision has been made as to whether it belongs in the cost section or in another section of the report.

When making a business decisions, an economical analysis forms the primary basis for making decisions. However, when considering whether to make an investment in water use efficiency, a business may also want to look at other factors that are not as simple to quantify. Businesses may consider the external risks on the business that would be associated with taking no action. These risks may include reduced reliability, potential for future mandates, costs, and reputational risks or benefits. Assessment of these risks will require close communication and cooperation between the business community and its local water supplier. While it is possible to quantify the risk, doing so would require complex analysis and modeling which may require excessive effort to complete.

Reliability of Water Supply

A business may want to consider the reliability of the local water supply in the region or community, the possible impacts of disruptions in the water supply, or a lack of adequate supply would have on the operations and the long term profitability of the company. This assessment would be based on the conditions of the local utility supplying water.

Potential for Mandated Reductions

The risk of mandated water supply reductions may be a consideration for any area with a history of water shortages. Water use efficiency measures can reduce the possibility of shortages and mandated reductions. In addition, businesses that have demonstrated that they have already achieved a high level of efficiency could make a strong case to avoid future mandated reductions.

Reputational Risks and Benefits

A business that has a large presence in a community will generally strive to maintain a positive reputation and good relations with the rest of the community. In communities that are experiencing water shortages, particularly where users are subject to restrictions, the ability to demonstrate efficient water use on the part of business and industry will help maintain a positive reputation in the community In addition, many businesses have taken proactive approaches to being good environmental stewards to better market their company. Companies that have taken this approach can include water use efficiency as a priority in demonstrating their environmental stewardship.

Replacement of Outdated Equipment

As better technology becomes available CII businesses may decide to upgrade their water using equipment, fixtures, and machines when they reach their useful life as a cost effective measure. Older equipment by their design will use more water, energy, chemical, and wastewater than newly designed equipment. As a good business practice the CII business should evaluate the equipment and the maintenance and operational practices needed to achieve an industry standard of water use efficiency for the new equipment being purchased.

Calculating the Cost of Individual BMPs

An important consideration in calculating the costs of BMPs such as:

1. Water and wastewater savings

2. Cost of the measure
3. Expected usable life of the measure
4. Energy cost decrease or increase
5. Chemicals costs or savings
6. Waste disposal costs associated with water treatment or use
7. Labor costs or savings
8. Liability
9. Usable life of equipment or processes

Costs are typically calculated for each BMP within a comprehensive CII water conservation program.

Developing the Benefit/Cost Estimate:

Benefit/cost analyses entail such concepts as "payback," return on investment (ROI), net present value, Inflation, and amortization. The purpose of these calculations is to determine the benefits to a specific industry or business and divide those benefits by the total costs. A simple payback calculation provides an initial example. That calculation totals applicable benefits, reduced water, wastewater, energy, etc., then divides the total by the installed cost of the equipment. The result provides simple payback in years. Many firms want a simple payback of two years or less.

Installed cost of BMP / Total Savings of BMP to business per year = payback in years

Completing this calculation requires knowing the unit value of water. The following examples show how to calculate the unit value of heated water:

Calculating the Unit Value of Water: Obtain the unit cost of water, which is usually expressed in dollars per thousand gallons, or dollars per 100 cubic feet. Do the same for wastewater if it is charged based on the volume. Add the costs for water and wastewater to obtain the total cost of water. (If costs are expressed in 100's of cubic feet (CCF), convert it to gallons by multiplying by 0.748.)

<u>EXAMPLE 1</u>:

Question – If a business used 52 CCF in a month, how many gallons did it consume?

Answer - 52 X 748 = 38,896 gallons per month

<u>EXAMPLE 2</u>:

Question – If water costs $7.50 per CCF, what is that cost in dollars per thousand gallons.

Answer - $7.5/ 0.748 = $10.03 per thousand gallons

Total annual water and wastewater cost would then be equal to [(38,898 X 12)/1000] X $10.03 = $4,681.76 per year

For heated water, determine the type of energy used to heat the water (gas, electric, solar, or other) and its cost per unit (cents per kilowatt hour, dollars per therm, dollars per MCF [thousand cubic feet] of natural gas, etc.) For calculation purposes assume water is heated from 55°F to 120°F, which is typical of water heated either for domestic use. High temperature use in a commercial dishwasher in Southern California typically requires a temperature rise from 125 °F to 180°F.

If the gas is billed in therms, convert the cost to dollars per thousand cubic feet (MCF) of gas by multiplying the cost of the gas in therms by 10 to convert it to dollars per MCF.

One MCF of propane contains approximately one million BTUs, which is equivalent to approximately 11 gallons. A propane cost of $2.00 per gallon is equivalent to natural gas costing $22.00 per MCF.

***EXAMPLE 3*:**

Question – If natural gas costs $0.80 per therm, what is the cost of raising the water's temperature by 55°F?

Answer - $0.80 X 10 = $8.00 per MCF which is equal to approximately $5.00 per thousand gallons.

Additional costs, such as for softening or other treatments, must also be estimated.

EXAMPLE 4:

Question – If water costs $3.50 per CCF and wastewater cost $4.00 per CCF, and the water is heated with electricity that costs 10 cents per kilowatt hour, what is the cost of heating the water by 55°F?

The water and wastewater cost $7.50 per CCF ($3.50 + $4.00) or $10.03 per thousand gallons ($7.50 / 0.748 = $10.03).

The cost of heating the water by 55°F is $14.20 per thousand gallons.

Total water costs include energy plus water plus wastewater:

Total Cost = $10.03 + $14.20 = $24.23 per thousand gallons or 2.423 cents per gallon.

Calculating Payback, Return on Investment and Net Present Value

Replacing a 3.5-gallon per flush toilet with a 1.28-gallon per flush toilet saves 2.22 gallons per flush. The combined water and sewer cost for that toilet is $6.50 per 100 cubic feet (CCF), or $8.69 per thousand gallons, or 0.87 cents per gallon. Therefore, each flush saves 1.93 cents. If the toilet is flushed an average of 35 times per day and the building is open 255 days a year, installing the 1.28 gallons per flush toilet will save $172.38 in water and sewer costs each year. If the total installed cost of the toilet (toilet and labor) is $275.00, the payback is 1.6 years ($275 / $172.38). The return on investment is the percent of payback the BMP produces per year. In this example, the ROI is 62.5% per year (100 / 1.6). Additional costs, such as energy, chemicals, or labor and insurance, must be included in the denominator.

The National Utility Service, *Inc***.** (*NUS Consulting Group)* annual survey shows that between 2004 and 2008, water and wastewater costs nationwide have increased by an average of 6.5 percent per year, far more than consumer price index inflation. To take this increase into account, all costs should be converted to present value. In this situation, the cost of the retrofit will remain the same, but the actual savings will include expected increases in water and wastewater costs over the anticipated useful life of the BMP. Additional costs and savings, such as energy, chemical, labor, tax, insurance must also be included. The general formula for calculating present value is:

$$\text{PV Costs} = \sum \text{Costs}_t/(1 + \text{discount rate})^t$$

Estimates of costs and benefits can reflect complicated math, and each business or industry must decide how much detail they want in their payback. For most businesses, simple payback is sufficient to determine the cost effectiveness of a measure.

The above discussion also shows that determining a payback for any given measure is local in nature. Local water and energy rates, the type and volume of business, the type of equipment used, and previous measures can all come into play.

Looking at Your Facility

To conduct a study of the Best Management Practices that will be effective for a given business or industry, the facility should either conduct a water audit themselves or obtain the services of a professional consultant trained in this area. This Best Management Practice Guide provides commercial, industrial, and institutional water users with information they can use to reduce water and wastewater bills and to help reduce water use, but it is up to the entity to evaluate specific circumstances. Many facilities managers have found that they can begin the process by simply looking at water and wastewater bills and comparing their use to similar facilities that their company may operate. Really understanding water use and the value of increased water efficiency requires a more thorough analysis.

The audit looks at the current water use by the facility, including water use and types of water using equipment. The audit then asks seven important questions:

1. How much water is the facility using?
2. Where in the facility is the water being used?
3. When is the water being used?

4. How and for what is it being used?
5. Who controls its use?
6. Why is water needed here?
7. Are there other ways to do the same work that do not use water?

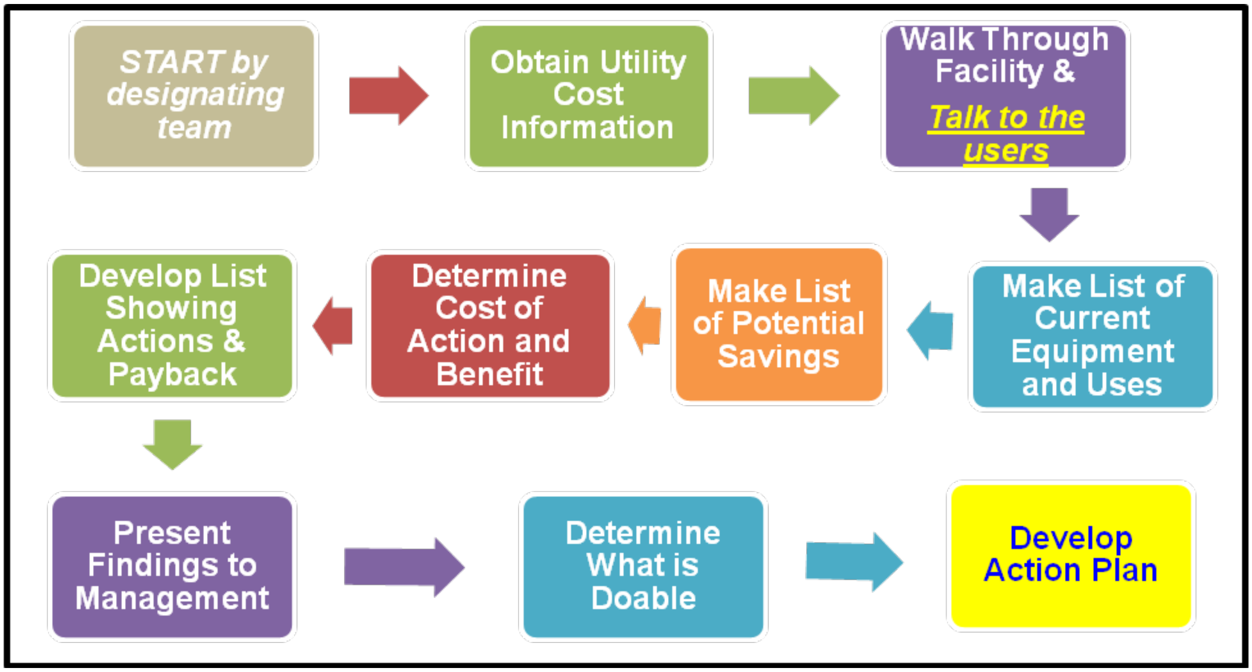
Once these seven questions have been answered, the facility manager can evaluate ways for each individual operation to reduce use. The first step, of course, is to repair malfunctions and leaks. Following that, the best ways to reduce use entails and assessment of all of the available options. Generally, these options fall into one of five measures, starting with the lowest in cost:

1. Adjust existing equipment to use less water.
2. Modify existing equipment or install a water saving device.
3. Replace existing equipment with more efficient models or types.
4. Reuse and recycle water where possible.
5. Choose equipment or methods that eliminate water use.

One of the main objectives of this guide is to provide the commercial, institutional, and industrial water user with information they can use to reduce water bills using cost-effective measures. One method of reducing potable and freshwater use, for example, is to use recycled water from a public utility. Another is to examine how water may be reused within a facility. This reuse can range from process water in an industry to the capture of rainwater or air conditioning condensate for use for irrigation or in a cooling tower. The following table may help the facility manager or engineer identify all water uses, the water quality needed for that operation, and the water streams from their operation to see if they may be candidates for reuse either as is or after additional treatment.

Figure C

The Audit Process


START by designating team
Obtain Utility Cost Information
Walk Through Facility & Talk to the users
Make List of Current Equipment and Uses
Make List of Potential Savings
Determine Cost of Action and Benefit
Develop List Showing Actions & Payback
Present Findings to Management
Determine What is Doable
Develop Action Plan

5D: Preliminary Working Draft - Estimating Savings By Application of BMPs

This section has not yet been reviewed by the members of the Task Force

First and foremost, many commercial, institutional, and industrial (CII) facilities in California are already practicing up-to-date water efficiency techniques. The selection and implementation of these BMPs is often determined by local economics and design. Others have real opportunities to reduce water use further in an economic manner. The State of California does not currently have the data necessary to establish the baseline of use in each CII sector. One of the major objectives of the section on metrics is to begin to gather the information needed to make this evaluation on a statewide basis.

This document contains numerous examples of water savings. They may found in the text of the BMPs themselves, as examples along with the text, and in Appendix ??, which contains a number of case studies to illustrate potential savings. In most cases, the information needed to estimate statewide savings must await the development of the baselines and metrics recommended in this report. However, there are two examples of statewide achievement that illustrate the potential benefits of such analyses. The first example is the California Department of Corrections and Rehabilitation, which has already realized a 21 percent reduction totaling over 2.4 billion gallons of water annually (7,365 acre-feet). The second is in the Water Recycle section: Based on a 2009 survey, 218 billion gallons of water are being recycled annually (670,000 acre-feet).

The BMPs and the examples and case studies describe many ways to reduce freshwater use, but these methods can be summarized into the following five categories:

Adjust equipment and fix leaks - Make adjustments and repairs to existing equipment and processes so that they operate more efficiently. For example, in the General Building Sanitation Section, there is an example of the Park 55 Wyndham Hotel in downtown San Francisco. The toilet retrofit there resulted in larger-than-expected savings based on "engineering" estimates because leaks and faulty equipment were fixed. In another example, Eagle Food in Sun Valley, California audited their facility and implemented the following measures:

- Restrict water flow at hose stands (Eagle Foods installed flow control valves to reduce water flow from 7.5 gallons per minute (gpm) to 3.5 gpm.)
- Use water brooms instead of hoses to wash down for sanitary purposes
- Install hose bib connectors to reduce leakage at water tanks.
- Replace cracked hoses as needed to reduce leakage.

The first two measures were examples of modifying or installing more efficient equipment, and the last two measures reduced leaks. The combination of measures resulted in savings of nearly 230 gallon per day.

Modify equipment or install water saving devices and controls - Add devices, automated systems, or equipment to existing water using equipment and processes. For example, the Los Angeles County, Department of Parks and Recreation (LACDPR) installed weather-based controllers, rain sensors, and monitoring system at its El Cariso Park & Golf Course and Veterans Park resulting in a 27 percent reduction in water use of 64.5 million gallons per year (198 acre feet).

Artistic Plating and Metal Finishing, Inc. of Anaheim, California installed electrodeless conductivity controllers on nine tanks on the plating line, reducing water use by 49% and chemical costs by 20%. The total cost was $14,500, and it saves $13,800 per year, a payback of 13 months.

Replace with more efficient equipmen*t* - Replacing older inefficient water using equipment and fixtures with water saving types of equipment is one of the most recognized ways to reduce water use. For example, the General Building Sanitation Section notes a 2005 estimate of total potential statewide water savings that could result from the replacement of existing CII toilets with high-efficiency toilets. That analysis estimated the potential water savings as being between 26,000 and 38,000 acre-feet per year (AFY). Another 3,000 to 5,000 AFY could be saved through legislation, codes, and standards applied to new construction. In a similar manner, installing a clean-in-place system in a food processing plant can cut the water use by half for washing pipes and vessels.

Water reuse/recycle - The many case examples of water recycling in California show the potential for using this source of fresh, non-potable water. On-site sources of water are also being used. Examples range from the low-impact stormwater management options used in San Diego County to rainwater harvesting and air conditioning condensate recovery in many places in the United States. The food processing industry provides many examples of the reuse of their effluent for crop production.

Change to waterless process - There are a number of examples in the BMPs of replacing water-using equipment with equipment that does not use water. The section on Thermodynamics, for example, notes the use of air cooling and ground effect (geothermal) air conditioning systems to eliminate cooling tower water use entirely. Conventional cooling towers use approximately 2.5 gallons of water per ton hour of cooling, meaning that a large office building can use 20,000 to 30,000 gallons per day during the hottest part of the summer just for the cooling towers.

The use of dry vacuum pumps in laboratories and medical facilities offers another example. In recent years, most major radiology departments in hospitals have converted to digital imaging because of its superior medical diagnostic capabilities, resulting in the elimination of water for large plate X-ray film development and saving as much as 500,000 gallons of water per year per film developer.

The reader is urged to read the many examples in the text of this document and in the case studies found in the in the Appendix.

6 Preliminary Working Draft - Appropriate Metrics

This section has not yet been reviewed by the members of the Task Force.

When setting targets for urban water use efficiency, SB X7-7 directed urban water suppliers to use the metric of gallons per capita per day (GPCD). However, the Legislature recognized the difficulty that commercial, industrial, and institutional (CII) water users have correlating changes in water use due to factors such as population, economic growth, and technology changes. Accordingly, the Legislature allowed urban water suppliers to make adjustments to their targets or their compliance values to account for CII water use (Water Code sections 10608.24(d) and (e)). Therefore, SB X7-7 directed the CII Task Force to report to the Legislature on other "appropriate metrics for evaluating commercial, industrial, and institutional water use" (Water Code section 10608.43(a)).

According to the American Water Works Association, Water Conservation Division, Subcommittee Report on Water Conservation Measurement Metrics dated January 2010:

> "A *metric* is a unit of measure (or a parameter being measured) that can be used to assess the rate of water use during a given period of time and at a given level of data aggregation (e.g., system-wide, sector-wide, customer level, or end-use level). Another term for a *metric* is *performance indicator*."

This section will consider that definition in addressing the CII Task Force's analysis and reporting responsibilities. Additionally**,** 4**.**4.1 of this section includes three specific recommendations for addressing data needs and the data collection process. Finally, most metrics have inherent limitations and to apply them across a wide range of businesses can lead to erroneous conclusions. At the industry or sector level most metrics provide a gross reference point that will be subject to a number of qualifications.

Approaches to Data Collection and Assessment

The purpose of the Appropriate Metrics Section is two-fold. The first, as noted above, is to assess how water is used in California's CII sectors, from an accounting perspective. The second is to enable CII water customers and users to evaluate their individual water use such that cost-effective water-use efficiency tools, techniques, and processes can be utilized at the micro-level. As such, the metric may include the factor of volume of water use and another factor that correlates to the benefit obtained from that water use in the CII sectors, such as employment, quantities of manufactured output, or square foot of land or building space. Water use metrics can be applied at different consumption points and may be different for each approach. For instance, areas that have been identified for potential data gathering and reporting purposes thus far are:

1. Broad aggregated CII sectors (commercial, industrial, and institutional), at regional or statewide levels.

2. Specific CII subsector, such as petroleum refining, commercial laundries, or hospitals, at regional or statewide levels.

3. Water suppliers including retail and wholesale water agencies usually tracked at the sector level, but may be tracked at the subsector level as well.

4. Customer or water delivery to the site, usually tracked at the account level, but possibly tracked at the meter level.

5. Specific process or application of water use within a CII facility, such as cooling towers or vegetable washing. A subset of this level would be specific efficiency standards for designated technologies, such as toilets or laundries. Note: This latter approach is addressed in the standards and codes section.

SB X7-7 also calls for the Task Force to develop BMPs and to do an "assessment of the potential statewide water use efficiency improvement in the commercial, industrial, and institutional sectors that would result from implementation of these best management practices" (Water Code section 10608.43). This assessment implies a need for metrics at levels 4 or 5 above. The last evaluation of CII metrics was performed by DWR in 1995. Currently, there is little or no updated data available statewide to be able to make a more accurate assessment and the corresponding development of metrics is challenging. Additionally, appropriate metrics need to be identified for projecting savings in the BMP process so that accurate cost effectiveness and aggregate savings calculations may be performed.

Currently Used Metrics

Various currently used metrics have been proposed that may be applicable to specific sectors or to aggregated sectors.

The success of any metric depends on the availability and accuracy of the data incorporated into that metric. Water utilities measure the water delivered to customers and are the primary source of water use data at the macro level. However, they often do not collect or report data at the level of detail needed to evaluate water use efficiency in the CII sectors. A major gap is data for self-supplied water, which is water that is developed and supplied by the user. In many cases this is locally available groundwater extracted at or near its point of use. A minority of Task Force members contends that compiling self-supplied water is not within the scope of the Task Force under SBX7-7 and should not be considered in this report. However, improved data collection on water use in the various sectors is required before further assessment of the potential for saving water can be made on a statewide basis. Some industries may have industry- or business-specific data available, which can be helpful in setting metrics or BMPs, and in evaluating trends at the micro level. It is the opinion of the Task Force that greater efforts should be made to develop strategies, approaches, and standards for water use data and metric development for the diverse CII water uses in California on the aggregate level.

Table 6.1 - Potential Metrics

Metric	Advantages	Disadvantages	Data Availability	Time Term	Comments
Acre foot (AF)	Used for large volumes	Not used for small volumes	Good	NA	Useful for water agencies
Cubic foot (CF)	Used for measuring capacity		Good	NA	Can be use for large scale flow analysis
Cubic foot per second (CFS)	Used for measuring flow rates		Good	NA	
Gallons	Used for measuring deliveries		Good	NA	Can be used for aggregate metrics
Hundred CF (HCF)	Used for measuring deliveries		Good	NA	May be used for retail account billing
Million gallons (MG)	Used for waste water volumes		Good	NA	Best to use MG per day annual average
Million gallons per day (MGD)	Used for waste water volumes		Good	Day	Best to use per day annual average
Per capita	Water production and population info. available	Information may not be matched to agency area	Good	Year	Includes all general population of water agency
Per employee	More relative than per capita	Employee info. may not be available	Poor	Year	Includes employees for account location
Per account	More relative than per capita	Differences in water use characteristics	Fair	Year	
Per equivalent account	More precise than per capita	Depends on sectoral water use characteristics	Fair	Year	
Per square foot of irrigated area	More precise than above categories for outdoor use	Depends on accurate land area measurement	Fair	Year	Climatic differences
Per square foot of building area	More precise indoor use	Depends on accurate building area measurement	Poor	Year	
Per square foot of heated building	More precise indoor use	Depends on accurate building area measurement	Poor	Year	Climatic differences
Per unit of manufactured item		Users may be reluctant to share information	Poor	Year	Difficult to apply across industries
Per dollar of value added		Users may be reluctant to share information	Poor	Year	Difficult to apply across industries

Potential Metrics for Aggregate Sectors

There are a number of options available for evaluating water use in each of the CII sectors. Specific recommended approaches for evaluating each of those three sectors are presented below.

Commercial and Institutional Sectors

The majority of water used in the Commercial and Institutional sectors can usually be attributed to one of four general categories: water using fixtures, water using appliances, irrigation devices and other outdoor uses (i.e. swimming pools,) or service process uses (i.e. carwashes.) Therefore, potential metrics for those two sectors are similar enough that it is appropriate to consider the same evaluation options for both. Each of the options, as well as related statewide advantages and disadvantages, are discussed below. See Table 4-1 for additional information on additional potential metrics. Additionally, indoor and outdoor water use will vary between CII groups and those differences must be considered.

Gallons per capita

This option includes all of the general population of the water agency's service area in calculating the gallons per capita of consumption for CII sectors.

- Advantages - Water production and population information can be readily available and the calculation is relatively easy to perform.
- Disadvantages – the population within the water agency's service area may not be related to CII use.

Gallons per employee

This option considers all employees known to work at the site location for the accounts.

- Advantages – The calculation results are more likely be reflective of actual water use than the per capita option.
- Disadvantages – Accurate and current employee information may not be reliably available.

Gallons per square feet of (occupied) building space

This option considers the square footage of building space known to be in use by the CII customers at the time of the calculation.

- Advantages – This calculation is also likely to result in an outcome that is more closely related to actual water use than the per capita option.
- Disadvantages - Current occupied building space in use information changes over time and current information is not likely to be readily available. Additionally, outdoor water use is not considered in the calculation.

Gallons per dollars of economic output and/or gallons per unit of output

These options consider the economic value derived from the water used compared to the dollar value realized from the perspective of the number of units produced by the water supplier.

- Advantages – These calculations are likely to result in outcomes that correlate the value of the water supply to the resulting economic output
- Disadvantages – The value of goods produced can change over time distorting year to year comparisons. For a number of reasons not related to water consumption, the number of units produced may fluctuate and make comparisons inaccurate.

> *The above generic metrics however, are not universally applicable to all commercial and institutional sectors. It may be appropriate for DWR to work with individual sectors within the broader range of sectors to identify more appropriate metrics applicable to the specific concern. DWR and other implementing agencies should recognize and address this need for specific water use metrics as appropriate*

Industrial Sector

A portion of Industrial sector water use can normally be attributed to many of the same four general use categories as the Commercial and Institutional sectors. These uses can often be concentrated in plumbing fixtures (i.e. toilets, urinals, faucets,) and landscape irrigation. However, the major use type for the Industrial sector is normally for production water use. The types and amount of production water use can range as dramatically at the types and volumes of goods produced. Accordingly, it is recommended that two different approaches be taken for determining aggregate industrial sector water use.

In some cases metered deliveries of potable or recycled water used specifically for non-production purposes can be clearly tracked. Potential metrics for those supplies of potable water could be evaluated using the same options listed above for the Commercial and Institutional sectors. Finally, potable, recycled, or non-municipal water use for production purposes, which can be up to 95% of total water use, will need to be tracked and considered separately.

The generic metrics described above are not universally applicable to all industrial sub-sectors. In fact, industrial facilities may have other constraints, such as waste water and contaminant discharge regulations and requirements that make the generic metric listed above even more inappropriate for certain industrial sectors.

Summary of Data Needs and Collection

Most municipal water districts in the State have been tracking aggregate CII sector water use at least since the 1980s, and in many cases longer. However, the definitions of the various sectors can vary between water agencies because of non-uniform customer class descriptions. Additionally, the water agency's customer information system capabilities can limit the amount of disaggregated CII water use data availability and the consistency in reporting and water uses across water agencies. Both of these obstacles will need to be overcome to achieve reliable statewide data. Examples of how two California water agencies currently gather and use CII sector water use are detailed below.

East Bay Municipal Utility District (EBMUD) is one of the largest retail water agencies in the State. For years it has tracked specific CII water use data by customer and then aggregated that data by Business Classification Code. Table 4-2 below presents a summary of the data collected.

Table 6-2

Business Classification Code (BCC)	2005 Demand (1,000 gallons)	2005 Demand (GPD)	2005 Accounts in BCC	2005 Demand per Account (GPD)
0100 - AGRICULTURE	82,135	225,027	113	1,986
0700 - VETERINARIAN SERVICES	23,684	64,888	95	681
1200 - MINING AND QUARRYING	11,064	30,312	<10	6,062
1500 - CONSTRUCTION	33,172	90,882	702	129
2010 - MEAT PRODUCTS - PROCESSING/PKG	38,650	105,890	31	3,416
2011 - SLAUGHTERHOUSE	-	-	-	-
2020 - DAIRY PRODUCT PROCESSING	66,823	183,077	16	11,209
2030 - FRUIT AND VEGETABLE CANNING	536	1,468	<10	210
2040 - GRAIN MILLS	12,264	33,600	<10	6,720
2050 - BAKERIES	54,680	149,808	77	1,943
2051 - BAKERIES - MFG BREAD ONLY	23,822	65,266	23	2,901
2060 - SUGAR PROCESSING	780,614	2,138,668	13	165,574
2070 - FATS AND OILS	16,311	44,688	<10	5,586

2077 - RENDERING TALLOW	-	-	-	-
2080 - BEVERAGE MANUFACTURE	398,505	1,091,795	17	64,223
2090 - SPECIALTY FOOD MANUFACTURING	28,891	79,153	31	2,519
2091 - SEAFOOD PROCESSING	1,335	3,658	<10	1,513
2300 - TEXTILE GOODS MANUFACTURING	10,209	27,970	62	455
2400 - LUMBER AND WOOD PRODUCTS MFG	4,426	12,126	31	390
2500 - FURNITURE	9,838	26,953	87	309
2600 - PULP AND PAPER PRODUCTS MFG	27,139	74,353	23	3,210
2700 - PRINTING, PUBLISHING	17,782	48,718	146	333
2810 - INORGANIC CHEMICALS MFG	85,689	234,764	20	11,787
2820 - SYNTHETIC MATERIALS MFG	23,803	65,214	41	1,594
2830 - DRUGS MANUFACTURING	139,573	382,392	35	10,900
2840 - CLEANING AND SANITATION PROD MFG	6,396	17,523	16	1,113
2850 - PAINT MANUFACTURING	7,954	21,792	12	1,816
2860 - ORGANIC CHEMICALS MANUFACTURING	163,312	447,430	<10	49,714
2870 - AGRICULTURE AND CHEMICALS MFG	715	1,959	<10	603
2891 - ADHESIVES AND GELATIN MFG	3,460	9,479	<10	1,896

2893 - INK AND PIGMENT MANUFACTURING	2,714	7,436	12	620
2900 - PETROLEUM PRODUCTS MANUFACTURING	4,937,509	13,527,422	36	377,509
3000 - RUBBER PRODUCTS	2,046	5,605	10	561
3110 - LEATHER TANNING	-	-	-	-
3200 - EARTHENWARE MANUFACTURING	150,400	412,055	64	6,455
3300 - PRIMARY METALS MANUFACTURING	61,803	169,323	65	2,602
3400 - METAL PRODUCTS FABRICATING	35,706	97,825	201	488
3410 - DRUMS AND BARRELS MFG	626	1,715	<10	858
3470 - METAL FINISHING	14,288	39,145	40	975
3500 - MACHINERY MANUFACTURING	5,120	14,027	41	345
3590 - MACHINE SHOP JOBBING/REPAIR	15,841	43,400	132	328
3600 - ELECTRICAL MACHINERY MFG	19,340	52,986	58	907
3700 - TRANSPORTATION EQUIPMENT MFG	180,554	494,668	22	22,831
3730 - SHIPBUILDING	18,239	49,970	15	3,388
3800 - PRECISION EQUIPMENT MFG	7,554	20,696	39	532
3900 - MISCELLANEOUS MANUFACTURING	26,685	73,110	91	805
4000 - RAILROAD TRANSPORTATION	9,580	26,247	21	1,250

4100 - LOCAL AND SUBURBAN TRANSIT	36,521	100,058	82	1,223
4200 - WAREHOUSING	376,527	1,031,581	1,315	785
4400 - WATER TRANSPORTATION	70,473	193,077	126	1,537
4500 - AIR TRANSPORTATION	138,524	379,518	12	31,408
4700 - TRANSPORTATION SERVICES	25,298	69,310	75	925
4800 - ELECTRONIC COMMUNICATIONS	36,632	100,362	120	838
4900 - ELECTRIC, STEAM AND NATURAL GAS	29,689	81,340	66	1,229
4950 - SANITARY COLLECTION AND DISPOSAL	77,126	211,304	126	1,673
5000 - WHOLESALE TRADE	40,219	110,189	305	362
5300 - RETAIL TRADE, OTHER	854,411	2,340,852	4,153	564
5400 - FOOD SALES	272,173	745,679	888	840
5540 - GASOLINE AND OIL DEALERS	93,786	256,948	294	875
5811 - EATING PLACES, FAST FOOD	173,054	474,121	495	958
5812 - EATING PLACES, RESTAURANTS	616,794	1,689,847	1,331	1,270
5813 - DRINKING PLACES, BARS, CLUBS	50,476	138,290	199	694
6500 - CEMETERIES	90,358	247,556	20	12,588
6800 - OFFICES	1,524,915	4,177,849	4,256	982

7000 - HOTELS WITH FOOD	307,041	841,208	127	6,637
7001 - HOTELS WITHOUT FOOD SERVICE	318,717	873,197	243	3,587
7020 - BOARDING HOUSES	173,537	475,444	286	1,661
7200 - PERSONAL SERVICES	168,186	460,784	1,259	366
7210 - COMMERCIAL LAUNDRIES	75,451	206,715	63	3,264
7215 - COIN OPERATED LAUNDROMATS	299,780	821,315	231	3,554
7216 - CLEANING AND DYEING FABRICS	40,803	111,789	116	968
7218 - INDUSTRIAL LAUNDRIES	65,543	179,570	<10	69,511
7260 - CREMATORIES, FUNERAL HOMES	10,164	27,847	41	676
7300 - LABORATORIES	514,644	1,409,984	152	9,291
7342 - FUMIGATING	284	778	<10	130
7500 - AUTOMOBILE REPAIR SERVICES	134,065	367,301	1,139	323
7539 - BATTERY SERVICE	859	2,353	10	241
7542 - AUTO LAUNDRIES	85,051	233,016	108	2,153
7600 - MISCELLANEOUS REPAIR SERVICES	7,742	21,211	132	161
7699 - SEPTIC TANK CLEANING	7,321	20,058	<10	6,686
7900 - AMUSEMENT SERVICES	375,653	1,029,186	476	2,163

7940 - EQUESTRIAN ACTIVITIES	80,594	220,805	19	11,621
7950 - IRRIGATION USE ONLY	3,547,174	9,718,285	4,345	2,237
7990 - PARKS AND GARDENS	1,085,221	2,973,208	612	4,860
8000 - HEALTH SERVICES	642,367	1,759,910	1,184	1,487
8060 - HOSPITALS	399,900	1,095,616	132	8,295
8200 - SCHOOLS	1,636,542	4,483,677	1,172	3,824
8600 - NON-PROFIT SERVICES/ORGANIZATION	534,910	1,465,507	1,829	801
CII Subtotal	**22,579,312**	**61,861,129**	**29,974**	**1,596**

The Metropolitan Water District of Southern California (Metropolitan) has relied on gallons of water used per employee (GPE) as a key variable in projecting future CII water use in its service area. The GPE approach assumes equal productivity across sectors and is distorted to the extent that this assumption does not hold. The GPE data is collected from a sampling of Metropolitan's member agencies and used in the MWD MAIN econometric forecasting model, which has been a key component in Metropolitan's water resources planning since the late 1980s.

It must be stressed that in both these examples the metrics data is highly dependent on the initial reliability of the business type classification of the water user account, and it is important to stay vigilant to assure the accuracy of use code updates should the facility change business characteristics.

While there are examples of water agencies that do have good mechanisms in place to track CII water use, there has been no recent accurate statewide assessment of CII sector water use collection or analysis. There is even less availability of reliable data on non-municipal water deliveries to CII user and subsequent uses.

Recommendations for Addressing Data Needs and Collection

Four initial recommendations for addressing data needs and collection have been developed by the Task Force. It is anticipated that a procedure for additional data gathering will be needed to achieve a more sophisticated level of collection and analysis.

A comprehensive analysis of state-wide tracking of municipally supplied CII water must be completed. The current level of CII sector water supply deliveries of a reliable sample of retail water agencies must be analyzed and summarized. Additionally, any past CII water use sampling efforts should be reviewed and considered.

An analysis of CII water, self-supplied or obtained from non- municipal sources (e.g. groundwater, storm water, or other sources) must be completed to project the volume of water used and types of uses. This effort must consider opposition by some water users to data collection as they contend it is out of the scope of the Task Force's Legislative charge under SBX 7-7.

A process that will allow the State agencies involved to work with stakeholders to collect and analyze data from at least a sampling of municipal and non-municipal CII sector water sources and uses must be developed.

DWR should work with all stakeholders to develop the data needs and collection framework that allows for the orderly and cost-effective collection of needed data to achieve the needs and collection goals of the state.

Alternative Approaches to Measuring, Monitoring, and Reporting on Water Use

Some CII water users have developed and are using alternative approaches to measure, monitor, and report on their water use. Four of those alternative approaches are described below. Appropriate alternative approaches should be voluntarily selected by CII water users.

Indexing to accommodate variations across years and products - CII water use can fluctuate for a variety of reasons that are not related to level of water use efficiency. For instance, Industrial users may shift to producing a variety of different product over the course of a year or years. The water needs to these products may vary dramatically and cause production water demand to increase for periods of time and also experience increased average annual water use. Indexing water use to a baseline period or average years of water use may be most helpful in assessing water use efficiency progress.

Energy/water audits – Some CII customers have completed comprehensive energy and water use audits. These audits can result in detailed recommendations for improved efficiency in the use of both energy and water. These audits are a valuable resource that should be considered in measuring, monitoring, and reporting improvements in water use efficiency. Additionally, the motivations identified for the CII user to implement the water use efficiency changes should be considered.

Federal Executive Orders (EO) – Department of Defense installations are typically large institutional water users. EO 13423 required a 16% reduction in installation water use intensity by 2015. Meanwhile, EO 13514 augments those requirements and stipulates:

- A 26% reduction in potable use by 2020
- A 20% overall reduction in industrial, landscape irrigation, and agricultural water use by 2020
- Installations are to identify, promote, and implement water reuse strategies that reduce potable water consumption

Finally, a military installation would be deemed water efficient if it demonstrates specific criteria.

Other water use metrics - CII water users should consider other appropriate water use metrics that allow for the effective measurement of trends and changes in water use within their specific sector. The CII sectors and facilities should evaluate and implement data collection and analysis approaches and metrics that allow for the cost-effective gathering and analysis of data to achieve measure water use trends and changes. An example is the California Green Lodging Program that tracks progress in the hospitality sub-sector.

It is important to note that CII water use analysis and reporting will be done on a statewide aggregated basis and the confidentiality of individual CII water users supplying data must be assured. Additionally, flexibility and steak holder involvement will be necessary to determine the best approach.

CII User Specific Metrics

Most of the best management practices (BMPs) in this report are applicable to specific processes or applications of water use and appropriate metrics to assess the effectiveness of specific BMPs are included in sections of the report that address specific CII BMPs. Individual water users are encouraged to develop metrics that can be used for specific CII subsectors. Table 4-3 provides some useful examples of metrics currently used by a sample of international CII users.

Examples of Metrics Used by a Sample of Specific Corporations

Available at Corporate Web Sites

Table 6-3

Corporation	Metrics Used
Beverage Industry Environmental Roundtable	Water used in billion of liters, production in billions of liters, and water use ratio
Coca Cola Company	Liters of water to produce 1 liter of beverage
International Car Wash Association	Gallons per vehicle

Nestle	Cubic meters of water equated to cubic meters per ton of product
PepsiCo	Liters per unit of production
SABMiller	Water to beer ratio measured in hectoliters
Unilever	Water per cubic ton of production

Finally, users should consider sub-metering to track more accurate disaggregated water use where appropriate (See Section 7 for additional information.)

References:

http://www.thecoca-colacompany.com/citizenship/water_main.html
http://bieroundtable.com/water_stewardship.html
http://www.unilever.com/sustainability/environment/manufacturing/?WT.LHNAV=Eco-efficiency_in_manufacturing
http://www.sabmiller.com/index.asp?pageid=913
http://www.nestle.com/CSV/WaterAndEnvironmentalSustainability/Water/Pages/PerformanceDirectOperations.aspx
http://www.carwash.org/industryinformation/WaterSavers/Pages/WaterSaversEnvironmentalReports.aspx

7A: Commercial and Institutional Sectors

7A1 Commercial Food Service

Introduction

General

According to information from the National Restaurant Association and the 2003 Census, California has more restaurants than any other state. Table 7.1 shows the ranking and restaurants per capita for each state based on that study. California, New York, Texas and Florida account for one third of all restaurants in the United States.

Table 7.1 Top Five States by Number of Restaurants In 2003

State	Number of Establishments	Restaurants per 1,000 Population
California	87,225	2.41
New York	58,027	3.01
Texas	53,631	2.35
Florida	41,901	2.36
Pennsylvania	31,466	2.53
National Totals	**714,232**	**2.41**

Source: National Restaurant Association and 2003 U.S. Census information

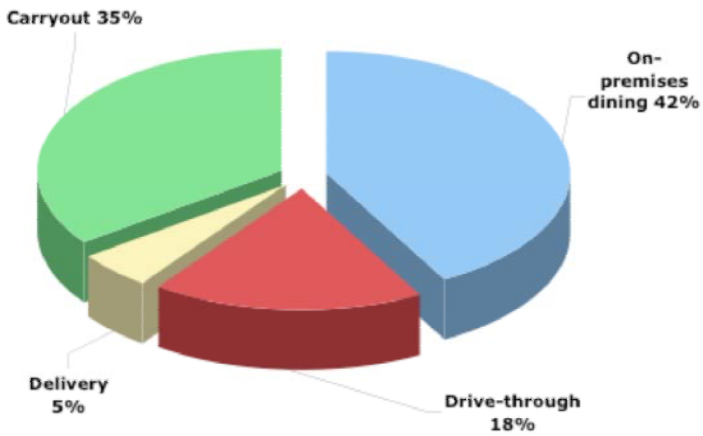
(http://en.wikipedia.org/wiki/List_of_US_states_by_number_of_restaurants_per_capita)

As Table 7.1 shows, California had approximately 12 percent of the restaurants in the United States in 2003. Based upon the above table, the seven-year increase in population, and other information, there may have been as many as 87,000 to 92,000 restaurants in the state in 2010[2].

The national distribution of restaurants by type, as shown in Figure 2, would apply to California.

[2] Does not account for closures due to 2010-2011 economic conditions

Figure 2. U.S. Distribution of Restaurant Customer Traffic - 2001



Source: University of Georgia, Business Outreach Services, 2002

In addition to the restaurant traffic shown in Figure 2, there are numerous institutional food service establishments, such as schools, prisons, municipal buildings, and military mess halls, most of which have commercial dishwashers. According to State of California data, the state is also home to 9,972 public schools, 3,782 private schools, over 200 universities and colleges, and several hundred jails and prisons. Military facilities include 21 Army, Navy, Marine, and Air Force installations, along with several dozen Coast Guard facilities. Many of the food service operations in these facilities are operated by the "managed services companies," but a large percent are self-operated. Add bars to this number, and the number of California's food service facilities easily exceeds 100,000, a large percentage of which contain commercial dishwashers[3].

[3] Koeller and Company, 2010. *A Report on Potential Best Management Practices—Commercial Dishwashers,* for the California Urban Water Conservation Council. June.

Kitchens in commercial and institutional facilities utilize a variety of practices, technologies, and equipment to prepare food, manage food waste, and maintain sanitary and safe conditions. The amount of water used in these activities depends largely upon the type of technology applied and the volume of food produced, although personnel practices play a large role as well.

Water use characteristics and best management practices of warewashing and food preparation within the context of overall food service operations are covered in the following sections:

1. Scullery operations
2. Pre-rinse spray valves
3. Dishwashers (warewashers)
4. Ice machines
5. Combination ovens
6. Dipper wells
7. Steam cookers
8. Steam kettles
9. Wok stoves
10. Washing and sanitation

Technical Feasibility

All of the practices, products and technologies described within this report section have been in existence for an extended period of time and found to be technically feasible. In each case, however, economic feasibility must be evaluated within the context of the physical condition and demands of the specific property or building being considered for food service operations.

Scullery Operations

Within the food service sector, it is important to understand how the warewashing (scullery) process begins and how it may impact total water use for a food service establishment. First, some smaller food service establishments and many fast food restaurants that serve on disposable ware do not utilize an automatic dishwasher. Instead, they depend upon the "three-compartment sink" to wash pots, pans and other cooking utensils. However, almost all other restaurants and food service establishments of any size do use commercial dishwashers.

Water use in the scullery operations can include:

1. Garbage disposal with grinders, pulpers and similar equipment[4];
2. Waste transport in sluice troughs;
3. Pre-rinsing of dishes prior to washing;
4. Soaking of pots and pans in special equipment;
5. Washing pots and pans either by hand or in a dishwasher;

[4] It should be noted that garbage grinders (disposers) are prohibited in some jurisdictions.

6. Cleaning and sanitation of the scullery work area.

One water-using area found in almost every restaurant is the three-compartment sink. Many use these sinks for washing pots and pans or "pre-cleaning" them prior to placing them in a dishwasher.

The first scullery step in most restaurants and food service establishments is to scrape the dish, pot, pan, or tray into a garbage can. However, some facilities only remove the silverware and paper and cloth items and then use sluice troughs, which feed into a garbage disposer. Flow rates in these troughs can range from 2.0 gallons per minute (gpm) to over 15 gpm depending on how many nozzles flow into the trough to wash the food waste towards the disposal.

Garbage grinders (disposers) are also found in many restaurants. The purpose of a grinder is to break the food waste into small particles that are then mixed with water. This mixture is discharged to the sanitary sewer. The use of grinders increases the loading on wastewater treatment plants and, as such, wastewater utilities vary on their support of the use of these scullery appliances. Also, solids will build up more rapidly in a grease trap if the waste passes through the grease trap. Because of this build up, some cities have either banned disposers or placed excessive sewer charges on the operations using grinders. Grinders, however, *do* remove food waste from the solid waste disposal stream, an advantage in some cities. On the other hand, some jurisdictions are concerned with food waste being placed in dumpsters that may draw rodents and flies and add to solid waste disposal volume. They, therefore, encourage grinders. Others encourage composting of food scraps.

Food waste pulpers are used by some entities to collect the food scraps and extract water from the disposal process. They are located where a grinder would otherwise be located. They can also recover the extracted water so that it can be reused to pre-rinse dishes and act as a sluice trough where food wastes are dumped. When a recirculation system is used, pulpers recirculate from 5.0 to 15 gallons per minute (gpm) of water through the system; fresh makeup water rates are typically below 2.0 gpm.

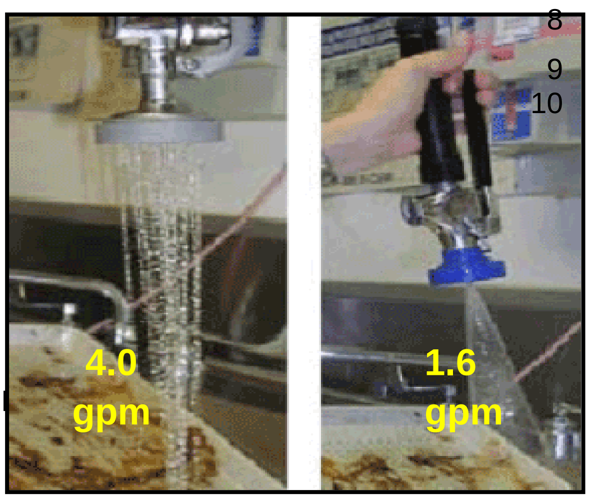
Another system called a Salvajor works similarly to a pulper and can recirculate water for sluicing of food scraps, but it uses a strainer basket system to collect food waste for disposal as a solid waste.

An alternative to the mechanical systems discussed above is the simple scrap basket or strainer basket system. Strainer baskets can either be an under-the-sink type as the one pictured here or simply a basket with holes or slots in it placed in a sink. Food scraps are emptied into a garbage can for solid waste disposal or composting.

The choice of waste disposal methods also impacts energy and water use in the scullery operations. Table 7.2 summarizes the water, energy, and solid waste considerations for each disposal method.

Table 7.1.2. Summary of Four Waste Disposal Methods

Parameter	Grinder	Salvajor	Pulper	Strainer Basket
Solids to Sewer	Yes	No	No	No
Recirculate	No	Yes	Yes	No
Strain Solids	No	Yes	Yes	Yes
Compost Produced?	No	Yes	Yes	Yes
Solid Waste Produced?	No	Yes	Yes	Yes
Flow Restrictor?	Yes	No	No	N/A
Horsepower	1-10	0.75-7.5	3-10	0
Potable Water Use (gpm)	3-8	1-2	1-2	0
Sluice Trough (gpm)	2-15	2-15	2-15	0



Pre-rinse spray valves (PRSVs) are used to rinse dishes prior to their being placed in the dishwasher. Since 2005, the Federal energy policy act (EPAct) has required that spray valves use no more than 1.6 gpm. New models have even lower flow rates[5]. The photos on the left show an old type spray valve using four gallons per minute while the picture on the right shows one using only 1.6 gallons per minute. Refer to Section 5.3.4.3 for more information on PRSVs.

[5] Anecdotal information from the field indicates that, in some cases, PRSV flow rates below 1.3 gpm may result in longer cleaning times and user dissatisfaction. The U.S. EPA's WaterSense program will be releasing a draft specification for PRSVs that will likely set the maximum flow rate near 1.3 gpm. Before purchase of a PRSV designed to operate at less than 1.3 gpm, the food service operator should field trial the unit to ensure that it will operate satisfactorily, particularly if the facility experiences low water pressure.

Another water-using device found in some larger facilities is a powered pot-soaking tank. Pots and pans are placed in the tank containing hot water with a special detergent. Pumps circulate the water around the tank softening cooked-on food deposits. These tanks are normally filled at the beginning of the day and dumped down the drain at the end of the day. In especially busy restaurants, the tank may need dumping and filling more often.

As the above equipment examples show, washing and sanitizing dishware in commercial food service involves much more than just a dishwasher. The amount of water used to clean and sanitize involves the total water use of all of this equipment.

Operation, Maintenance, and User Education

For optimum garbage grinder efficiency, consider the following:

- Turn off the water during idle periods when the unit is not in use and when the facility is closed.
- Scrape larger food scraps into a trash receptacle prior to rinsing food waste into the disposal unit. Consider composting food waste if appropriate.
- <u>Never</u> pour grease into the garbage grinder unit, as this will lead to clogged drainlines.
- Do not place any hard objects into the unit. This can dull the blades, reducing the unit's efficiency.
- Always run cold water through the garbage grinder unit during its use. Hot water may damage the unit. Cold water helps to keep the unit cool.
- Regularly inspect and clean the unit to make sure the blades are sharp and the unit is not clogged with debris.

Retrofit Options

To reduce the water use associated with a traditional garbage grinder, consider installing a device that can sense the grinder motor's load and regulate the amount of water necessary to complete the disposal task. These devices can reduce the idle flow rate when the garbage disposal is not in use, from between 2.0 to 15 gpm to as low as 1.0 gpm, saving a significant amount of water. Also, consider installing a timer to stop the flow of water to the grinder after 15 minutes, requiring the user to periodically reactivate the system.[6]

Replacement Options

When purchasing a new garbage grinder unit or looking to replace an existing unit, consider these options:

- Purchase a garbage grinder with a load sensor that regulates the amount of water conveyed through the unit based upon its use.
- Install a food pulper or food pulper/strainer combination system, which can recycle 75 percent of the water used for the food disposal process.
- Replace mechanical food disposal systems with food strainers, which use little to no water.

Savings Potential

A conventional garbage grinder connected to a sluice trough can use more than 650,000 gallons per year and cost a facility more than $4,500[7] in water and sewer bills. This water use can be significantly reduced either through a retrofit with a load sensor to regulate and reduce the amount of water used by the existing garbage grinder during idle mode *or* by replacing the unit with a food pulper or food strainer. To estimate facility-specific water savings and payback from retrofits and replacements, use the following information:

<u>Conventional Garbage Grinder Retrofit</u>

Conventional garbage disposals can use a constant flow of 2 to 15 gpm when in use. Water use can be significantly reduced by retrofitting an existing conventional garbage grinder with a load sensor. Load sensors can reduce the flow rate through the garbage disposal to as little as 1.0 gpm when the garbage disposal is not in use. The estimated water savings from the reduction in flow rate during idle use can be calculated as follows:

Current Water Use

To estimate the current water use of an existing garbage disposal during idle periods, identify the following information and use Equation 1 below:

- Flow rate of water through the garbage disposal. This flow rate typically ranges from 2 to 15 gpm.

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[6] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD 9-11.

[7] Assumes a water and sewer rate of $7.16 per 1,000 gallons; from Raftelis Financial Consulting. 2008. *Water and Wastewater Rate Survey*. American Water Works Association.

- Average daily idle period of the garbage grinder. Idle period is the time when the unit is turned on but not in use. While this time will vary by facility, some estimates indicate that garbage grinders are typically in a fully operating mode about 3 hours per day. For a commercial food service facility operating 12 hours a day, this would mean an idle period of 9 hours if the garbage disposal is kept on throughout the day.[8]
- Days of facility operation per year.

Equation 1:

Water Use of a Garbage Disposal During Idle Use (gallons/year) = Flow Rate (gallons/minute) X Daily Idle Period (minutes/day) X Days of Facility Operation (days/year)

Water Use After Retrofit

To estimate the water use from an existing garbage grinder that is retrofitted with a load sensor during idle period, use Equation 1, substituting the reduced idle flow rate. A load sensor can reduce the idle flow rate when the unit is not in use to as little as 1.0 gpm.

Water Savings

The expected water savings is determined by subtracting the water use after retrofit from the current water use.

Payback

To calculate the simple payback for retrofitting an existing conventional garbage grinder, identify the following information and use Equation 2 below:

- Equipment and installation cost of the retrofit load sensor.
- Water savings as calculated in Equation 1.
- Facility-specific cost of water and wastewater.

Equation 2:

Payback (years) = Equipment and Installation Cost ($) / Water Savings (gallons/year) X Cost of Water and Wastewater ($/gallon))

Conventional Garbage Grinder Replacement – Food Pulper

[8] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD 9-11. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

Conventional garbage grinders can be replaced with a food pulper. A food pulper can recycle and reuse up to 75 percent of the water used for the food disposal process, thus reducing the potable water required to operate the garbage disposal unit.

Current Water Use

To estimate the current water use of an existing garbage disposal, identify the following information and use Equation 3 below:

- Flow rate of water through the garbage disposal. This flow rate typically ranges from 2 to 15 gpm.
- Average daily use time of the garbage disposal. While this time of use will vary by facility, some estimates indicate that garbage disposals are typically in full operation a total of 3 hours per day.
- Days of facility operation per year.

Equation 3:

Water Use of a Garbage Disposal In Use (gallons/year) = Flow Rate (gallons/minute) X Daily Use Time (minutes/day) X Days of Facility Operation (days/year)

Water Use After Replacement

To estimate the water use of a replacement food pulper, use Equation 3, substituting the flow rate of fresh water through the food pulper. Fresh water flow rate through a food pulper is typically 2 gpm.[9]

Water Savings

The expected water savings is determined by subtracting the water use after replacement from the current water use.

Payback

To calculate the simple payback from replacing a conventional garbage grinder, identify the following information and use Equation 4 below:

- Equipment and installation cost of the replacement food pulper.
- Water savings as calculated using Equation 3.
- Facility-specific cost of water and wastewater.

[9] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD 9-11. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

Equation 4:

Payback (years) = Equipment and Installation Cost ($) / (Water Savings (gallons/year) X Cost of Water and Wastewater ($/gallon))

<u>Conventional Garbage Grinder Replacement – Food Strainer</u>

Conventional garbage disposals can be replaced with a food strainer. Since a food strainer does not use water, installing a food strainer to replace an existing garbage disposal can completely eliminate water use.

Current Water Use

To estimate the current water use of an existing garbage grinder, use Equation 3.

Water Use After Replacement

A food strainer can completely eliminate the use of water for the food disposal process.

Water Savings

In the event of complete replacement, water savings would be equal to the current water use.

Payback

To calculate the simple payback from replacing an existing conventional garbage disposal with a food strainer, use Equation 4.

Additional Resources

East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD 9-11. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

Koeller and Company, 2010. *A Report on Potential Best Management Practices—Commercial Dishwashers*, by Bill Hoffman, P.E., for the California Urban Water Conservation Council. June.

Raftelis Financial Consulting. 2008. Water and Wastewater Rate Survey. American Water Works Association.

Sydney Water, 2001. *Save Water, Money, and the Environment – Kitchens.*

http://www.sydneywater.com.au/Publications/FactSheets/SavingWaterKitchens.pdf

Sydney Water, 2006. The Conserver: *Water Cuts are on the Menu at McDonalds.* http://www.sydneywater.com.au/Publications/CaseStudies/HiltonConserver13.pdf

Sydney Water, 2007. The Conserver: *No Water Wasted at the Mandarin.* http://www.sydneywater.com.au/Publications/CaseStudies/MandarinShoppingCentreConserver12.pdf

Pre-Rinse Spray Valves

Overview

Dishwashing operations in a typical restaurant generally can consume over two-thirds of all of the water used by that establishment. In some cases, nearly 50 percent of the water used in dishwashing is consumed by a pre-rinse spray valve (PRSV)[10], which is used to remove food residue from dishware, utensils, and pots and pans prior to placing them in the dishwasher for sanitation. Commercial PRSVs consist of spray nozzles that use water under pressure and are different from typical spray valves that are used for filling pots, or kettles, or for washing down countertops, floors, and other kitchen areas, all of which operate with higher flow rates[11]. Pot and kettle fillers, spray valves used on produce in grocery stores, and spray valves used in pet grooming facilities are not covered under this BMP.

PRSVs designed for commercial dishwashing are connected to a hose, which, in turn, is connected to the pressurized building water supply. These handheld devices consist of a spray nozzle, a squeeze lever that controls the water flow, and a dish guard bumper. They often include a spray handle clip, allowing the user to lock the lever at full spray for continual use, which can reduce hand irritation from repeated use. They can be installed at the end of a flexible stainless steel hose and may include a foot-operated, on-off lever. PRSVs are usually located at the input side of a dishwasher or over a sink and are used in conjunction with a faucet fixture fitting.


[10] The Food Service Technology Center (Delagah, 2011) reports that recent field monitoring studies have shown a significantly higher percentage of water use at the dishwasher (75 percent of total hot water usage) as older dishwashers operate outside of their original design specification at the same time as older PRSVs are replaced with new efficient models, thereby altering the ratio of water use between dishwasher and PRSV.

[11] Pot and kettle fillers are primarily volume-dependent, and lowering the flow rate could unnecessarily impact user satisfaction by significantly increasing wait times.

The Energy Policy Act (EPAct) of 2005 established the maximum allowable flow rate for all commercial PRSVs sold in the United States at 1.6 gallons per minute (gpm). Older models can use between 3.0 and 4.5 gpm. Since the EPAct maximum was established, more efficient products have been developed with flow rates as low as 0.65 gpm, although the performance of PRSVs at flow rates below 1.0 gpm may be significantly affected by low pressure situations (<30 psi). Similarly, in very high-pressure installations (>80 psi), severe splatter may occur, leading to user dissatisfaction. A pressure-reduction device should be installed on the feed line in those cases.

On average, PRSVs are reported to experience a physical life of about five (5) years.

Operation, Maintenance, and User Education

Because most operational uses of PRSVs involve pre-rinsing with heated water, any reduction in flow rates and water usage has the potential to reduce energy consumption as well. Therefore, both water and energy benefits result from proper installation and use of PRSVs.

For optimum PRSV operation, system pressure should be tested to ensure that it is between 30 and 80 pounds per square inch (psi). This pressure range will help to ensure that the PRSV will deliver the expected flow and performance. In addition, consider the following practices to maximize efficiency and performance:

- Ensure that the pre-rinse spray valve unit's hose height is appropriate for the user (neither too high nor too low). In the absence of an optimal installation height, users could choose to use other kitchen sprayers, which may have higher flow rates and wastewater.
- To decrease water use, train users to manually scrape as much food waste from dishes as possible before using the PRSV. (See the Scullery Operations section of this document.)
- If possible, pre-soak heavily soiled dishes in a basin of water to loosen food residue.
- Train users how to properly use the spray handle clip ('always-on' clamp), if available on the PRSV. Improper use of the clip could lead to unnecessary water waste. If a constant stream of water is not necessary, train users to manually depress the PRSV handle only when water is needed.
- Periodically inspect PRSVs for scale buildup on the faceplate orifices to ensure flow is not being restricted. Use cleaning products designed to dissolve scale. Do not attempt to bore or otherwise enlarge holes in the PRSV faceplate, as this may lead to increased water and energy use or cause cleaning performance problems. If scale cannot be removed, consider replacing the PRSV with a new model[12].

[12] Unless the unit is of substandard manufacture, is improperly installed, is abused, or is installed in a facility with very poor water quality, there is no reason to believe that a typical pre-rinse spray valve would last less then the expected five years.

- Periodically inspect PRSVs for leaks and broken or loose parts. If necessary and possible, tighten screws and fittings to stop leakage. If the product cannot be manually adjusted to perform properly, consider replacing the entire unit.
- Conduct routine inspections for leaks and train appropriate custodial and cleaning personnel and users to identify and report leaks.

Retrofit Options

Because PRSVs are relatively inexpensive, consider replacement rather than a retrofit or extensive repair. In general, avoid retrofitting existing, inefficient PRSVs with flow control inserts (which restrict water flow) to reduce the flow rate. These devices will generally fail to provide adequate rinse performance in some facilities, thereby increasing use time and total water used.

Replacement Options

When installing new PRSVs or replacing older, inefficient units, choose models with flow rates of 1.3 gpm or less. However, give consideration to building water pressure when selecting a PRSV. In some cases, it may be advisable to actually install and test a PRSV in your facility before making a purchase commitment.

Savings Potential

Sizable water savings can be achieved by replacing existing PRSVs. Because water use of PRSVs depends on facility operations, such as average throughput, water savings will vary by facility. To estimate facility-specific water savings and payback, use the following information:

PRSV Replacement

Current Water Use

To estimate the current water use of a pre-rinse spray valve, identify the following information and use Equation 1 below:

- Flow rate of the existing pre-rinse spray valve. Pre-rinse spray valves installed after 2005 may operate at 1.6 gpm or less, although older higher flow rate valves may still be in place. Pre-rinse spray valves installed before 2005 can have flow rates of up to 4.5 gpm. In both cases, it is prudent to determine the flow rate by collecting the valve output in a containment vessel for a defined period of time and measuring the volume of the collected water.
- Average daily use time. This will vary by facility, but PRSVs are generally operating in the ‘on’ position for no more than 90 minutes per day.[13]
- Days of facility operation per year.

[13] Pre-rinse spray valve use time data was collected from facilities that participated in EPA’s Pre-Rinse Spray Valves Field Study in 2010.

Equation 1

Water Use of a Pre-Rinse Spray Valve (gallons/year) = Flow Rate (gallons/minute) X Daily Use Time (minutes/day) X Days of Facility Operation (days/year)

Water Use After Replacement

To estimate the water use of a more efficient replacement pre-rinse spray valve, substitute the flow rate of the replacement pre-rinse spray valve into the above equation. Efficient pre-rinse spray valves use 1.3 gpm or less.

Water Savings

Determine the expected water savings by subtracting the water use after replacement from the current water use.

Payback

To calculate the simple payback from replacing an existing PRSV, identify the following information and use the equation below:

- Equipment and installation cost of the replacement pre-rinse spray valve. Pre-rinse spray valves typically cost less than $100. Installation cost is negligible.
- Water savings as calculated above.
- Facility-specific cost of water and wastewater.

Equation 2

Payback (years) = Equipment and Installation Cost ($) / (Water Savings (gallons/year) X Cost of Water and Wastewater ($/gallon))

By replacing a pre-rinse spray valve with a lower flow model, facilities may also save a significant amount of energy due to the reduction in hot water use. This energy savings will further reduce the payback time and increase replacement cost-effectiveness.

Water Savings - California Potential

As of 2009, the California State Board of Equalization had issued sales tax permits to 91,000 restaurants and similar food establishments in the state[14]. This figure does not include food service operations within a larger commercial or industrial entity (such as company cafeterias or food service operations within hospitals or schools, for example), firms whose business is to manufacture and/or prepare food for sale by others[15], and other similar operations. On the

[14] California State Board of Equalization, *Taxable Sales in California (Sales & Use Tax), 2009 Fourth Quarter*, no date.
[15] Food product processors and manufacturers, catering firms, etc.

other hand, this figure does include very small restaurants that do not use a pre-rinse spray valve.

With very limited information on the current number of installed pre-rinse spray valves in California, the above inventory information was coupled with the experience gained through the California Urban Water Conservation Council's (CUWCC) Rinse 'n' Save Program (for statewide PRSV replacement) to arrive at an estimate of approximately 120,000 installed hot water valves, with a range of between 100,000 and 130,000.

Through implementation of the CUWCC's Program and subsequent natural PRSV replacement, the estimated statewide saturation rate (as of 2007) of water efficient valves is about 70 percent.

We estimate the potential water-savings benefit of replacing the remaining 30 percent of the 120,000 hot water PRSVs in California to be as follows:

30% X 120,000 valves X 0.874 acre-feet average savings per average valve = 31,000 acre-feet total, or approximately 6,000 acre-feet per year

Additional Resources

Alliance for Water Efficiency. Commercial Food Service Introduction. www.allianceforwaterefficiency.org/Commercial_Food_Service_Introduction.aspxCalifornia State Board of Equalization, *Taxable Sales in California (Sales & Use Tax), 2009 Fourth Quarter*, no date.

Federal Energy Management Program. Buying Low-Flow Pre-Rinse Spray Valves. **www1.eere.energy.gov/femp/technologies/eep_low-flow_valves.html**

Food Service Technology Center. Pre-Rinse Spray Valves. www.fishnick.com/equipment/sprayvalves/

Koeller and Company, 2004. *Evaluation of Potential Best Management Practices—Pre-Rinse Spray Valves for the Food Service Industry,* for the California Urban Water Conservation Council. August.

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Sydney Water, 2006. The Conserver: *Water Cuts are on the Menu at McDonalds.* http://www.sydneywater.com.au/Publications/CaseStudies/HiltonConserver13.pdf

Sydney Water, 2007. The Conserver: *No Water Wasted at the Mandarin.* http://www.sydneywater.com.au/Publications/CaseStudies/MandarinShoppingCentreConserver12.pdf

Commercial Dishwashers (Warewashers)

Overview

Dishwashing is one of the largest water users in commercial food service operations. These installed systems (dishwashers and pre-rinse spray valves) clean and sanitize plates, glasses, bowls, utensils, and other food service ware.[16]

NSF International, a certifying body that provides a directory of commercial dishwashers, currently lists approximately 900 individual machine models in today's marketplace. Dishwashers (warewashers) are found in diverse settings ranging from conventional restaurants to health care and other institutional food service facilities, as well as to catering and similar food preparation operations. Equipment has been designed for specific purposes such as general dish, pot and pan, and glass washing.

Dishwashers in many commercial food service operations are owned by a leasing company and provided to the food service operator. Whereas ownership of the machine is held by the lessor, the water and energy costs associated with operating the equipment are borne by the operator. As such, the lessor's incentive for purchasing and installing the most water- and energy-efficient equipment does not always exist. In the case of single-rack door machines, for example, it is estimated that 75 percent of these machines are leased, usually for a five-year period[17]. Similarly, the larger dishwashers in the largest establishments are leased equipment as well and the same diminished incentives for efficiency exist there as well.

Types of Dishwashing Equipment

Commercial dishwasher design can vary greatly by application, depending on the how many employees, visitors, and/or customers are served by the commercial kitchen (i.e., the amount of facility throughput). Commercial dishwasher technologies are typically differentiated in three ways: sanitizing method, basic design, and water reuse potential.

The equipment described here includes both standard dishwashing machines and those designed for washing trays, glassware only, and pots and pans. To understand the technologies available, three equipment variants are described.

Fill-and-dump machines: dump water after each wash (as opposed to the type that house holding tanks and supply make-up water through the rinse cycle). For those with holding tanks, the number of tanks can vary from one to three. These holding tanks allow dishwashers to recycle water from one load to the next and reduce energy use by reducing the need for water heating.

The second variant relates to how dishes are sanitized.

[16] Alliance for Water Efficiency. Commercial Dishwashing Introduction. www.allianceforwaterefficiency.org/commercial_dishwash_intro.aspx?terms=commercial+dishwasher

[17] Cardwell, 2011. Contra Costa Water District, personal communication, December 19.

The most commonly found sanitizer in small restaurants is the chemical type machine, also known as the low-temperature machine. This type typically uses a chlorine-based disinfectant to sanitize the dishes. While these chemicals can often damage plastic and flat ware, the lower temperatures are desired for items that have low heat tolerance.

The other type of sanitizer is the high temperature machine. The high-temperature machine uses water at 180^{o} F (82^{o} C) or higher for sanitation and may employ a booster heater to achieve these high water temperatures. These machines do not require the addition of chlorine-containing chemicals and do not damage flatware or plastic dishes.

The third variant has to do with the basic design of the washer. Four fairly distinct types of equipment exist:

- Under-counter types are commonly found in bars where only glassware is washed or in small restaurants serving fewer than 60 persons per day. They generally use heat to sanitize and are the closest to residential dishwashers in design and cost.

- Door- or hood-types are primarily found in restaurants that serve fewer than 150 customers a day. Racks holding dishes[18] are either hand loaded into the machine or loaded with an automatic system. The cost for these types of machines generally ranges between $10,000 and $20,000, plus installation[19].

[18] Generally of 20-in. by 20-in. size, roughly the size of those commonly found in most residential dishwashers.
[19] Delegah, Amin, 2011. Food Service Technology Center. Personal communication, December 2.

 

The C-Line or conveyor-type machine pulls the rack of dishes through the washer and pushes the clean rack out the other side. Larger restaurants serving between 150 and 300 people a day commonly use this type. Machine cost is approximately $60,000, plus installation[20].

- Flight-type machine is designed for service to many hundreds or even thousands of people per day. They are typically found in large institutional facilities, hospitals, and large hotels with banquet facilities. These machines have a continuously moving belt with pegs or fingers onto which the dishes are placed. Machine cost is generally $90,000 or more, depending upon design and size[21]. Installation is extra.

The most efficient commercial dishwashers reuse water from one wash load to the next, using one or more holding tanks. This design not only reduces water use, but also reduces the amount of energy required to heat additional water. Alternatively, fill-and-dump commercial dishwashers discard water after each load, making this type of commercial dishwasher inherently less efficient.

There are no federal standards limiting the water or energy consumption of commercial dishwashers. However, the Energy Star program qualifies dishwashers for its voluntary labeling program[22], including under-counter, door, and conveyor (multi- and single-stage tank) type machines. Flight type machines are not currently rated. Energy Star-qualified commercial

[20] Ibid.
[21] Ibid.
[22] www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers

dishwashers can reduce both energy and water use by up to 25 percent, according to the U.S. EPA.

Water Use Characteristics

The primary use of water by commercial dishwashers is for washing, rinsing, and sanitizing dishes. The amount of water used for this process varies with the type, model and method of sanitation. In some cases, however, potable water can *also* be used for drain water tempering where code requirements set a maximum temperature of 140 °F (60°C) for drain water.

Drain Water Tempering

Drain water tempering kits work by opening a potable water valve whenever the water being discharged from a dishwashing machine exceeds the code maximum. For example the Uniform Plumbing Code, 2009, paragraph 810.1 reads as follows[23]:

> *"No steam pipe shall be directly connected to any part of a plumbing or drainage system, nor shall any water having a temperature above 140°F (60°C) be discharged under pressure directly into any part of a drainage system."*

The following information is from the Hobart web page describing their information on water tempering[24].

> ***Requirement:*** *If water at or above 140 degrees Fahrenheit will be drained in cooking equipment with steamers and warewashers, a drain-water-tempering kit must be installed in the equipment to ensure the water does not soften the plastic piping.*
> ***Avoid the violation:*** *Prior to ordering cooking equipment, find out if draining water temperatures will be at or will exceed 140 degrees Fahrenheit. It is easier and more cost efficient to install the drain-water-tempering kit during the installation process rather than to add the kit after the equipment has been installed. If the water temperature is unknown, it is recommended that a measurement be taken. Though the final rinse water temperature on a conveyor dishwasher is 180 degrees Fahrenheit, it cools rapidly when sprayed through the final rinse nozzle and therefore might not exceed 140 degrees Fahrenheit by the time it enters the drain.*

Drain water tempering devices should not be installed unless absolutely necessary, since they usually lead to excessive water waste. Check with code officials and the dishwasher manufacturer before installing such devices.

Reaching Limits

The U.S. EPA Energy Star® criterion represents the lower end of water use and, in fact, may have already approached what is technologically feasible for the commercial dishwasher. For example, consider the multi-tank conveyor maximum water use threshold level of 0.54 gallons per rack. A rack holds 14 plates, which comes to about a half cup of water per plate to thoroughly wash, rinse and heat the plate to the sanitation temperature.

Water Use Information

[23] International Association of Plumbing & Mechanical Officials, 2009. 2009 Uniform Plumbing Code, an American National Standard, IAPMO/ANSI UPC 1 -2009
[24] http://www.hobartcorp.com/consultants/SegmentTrends/K12Schools/FoodEquipmentCodes

Under-counter, door- and conveyor-type machines

The amount of water used to wash a rack of dishes for under-counter, door, and conveyor machines varies with the model of machine and the type of sanitizing process used. Similar factors impact flight-type dishwashers, but since racks are not used in these machines, the parameter for comparison is gallons per dish washed. NSF International publishes dishwasher data for all available models[25].

NSF information was used to establish the U.S. EPA Energy Star® criteria. The NSF database is updated regularly as manufacturers develop new product. That information can be used to calculate water use per rack for all except flight machines. Table 7.1.4.1 displays the U.S. EPA Energy Star® commercial dishwasher criteria for those dishwasher types that it currently specifies.

Table 7.1.4.1. Energy Star® Efficiency Requirements for Commercial Dishwashers

	High Temperature Machine Requirements		Low Temperature Machine Requirements	
Dishwasher Type	Idle Energy Rate*	Water Use**	Idle Energy Rate*	Water Use**
Under-Counter	<= 0.9kW	= 1.00 gal/rack	<= 0.50kW	= 1.70 gal/rack
Stationary Single Tank**	<= 1.0 kW	<=0.90 gal/rack	<= 0.6 kW	<=1.18 gal/rack
Single Tank Conveyor	<= 2.0 kW	<= 0.70 gal/rack	<= 1.6 kW	<= 0.79 gal/rack
Multi Tank Conveyor	<= 2.6 kW	<= 0.54 gal/rack	<= 2.0 kW	<= 0.54 gal/rack

*Idle energy rate measured with door closed and representative of the energy used by the tank heater only.

** Includes pot, pan, and utensil machines.

Energy Star® qualified dishwashers are reported to use at least 41 percent less energy than the Federal minimum standard for energy consumption and much less water than conventional models. Other data has been developed for this study for conveyor and flight type dishwashers using the NSF International December 2009 data.

Flight-type dishwashers

Energy Star® criteria have not yet been developed for flight-type machines, although it is reported that plans exist to do so. Tables 4 and 5 summarize water use characteristics for both

[25] That data can be found at: http://www.nsf.org/Certified/food/Listings.asp?Standard=003

single-tank and multi-tank flight-type commercial dishwashers. Three parameters to rank efficiency were developed based on NSF International data. These were the:

- gallons used per square foot of the flight conveyor belt surface moving through the machine,
- gallons used per dish using the NSF International equations to estimate and
- gallons used per rack equivalent based on the standard 20-inch by 20-inch rack.

Gallons-per-dish is the most common parameter used by the industry to compare flight-type machines; as such, all data was sorted on that parameter. Tables 7.1.4.2 and 7.1.4.3 show the lowest quartile level, which roughly corresponds to where Energy Star® initially sets most of their qualification thresholds. It is important to note that very efficient flight-type models do exist.

Table 7.1.4.2.   Single Tank Hot Water Flight-Type Water Use Characteristics for 17 models

	Gal. / sq ft	Gal. / Dish	Gal. / Rack Equivalent
Maximum	0.61	0.031	1.70
Average	0.30	0.0185	0.83
Median	0.14	0.013	0.40
Lowest Quartile	0.11	0.009	0.30
Lowest	0.07	0.007	0.21

Table 7.1.4.3. Multi-Tank Hot Water Flight-Type Water Use Characteristics for 83 models

	Gal. / sq ft	Gal. / Dish	Gal. / Rack Equivalent
Maximum	0.45	0.041	1.26
Average	0.21	0.020	0.58
Median	0.19	0.017	0.52
Lowest Quartile	0.07	0.010	0.20

Lowest	0.05	0.005	0.13

Summary of water use – all machine types

Table 7.1.3.4 summarizes water use information from the various sources. To determine what would constitute very wasteful equipment, the 75th percentile figure for water use was chosen as the efficiency threshold. The table identifies what represents the current state of the market and provides insight as to the efficiency of the approximately 65,900 commercial dishwashers currently in use in California.

For the purposes of this analysis, the medial data for 2006 (or 2009 if the 2006 data is not available) was used to represent the water use for the base case estimates of total water used by commercial dishwashers in California. The 2010 Energy Star median number of qualified equipment was used as the water saving case.

Table 7.1.3.4. Examples of Commercial Dishwasher Use

75th percentile - 75% of machines are lower

Median - half of machines are lower

Hot Water Type Dishwashing Machines

	Units	75th percentile 2006	75th percentile 2009	Median for 2009 Machines	Median for 2006 Machines	Energy Star® Threshold	Energy Star® 2010 Median
Under Counter	Gal/rack	1.75			1.20	1.00	0.79
Door Type	Gal/rack	1.33			1.18	0.95	0.79
Single Tank Conveyor	Gal/rack	1.12	0.95	0.70	0.94	0.70	0.51
Multi-Tank Conveyor	Gal/rack		1.10	0.77		0.54	0.39
Single Tank Flight	Gal/plate		0.031	0.015			
Multi Tank Flight	Gal/ plate		0.032	0.017			

Chemical Type Dishwashing Machines

	Units	75th percentile 2006	75th percentile 2009	Median for 2009 Machines	Median for 2006 Machines	Energy Star® Threshold	Energy Star® 2010 Median
Under Counter	Gal/rack	1.87			1.75	1.70	1.18
Door Type	Gal/rack	1.98			1.22	1.18	1.09
Single Tank Conveyor	Gal/rack	1.22	1.08	0.79	0.95	0.79	0.49

Multi Tank Conveyor	Gal/rack		0.58	0.53		0.54	0.49
Multi Tank Flight	Gal/ plate		0.012	0.12			

Note: Shaded areas indicate that data was not available.

Sources: NSF International for dishwashers for 2006 and 2009, Energy Star, and CEE Commercial Kitchens Study.

Dumping of Wash Tanks

All dishwashers hold water in a reservoir called a wash tank. These tanks are necessary to allow the recirculating pumps to operate and to store water between washes. The volume of these wash tanks can range from under two gallons for an under-counter machine to up to 65 gallons for large flight-type systems. According to manufacturer specifications, door-type machines are supposed to be dumped every two hours of operation while others are dumped to drain after each meal. When the dishwasher is started again at the beginning of the next workday, the tanks must be refilled and reheated. If the average volume of these tanks is 15 to 20 gallons, they are dumped from one to six times per day, and there are an estimated 65,900 machines in California, this amounts to estimated water waste in the range of 2,000 to 5,000 acre feet per year.

Operation, Maintenance, and User Education

For optimum commercial dishwasher efficiency, follow these operating tips:

- Only run dishwashers when they are full. Each dishwasher rack should be filled to maximum capacity.
- Educate staff to scrape dishes prior to loading the dishwasher (see Scullery).
- Replace any damaged dishwasher racks.
- Ensure that the final rinse pressure and water temperature are within the manufacturer's recommendations.
- Operate the dishwasher close to or at the minimum flow rate recommended by the manufacturer. Set the rinse cycle time to the manufacturer's minimum recommended setting and periodically verify that the machine continues to operate with that rinse cycle time.
- Turn off machines at night when not in use.
- Install steam doors to reduce evaporation.
- Ensure that manual fill valves close completely after the wash tank is filled.
- Fix and repair any leaks. Inspect valves and rinse nozzles for proper operation and repair worn nozzles.

For conveyor-type machines, further steps can be taken to ensure optimum efficiency:

- Install and/or maintain wash curtains. Wash curtains are able to retain heat within the machine.
- Ensure the rinse bypass drain is properly adjusted so that the wash tank is adequately replenished during operation.
- Operate conveyor-type machines in auto-mode to save energy by running the conveyor motor only when needed.

Retrofit Options

Retrofit options are available for conveyor-type dishwasher units. When retrofitting an existing conveyor-type dishwasher, consider installing rack sensors that allow water flow only when racks or dishes are present, saving water by initiating the cleaning cycle less frequently.

Replacement Options

When purchasing or leasing a new commercial dishwasher or replacing an existing commercial dishwasher, look for Energy Star qualified models[26], which save water, energy, and reduce overall operating costs. For flight-type dishwashers, which are not subject to Energy Star product criteria, choose equipment with a flow rate of less than 170 gallons per hour.[27] Avoid fill-and-dump machines, which use the most water.

It is important to consider the typical kitchen throughput and select an appropriately sized commercial dishwasher. A commercial dishwasher that is larger than necessary may waste water if the machine is not loaded to capacity.

Savings Potential

Energy Star qualified commercial dishwashers use 25 percent less water than conventional models, on average. Use Energy Star's Life Cycle Cost Estimate tool[28] to estimate facility-specific water, energy, and cost savings achieved when replacing an existing commercial dishwasher with a model with the Energy Star label.

Depending upon the type of machine, a wide range of water and energy savings may be achieved. For example, potential savings achieved by replacing a conventional multi-tank, conveyor-type, high-temperature dishwasher with an Energy Star qualified model are shown in Table 7x.

Table 7x. Example of Potential Savings from Energy Star Qualified Dishwashers

	Conventional Unit Use	Energy Star Qualified Unit Use	Savings
Electricity (kWh/year)	238,000	117,000	121,060
Water (gallons/year)	38,000	26,000	12,000

Potential Future Water Savings for California

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[26] www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers

[27] Koeller and Company, 2010. *A Report on Potential Best Management Practices—Commercial Dishwashers*, by Bill Hoffman, P.E., for the California Urban Water Conservation Council. June.

[28] U.S. Environmental Protection Agency, Energy Star Program. Energy Star Life Cycle Cost Estimate for Qualified Commercial Dishwasher(s). www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorCommercialDishwasher.xls

Table 7x shows the median values for all machines currently in the marketplace, the median value for those that are listed by Energy Star®, and the potential savings.

Table 7x. Estimated Water Savings per Rack or Plate (gallons)				
Hot Water Type Dishwashing Machines				
Type	Market Median	Energy Star® Median	Savings	Measurement
Under- Counter	1.20	0.79	0.410	Gallons per rack
Door	1.18	0.79	0.390	Gallons per rack
Single Tank Conveyor	0.94	0.51	0.430	Gallons per rack
Multi-Tank Conveyor	0.77	0.39	0.380	Gallons per rack
Single Tank Flight	0.015	.010	0.005	Gallons per plate
Multi-Tank Flight	0.017	.009	0.008	Gallons per plate
Chemical Type Dishwashing Machines				
Type	Market Median	Energy Star® Median	Savings	Measurement
Under- Counter	1.75	1.18	0.570	Gallons per rack
Door	1.22	1.09	0.130	Gallons per rack
Single Tank Conveyor	0.95	0.49	0.460	Gallons per rack
Multi-Tank Conveyor	0.53	0.49	0.040	Gallons per rack
Multi Tank Flight	0.012	0.009 equivalent	0.003	Gallons per plate

Estimating the average number of racks or plates washed per hour or per day is a guess at best. An analysis was performed with assumed volumes of washer throughput. The Restaurant Report website[29] provides the maximum racks per hour for various types of dishwashing equipment. It further assumed that the actual number of racks washed is only 50 percent of the maximum and that the machines are in operation for 5.0 hours per day. Table 7x summarizes the results of this analysis.

[29] www.restaurantreport.com/departments/restaurant-dishwasher-buying-guide.html

Table 7x. Estimated Dishwasher Use*				
Meals/hour	Dishwasher type	Max racks per hour	Assumed Actual racks per hour	Racks per day based on 5.5 hours of operation
Up to 100	Under-counter	35	17.5	88
100-500	Door	125	62.5	313
500-2000	Conveyor	425	225	1,125
2000+	Flight**	11,450 plates per hour	5,000*** Plates per hour	25,000 Plates per day

* Based on http://www.restaurantreport.com/departments/restaurant-dishwasher-buying-guide.html

** Flight systems measured in plates per hour.

*** The average flight machine can process up to 11,450 plates per hour, but 5,000 is used as a more reasonable estimate of through-put for this analysis.

Using the estimated numbers of machines in California shown in Table 4, the estimated number or racks or plates washed per day, and the savings per rack or plate, the total annual savings was calculated. The estimated savings were collapsed into four dishwasher types: under-counter, door, conveyor and flight. Table 7x summarizes these savings.

Table 7x. Estimated Total Annual Potential Water Savings in California						
Dishwasher Type	Esti-mated Number in California	Saving per Operation* *(gallons)*	Operations* per day	Market Medial *(acre-feet per year)*	Energy Star® Median *(acre-feet per year)*	Annual Savings *(acre-feet per year)*
Under-counter	7,900	0.49	88	1,149	767	382
Door-Type	42,800	0.26	313	18,007	14,106	3,905
Conveyor-Type	11,900	0.328	1,125	11,959	7,048	4,895

Flight Type*	3,300	0.005	25,000	1,355	863	493
			TOTAL	32,470	22,783	**9,674**

* For flight machines one operation is one dish washed. For all others, it is one rack washed.

The table shows that current machines use a little over 32,000 acre-feet of water per year for washing dishes. Another 4,000 acre-feet are used when the machines are dumped to exchange water. Therefore, total use is in the order of 36,000 acre-feet per year.

The results show that by operating *only* with the median Energy Star qualified machines, California can save about 10,000 acre-feet of water annually.

Additional Resources

Alliance for Water Efficiency. Commercial Dishwashing Introduction. www.allianceforwaterefficiency.org/commercial_dishwash_intro.aspx?terms=commercial+dishwashers+introduction

Consortium for Energy Efficiency. June 26, 2008. *High Efficiency Specifications for Commercial Dishwashers*. www.cee1.org/com/com-kit/files/DishwasherSpecification.pdf

Delagah, Amin, 2011. Food Service Technology Center, personal communication, December 1.

East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

Food Service Technology Center. Dishwashing Machines. www.fishnick.com/savewater/appliances/dishmachines/

Koeller and Company, 2010. *A Report on Potential Best Management Practices—Commercial Dishwashers,* for the California Urban Water Conservation Council. June.

Sydney Water, 2001. *Save Water, Money, and the Environment – Kitchens.*

http://www.sydneywater.com.au/Publications/FactSheets/SavingWaterKitchens.pdf

Sydney Water, 2006. The Conserver: *Water Cuts are on the Menu at McDonalds.* http://www.sydneywater.com.au/Publications/CaseStudies/HiltonConserver13.pdf

Sydney Water, 2007. The Conserver: *No Water Wasted at the Mandarin.* http://www.sydneywater.com.au/Publications/CaseStudies/MandarinShoppingCentreConserver12.pdf

U.S. Environmental Protection Agency's Energy Star Program. Commercial Dishwashers. www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COH

Commercial Ice Machines

Overview

The use of ice for drinks, preserving and cooling food, and various other commercial purposes is common today, but it was not always so. Before the development of the commercial ice machine industry, ice was produced at large central ice plants and delivered to the commercial user in the form of either blocks or crushed ice. The crushed and block ice market is still a viable industry, but commercial ice machines have replaced delivered ice in routine commercial activities. This section summarizes the operational characteristics of commercial ice machines and examines the potential for both water and energy savings from a California-based perspective. To do this, it examines five items:

1. Types of ice-making technologies and equipment
2. Ice machine market dynamics
3. Regulations and incentives
4. Energy and water use chrematistics
5. Potential future water savings

The market for ice-making machines tends to increase in proportion to population. The hospital, food service and hotel industries purchase approximately 75 percent of all ice machines nationally, but ice machines are also found in other businesses and institutions (Figure 3)

According to information from the Pacific Gas & Electric Company (PG&E) Food Service Technology Center (FSTC) (Zabrowski, 2007), about 20 percent of the installed inventory of ice machines in California are water-cooled; the balance are air-cooled. According to the Air Conditioning and Refrigeration Institute (ARI), once-through water cooling of ice machines uses from 75 to 200 gallons of cooling water for every 100 pounds of ice made.

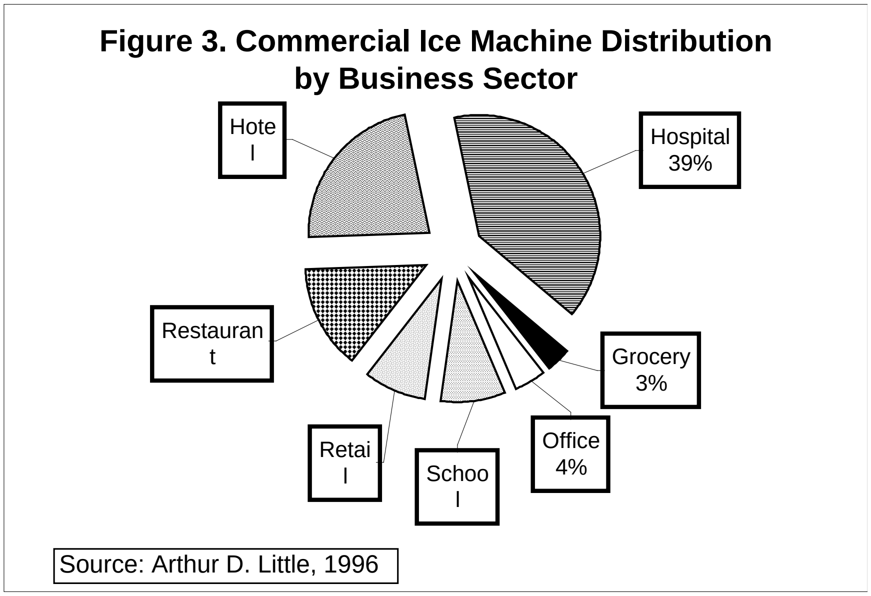

Figure 3. Commercial Ice Machine Distribution by Business Sector

In 2003, total nationwide ice machine sales were approximately 360,000 units, of which about 78 percent were cube machines; the others were flake and nugget machines or combination machines such as soda machines (Figure 4). According to a 2004 PG&E study, there are about 1.2 million ice machines in the United States, with about 174,000 are in California, or about 9 percent of the total[30]. Allowing for population growth, we estimate that California currently has an installed base of about 180,000 machines.

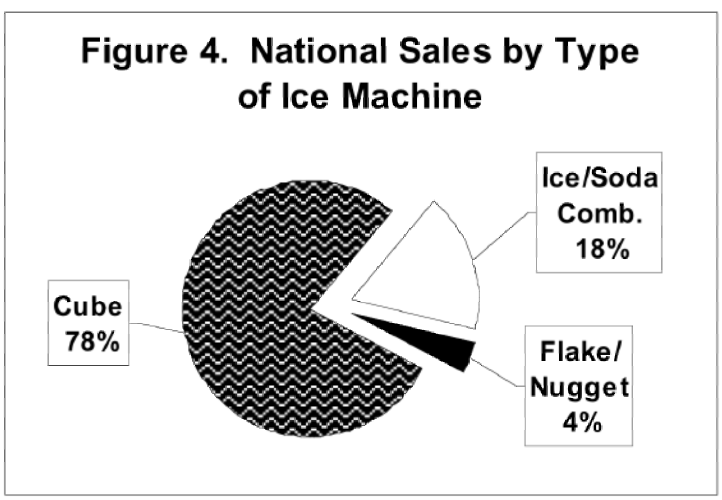

Figure 4. National Sales by Type of Ice Machine

[30] This figure was based on older studies performed in 1996 by Arthur D. Little.

In recent years there has been an increase in sales of nugget-type ice machines for soft drink use, since this ice absorbs some of the drink flavor and is chewable. However, according to information from PG&E FSTC (Zabrowski, May 2008), the percent increase is small. The importance of this trend is that nugget ice machines tend to be both more energy and water efficient.

The amount of ice consumed by various individual operations varies greatly, but ice machine manufacturers have developed estimates for each of those applications. Table 7x summarizes this information.

Table 7x. Approximate Ice Use by Activity or Product

Type of Use	Unit	Ice Use per Activity
Restaurant *(Either stand alone or at a hotel)*	Per Meal	1.5 lb. per person served
	Cocktail Bar	3 lb. per person served
	Salad Bar	40 lb. per day per cubic ft.
Cafeteria	Per Person	1 lb per person served
Hospital	Per Patient	10 lb per patient per day
Hotel	Per Guest	5 lb per guest per day
Catering	Per Person	1 lb per person served
Cold Soft Drinks & Tea	10-12 oz.	6-8 oz. per drink
	20 oz.	8-10 oz. per drink
	32 oz.	16 oz. per drink

Source: Information based on Ice-O-Matic and Cornelius Web sites.

Technologies

Commercial ice machines use refrigeration units to freeze water into ice. They have become a mainstay in all types of settings including restaurants, commercial kitchens, fast food establishments, convenience stores, grocery stores, schools, hotels/motels, hospitals, and laboratories. Ice machines typically use water for two purposes: cooling the refrigeration unit and making ice. There are mechanisms to address the efficiency of both aspects.

Because the ice-making process generates a significant amount of heat, either water or air is used to remove this waste heat from the ice machine's refrigeration unit. In the most basic configuration, water-cooled ice machines pass water through the machine once to cool it, and then dispose of the single-pass water down the drain. Water-cooled systems can use less water by recirculating the cooling water through either a heat exchanger connected to a chilled water loop or a cooling tower to lower the temperature, returning the water to the machine for reuse. To eliminate using water to cool the refrigeration unit altogether, air can be used to cool the unit instead. Air-cooled ice machines use motor-driven fans or centrifugal blowers to move air through the refrigeration unit to remove heat.[31]

There are three primary types of ice machines: *ice-making head units* (water- or air-cooled), *self-contained units* (water- or air-cooled), and *remote condensing units* (air-cooled). Ice-making head units have the ice-making mechanism and the condenser unit in a single package, and the storage bins are sold separately. Self-contained units have the ice-making mechanism, condenser unit, and a built-in storage bin in an integral cabinet. These units are typically small, under-counter units that produce a smaller volume of ice. Remote condensing units are models with the ice-making mechanism and the condenser unit in separate section. They transfer the heat generated by the ice-making process outside the building.

An ice machine's capacity is measured by the number of pounds of ice it can produce per day. Water-cooled ice machines with single-pass cooling consume between 100 and 300 gallons of water per 100 pounds of ice produced, while air-cooled ice machines consume less than 50 gallons of water per 100 pounds of ice produced.[32] While air-cooled machines are usually more water-efficient, water-cooled machines are usually more energy-efficient. Some air-cooled units, however, are able to match or exceed the energy efficiency of water-cooled units while also providing substantial water efficiency.[33]

Regardless of how the machine is cooled, all of the machines use water to produce ice. If a machine were perfectly water-efficient and wasted no water when producing ice, the machine would use approximately 12 gallons of water to produce 100 pounds of ice.[34] However, in order to create ice of acceptable quality, some water is used and sent down the drain during the process. As ice is formed in the freezing trays, minerals in the water collect on the equipment and must be rinsed occasionally. Depending on the water quality, some machines require more frequent rinse cycles than needed, thus wasting water. Reducing the frequency of rinse cycles can provide an opportunity for savings.

In addition, some ice machines are designed to produce clearer and smoother ice using a repeated freezing and partial thawing process. Ice produced using this method has fewer air bubbles and is more crystalline, but producing ice to this quality uses more water.[35]

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[31] U.S. Environmental Protection Agency's Energy Star Program. Commercial Ice Machines. <www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CIM>.

[32] Bohlig, Charles M. East Bay Municipal Utility District. February 2006. Presentation on Water Efficiency in Commercial Food Service.

[33] Alliance for Water Efficiency. Ice Machines Introduction. <www.allianceforwaterefficiency.org/Ice_Machines.aspx>.

[34] ibid

[35] ibid

Water used directly for the ice-making process ranges from 15 gallons to more than 50 gallons per 100 pounds of ice,[36] depending on the amount of water used to rinse the machine. For flake machines, this range includes the unfrozen water.

Ice machines can produce several kinds of ice:

- *Cube ice* (clear, regularly shaped ice weighing up to 1.5 ounces per piece and containing minimal amounts of liquid water);
- *Flake ice* (chips or flakes of ice containing up to 20 percent liquid water by weight);
- *Crushed ice* (small, irregular pieces made by crushing bigger pieces of ice); or
- *Nugget ice* (small portions of ice created by extruding and freezing the slushy flake ice into a nugget).[37]

Cubed ice machines are the most prominent in the market, accounting for approximately 80 percent of sales in the United States.[38] Most cubed ice machines use more water than flake ice machines because they run more water over the freezing ice to remove sediment and minerals that form as the water freezes. In general, the higher the quality of ice, the more water is needed for the ice-making process.

Crushed Ice Machine

[36] Koeller and Company, 2008. *A Report on Potential Best Management Practices – Commercial Ice Machines*. Prepared for the California Urban Water Conservation Council. Page 6. June.
[37] Pacific Gas and Electric Company. *Information Brief, Commercial Ice Machines*. <www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/hospitality/icemachinetech.pdf>.
[38] ibid

Cubed Ice Machine

The Department of Energy sets standards for ice machines[39]. In order to recognize energy- and water-efficient ice machines, the U.S. Environmental Protection Agency's (EPA's) Energy Star® program issued a specification[40] for commercial air-cooled cube ice machines that meet more stringent energy use and potable water use limits. On average, commercial ice machines that have earned the Energy Star label are 15 percent more energy efficient and 10 percent more water efficient than standard air-cooled models. Currently, only cube ice machines qualify to earn that label, although Energy Star plans to include flake machines in future specifications.

Operation, Maintenance, and User Education

Consider the following tips to ensure energy- and water-efficient ice machine use:

- Periodically clean the ice machine to remove lime and scale; sanitize it to kill bacteria and fungi. For self-cleaning/sanitizing machines, run the self-cleaning option. For machines without a self-cleaning mode, shut down the machine, empty the bin of ice, add cleaning/sanitizing solution to the machine, switch it to cleaning mode, then switch it

[39] See http://www1.eere.energy.gov/buildings/appliance_standards/commercial/automatic_ice_making_equipment.html

[40] http://www.energystar.gov/index.cfm?c=comm_ice_machines.pr_crit_comm_ice_machines

to ice production mode. Although water is wasted in the process, it is very important to create and discard several batches of ice to remove residual cleaning solution for health and safety considerations.

- Keep the ice machine's coils clean to ensure the heat exchange process is running as efficiently as possible.
- Keep the lid closed to trap cool air inside the ice machine so it does not have to work harder to maintain the appropriate temperature inside.
- Install a timer to shift ice production to nighttime or off-peak hours, cutting down on the facility's peak energy demand.
- Considering local water quality and site requirements, work with the machine's manufacturer to ensure that the machine's rinse cycle is set to the lowest possible frequency that still provides sufficient ice quality. If available, use the ice machine's ability to initiate rinse cycles based on sensor readings of minerals.
- Follow the manufacturer-provided use and care instructions for the specific model ice machine used at the facility.
- Train users to report leaking or otherwise improperly operating ice machines to the appropriate personnel.

Retrofit Options

If the machine is cooled using single-pass water, modify the machine to operate on a closed loop that recirculates the cooling water through a cooling tower or heat exchanger, if possible. If eliminating single-pass cooling is not feasible, consider reusing the cooling water for another application within the facility. See the *Alternative Water Sources BMP* for more information.

Replacement Options

When replacing the ice machine or installing a new one, ensure that the new model is sized appropriately to fit the facility's need. If the machine produces too large of a yield, water will be wasted by producing unneeded ice. Also choose an ice machine that is appropriate for the quality of ice needed. Producing ice of higher quality than required will use water unnecessarily. Consider selecting flake or nugget ice machines, which use less water and energy than cube ice machines.[41] Choose only Energy Star qualified models[42]. Also consider only air -cooled ice machines that meet the efficiency specifications outlined by the Consortium for Energy Efficiency (CEE)[43].

Savings Potential

[41] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses.* <www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook>.

[42] www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CIM

[43] www.cee1.org/com/com-kit/com-kit-equip.php3

A facility will see varying levels of water savings, depending on whether it is replacing an existing air-cooled ice machine or an existing water-cooled model. To estimate facility-specific water savings and payback, use the following information.

Air-Cooled Ice Machine Replacement

On average, Energy Star qualified air-cooled cube ice machines are 15 percent more energy-efficient and 10 percent more water-efficient than standard air-cooled models. Total savings depend on the type of machine selected. Switching to a 137-pound capacity Energy Star qualified air-cooled ice-making head unit from an equivalent conventional unit, for example, can result in water savings of 1,000 gallons per year. Energy savings of 1,600 kWh per year can also be expected, resulting in net cost savings of about $170 per year.[44]

Use Energy Star's Commercial Kitchen Equipment Savings Calculator[45] to estimate facility-specific water, energy, and cost savings for replacing an existing ice machine with an Energy Star qualified model. The Calculator estimates savings for the Energy Star suite of commercial kitchen products, but it can also be used to calculate individual savings from replacing an existing ice machine.

Water-Cooled Ice Machine Replacement

A facility will see the most water savings from replacing a water-cooled ice machine with an Energy Star qualified air-cooled model. Only cube ice machines currently qualify to earn the Energy Star label.

Current Water Use

To estimate the current water use from a water-cooled ice machine, identify the following information and use Equation 1 below:

- Ice machine's harvest rate, or how many pounds of ice it produces per day.
- The ice machine's maximum water use. This figure can be derived from EPAct 2005 requirements.
- Days of facility operation per year.

Equation 1:

Water Use of a Water-Cooled Ice Machine (gallons/year) = Harvest Rate (lbs ice/day) X Water Use (gallons/100 lbs of ice) X Days of Facility Operation (days/year)

Water Use After Replacement

[44] U.S. Environmental Protection Agency's Energy Star Program. Energy Star Life Cycle Cost Estimate for Qualified Commercial Ice Machine(s).

[45] www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/commercial_kitchen_equipment_calculator.xls

To estimate the water use of a replacement Energy Star qualified air-cooled model, use Equation 1, substituting the harvest rate (if it will change) and the new water use per hundred pounds of ice.

Water Savings

Determine the expected water savings by subtracting the water use after replacement from the current water use.

Payback

To calculate the simple payback from replacing a water-cooled ice machine, identify the following information and use Equation 2 below:

- Equipment and installation cost of the replacement Energy Star qualified air-cooled model. New ice machines may range in cost between $2,000 and $4,000.
- Water savings as calculated using Equation 1.
- Facility-specific cost of water and wastewater.

Equation 2:

Payback (years) = Equipment and Installation Cost ($) / (Water Savings (gallons/year) X Cost of Water and Wastewater ($/gallon))

California Water Savings Potential

Water savings (direct and indirect) can be derived from three sources. The first is the elimination of once-through cooling, which yields direct, significant savings. The second is moving to CEE Tier 3 water use levels for future ice-making machines, including the promotion of the more efficient flake and nugget machines, all of which yield direct savings of water. The third is the indirect water savings realized through reduced energy generation.

The following analysis is based on an estimated 180,000 ice machines currently installed in California, of which 36,000 are estimated to be water-cooled. For the purpose of this analysis, these water-cooled machines are assumed (1) to use 150 gallons of cooling water for every 100 pounds of ice made and (2) that the average daily production from all units is 600 pounds per day per unit. Two water use rates for ice making are assumed, 25 gallons per 100 pounds of ice and 20 gallons per 100 pounds of ice, with a net savings of 5 gallons per 100 pounds of ice. This assumption reflects Tier 2 (the Energy Star Standard) and Tier 3 standards, respectively, which, together, cover the majority of the market available today.

The potential statewide savings in water and energy use by the equipment itself (direct savings) and through the reduction in embedded energy use (indirect savings) are both shown in Table 7x. For assumptions related to the estimated savings, refer to CUWCC Potential Best Management Practices report on ice machines[46].

[46] Koeller and Company, 2008. *A Report on Potential Best Management Practices – Commercial Ice Machines*. Prepared for the California Urban Water Conservation Council. Page 6. June.

Table 7x. Summary of Total Potential Annual Water and Energy Savings in California

(by moving to a CEE Tier 3 mandate, which does not permit water-cooled machines)

Savings at Ice Machine (Direct Savings)				
Type	Number of installed machines	Water (acre-feet/year)	Energy (millions of kWh/year)	Notes
Water-cooled machine savings	36,000	36,300	-47	
Air-cooled machine savings	144,000		252	
All machines	180,000	6,000		
Total at machine		**42,300**	**205**	
Embedded Savings (Indirect Savings)				
Type	Number of installed machines	Water (acre-feet/year)	Energy (millions of kWh/year)	Notes
Water-cooled machine savings	36,000		82*	*Savings of embedded energy in reduced cooling water
All machines	180,000		14	
Total embedded		**230****	**96**	**Water savings resulting from reduced energy production
Net Savings – Direct & Indirect		**42,530**	**301**	Includes Embedded Savings

In summary, Table 5 shows that by eliminating once-through water cooling, about 36,000 acre-feet of water can be saved each year; the net energy savings would be about 300 million kilowatt hours per year when embedded energy is taken into account. Adding the savings realized by moving to Tier 3 or to flake and nugget machines will increase the projected statewide water savings to a total of about 42,300 acre-feet per year[47].

Additional Resources

Alliance for Water Efficiency. Commercial Food Service Introduction. <www.allianceforwaterefficiency.org/Commercial_Food_Service_Introduction.aspx>.

Alliance for Water Efficiency. Ice Machines Introduction. <www.allianceforwaterefficiency.org/Ice_Machines.aspx>.

California Urban Water Conservation Council. Resource Center, Commercial Food Services, Ice-Makers. <www.cuwcc.org/products/commercial-ice-makers.aspx>.

Consortium for Energy Efficiency. January 1, 2006. *High-Efficiency Specifications for Commercial Ice Machines*. <http://www.cee1.org/com/com-kit/com-kit-equip.php3>.

East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses.* < http://www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook>.

Federal Energy Management Program. How to Buy an Energy Efficient Commercial Ice Machine. <www1.eere.energy.gov/femp/procurement/eep_ice_makers.html>.

Food Service Technology Center. Ice Machines. <www.fishnick.com/savewater/appliances/icemachines/>.

Koeller and Company, 2008. *A Report on Potential Best Management Practices—Commercial Ice Machines,* for the California Urban Water Conservation Council. June.

Pacific Gas and Electric Company. *Information Brief, Commercial Ice Machines*. <www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/hospitality/icemachinetech.pdf>.

Sydney Water, 2001. *Save Water, Money, and the Environment – Kitchens.*

http://www.sydneywater.com.au/Publications/FactSheets/SavingWaterKitchens.pdf

Sydney Water, 2006. The Conserver: *Water Cuts are on the Menu at McDonalds.* http://www.sydneywater.com.au/Publications/CaseStudies/HiltonConserver13.pdf

Sydney Water, 2007. The Conserver: *No Water Wasted at the Mandarin.* http://www.sydneywater.com.au/Publications/CaseStudies/MandarinShoppingCentreConserver12.pdf

U.S. Environmental Protection Agency's ENERGY STAR Program. Commercial Ice Machines. <www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CIM

[47] This does not take into account the net savings in other *operating costs* (borne by the end user) by eliminating once-through cooling. Typically, over the lifetime of the machine, operating costs to the end user for air-cooled equipment are about half that of the equivalent water-cooled equipment.

Combination Ovens

Overview

Combination ovens help keep food from drying out while baking or roasting. They combine three modes of cooking into one oven: steam mode, circulated hot air (dry heat) mode, or a combination of both (combi-mode). The steam mode is used for rapid cooking of food items such as vegetables and shellfish. The circulated hot air mode operates in the same manner as a typical convection oven and is traditionally used for roasting meats or baking. The combi-mode is used to reheat, roast, bake, or oven-fry foods. Steam and combi-modes require generation of steam, an energy and water-intensive process.

Both gas and electric models are available in several configurations. One uses a boiler that produces steam, which is injected into the oven chamber. Others achieve high humidity with sprays, and some models have closed systems that recondense steam to achieve higher energy and water savings. The cooking capacity of a typical oven is significant. One six-pan model can cook as many as 32 chickens at a time[48].

The amount of water used by a combination oven primarily is dictated by whether it is boiler-based or connectionless (without a central boiler connection). Typical boiler-based combination ovens are connected to a boiler system that supplies the steam. These systems waste large amounts of water because they require a continuous stream of tempering water to cool the condensed steam before it is disposed down the drain. They may also supply steam regardless of whether the oven is in operation. In contrast, a connectionless combination oven has a self-contained water and heat source to create the steam required for the cooking process. This eliminates the use of a separate, central boiler system. Connectionless combination ovens are typically drained and refilled each day and do not require a drain of condensate or the frequent addition of cooling water.

A ten-pan boiler combination oven under heavy use can consume 30 to 40 gallons of water per hour, while boilerless misting ovens use only 10 to 15 gallons per hour, resulting in an annual savings greater than 110,000 gallons[49] Inefficient combination ovens can consume 360 to 480 gallons of water per day, while efficient models can reduce that usage to only 120 to 180 gallons per day.

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[48] Sorensen, Greg, 2006. *Rational Model SCC 62G Combination Oven Performance Test*. Food Service Technology Center. Fisher-Nickel, Inc., July.

[49] Reed, Clark, 2005. *Saving Water Counts in Energy Efficiency*. Energy Star. U.S. Environmental Protection Agency, October.

Operation, Maintenance, and User Education

For optimum combination oven efficiency, consider the following:

- Use the oven's programming capabilities to control the use of the different cooking modes in order to minimize water and energy use. Where feasible, use the steam and combi-modes sparingly because these modes consume more water and significantly increase energy use. Maximize the use of the circulated hot air mode.
- Turn the oven off or down during non-peak periods or when not in use.
- Keep the oven doors completely closed.
- Maximize the amount of food cooked per use by ensuring that the oven is loaded to its full capacity.
- Replace door gaskets when necessary and keep door hinges tight, to provide a firm seal to retain heat or steam.

Retrofit Options

If a boiler-based combi-oven is used, a condensate return system can be installed to direct the condensate back into the central boiler system for reuse. This process will improve both water and energy efficiency, as the condensate can be used as boiler makeup water. Packaged condensate return systems can be purchased from most steam equipment suppliers; plumb them directly into an existing system. Insulate condensate return lines to further improve efficiency.

There are currently no retrofit options available on the market to increase the efficiency of connectionless combination ovens.

Replacement Options

When purchasing a new combination oven or replacing an existing one, look for models that are boilerless or connectionless and that use no more than 15 gallons of water per hour[50] or 3.5 gallons per pan per hour.[51] Combination ovens come in varying sizes, depending upon the amount and types of food to be cooked. Consult the manufacturer to choose a combination oven that is appropriately sized for the cooking needs of the food service operation. A larger-than-necessary combination oven can waste water and energy to heat unused compartment space.

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[50] East Bay Municipal Utility District, 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Page 43. <www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook>.

[51] Food Service Technology Center. Combination Ovens. <www.fishnick.com/savewater/appliances/combinationovens/>.

Finally, all purchased combination ovens should be listed among the qualified products on the Fisher Nickel list for energy rebates in California[52]

Savings Potential

Boiler-based combination ovens can use as much as 30 to 40 gallons of water per hour.[53] Switching to a boilerless unit can reduce that water use to 15 gallons of water per hour or less.[54] According to the East Bay Municipal Utility District, replacing a boiler-based combination oven with a connectionless model can save nearly $3,000 in water and energy bills each year, which could provide payback for the cost of the new equipment in approximately 5 years.[55]

Current Water Use

To estimate the current water use of an existing combination oven, identify the following information and use Equation 1 below:

- Hourly water use in gallons per hour. A typical boiler-based combination oven may use as much as 30 to 40 gallons per hour.
- Average daily usage time. Varies by facility.
- Days of facility operation per year.

Equation 1:

Water Use of a Combination Oven (gallons/year) = Hourly Water Use (gallons/hour) X Daily Usage Time (hours/day) X Days of Facility Operation (days/year)

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[52] www.fishnick.com/saveenergy/rebates/combis.pdf

[53] U.S. Environmental Protection Agency, Energy Star Program. *Best Practices—How to Achieve the Most Efficient Use of Water in Commercial Food Service Facilities.* <www.energystar.gov/index.cfm?c=healthcare.fisher_nickel_feb_2005>.

[54] ibid

[55] Assumes that heat is electric. Payback may be longer for gas supplied heat. East Bay Municipal Utility District, 2008. *Turning up the Heat on Commercial Kitchen Water Savings*, March.www.energystar.gov/ia/partners/downloads/meetings/water_Richard_Harris.pdf

Water Use After Retrofit or Replacement

To estimate the water use of a system retrofit or replacement combination oven, use Equation 1, substituting the hourly water use for the retrofitted system or replacement combination oven. Boilerless combination ovens can use 15 gallons per hour or less.

Water Savings

Determine the expected water savings by subtracting the water use after retrofit or replacement from the current water use.

Payback

To calculate the simple payback from retrofitting or replacing an existing combination oven, identify the following information and use Equation 2 below:

- Equipment and installation cost of the retrofit or replacement combination oven. A combination oven may cost approximately $15,000.[56]
- Water savings as calculated using Equation 1.
- Facility-specific cost of water and wastewater.

Equation 2:
Payback (years) = Equipment and Installation Cost ($) / [(Water Savings (gallons/year) X Cost of Water and Wastewater ($/gallon)]

By switching to a boilerless combination oven, facilities may also save a significant amount of energy by reducing the water use and steam generation associated with the use of the combination oven. These energy savings will further reduce the payback time and increase replacement cost effectiveness.

Additional Resources

Alliance for Water Efficiency. Combination Ovens Introduction. www.allianceforwaterefficiency.org/1Column.aspx?id=650&terms=combination+ovens

East Bay Municipal Utility District. March 5, 2008. Turning up the Heat on Commercial Kitchen Water Savings. www.energystar.gov/ia/partners/downloads/meetings/water_Richard_Harris.pdf

East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

Food Service Technology Center. Combination Ovens. www.fishnick.com/savewater/appliances/combinationovens/

Sydney Water, 2001. *Save Water, Money, and the Environment – Kitchens.*

www.sydneywater.com.au/Publications/FactSheets/SavingWaterKitchens.pdf

[56] Ibid.

Sydney Water, 2007. The Conserver: *No Water Wasted at the Mandarin.* www.sydneywater.com.au/Publications/CaseStudies/MandarinShoppingCentreConserver12.pdf

U.S. Environmental Protection Agency's Energy Star Program. Best Practices—How to Achieve the Most Efficient Use of Water in Commercial Food Service Facilities.

www.energystar.gov/index.cfm?c=healthcare.fisher_nickel_feb_2005

Dipper Wells

Overview

Dipper wells are used for applications such as rinsing ice cream scoops, spoons and other utensils on the serving line between uses. Most dipper wells have a single spigot and a valve that controls the flow of either hot or cold water into a receiving well. Most serving lines have dipper wells running constantly during service hours to provide a continuous exchange of the water in the well to reduce the potential for bacterial growth.

Generally, dipper wells have flow rates between 0.5 and 1.0 gallon per minute (gpm).[57] Larger wells, however, have higher flow rates.

Food service locations should ensure that the requirements of the U.S. Department of Health and Human Services Food Code are met, specifically sections 3-304.11 and 3-304.12, when considering changes to facility operations that may involve installing, retrofitting, or replacing a dipper well.

Operation, Maintenance, and User Education

For optimum dipper well efficiency, consider the following:

- Turn off water when service periods are slow and the dipper well is not in use. Turn off the water to the well at the end of each day as well. Clean the dipper well prior to restarting the water in order to remove any bacterial build up.
- Keep the flow rate of the dipper well valve at its minimum level. Some municipalities recommend no more than 0.3 gpm.[58]
- Consider rinsing utensils with an existing faucet only as needed rather than using a dipper well.
- Use cold or warm water instead of hot water in dipper wells where appropriate for rinsing utensils.

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[57] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD8-FOOD9.
[58] Arizona Water. *Implementing a Water Management Plan Checklist for Facility Managers*. Page 8.

Retrofit Options

To reduce the water use associated with a dipper well, consider installing an in-line flow restrictor to reduce the flow rate from 0.5 or 1.0 gpm to 0.3 gpm.

Replacement Options

When looking to replace dipper wells, consider these options:

- Install a metering faucet for utensil rinsing.
- If the facility has a large volume of utensils, sufficient to run full dishwasher loads, consider installing an Energy Star®-qualified commercial under-counter dishwasher[59] instead of using a dipper well.

Potential Savings

During the course of a 12-hour operating day at a typical ice cream shop, dipper wells can consume 300 to 700 gallons of water, or 130,000 to 260,000 gallons per year. Water savings can be achieved by retrofitting the dipper well faucet to reduce the flow rate *or* by replacing a dipper well faucet with a metered faucet or an Energy Star qualified commercial under-counter dishwasher. Installing a flow-restricting device to reduce the water flow of a dipper well can result in water savings between 50,000 and 180,000 gallons per dipper well per year.

Dipper Well Retrofit with In-Line Flow Restrictor

Current Water Use

To estimate the water use of an existing dipper well, identify the following information and use Equation 1 below:

- Flow rate of the existing dipper well. Most dipper wells have flow rates between 0.5 and 1.0 gpm.[60] Measuring the actual flow rate is a fairly simple task that can be accomplished in a very short time.
- Average operating hours per day of the facility.
- Days of facility operation per year.

Equation 1:
Water Use of a Dipper Well (gallons/year) = Flow Rate (gpm) X Daily Use Time (minutes/day) X Days of Operation per Year (days/year)

[59] www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COH
[60] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD8-FOOD9.

Water Use After Retrofit

To estimate the water use after retrofitting an existing dipper well with an in-line flow restrictor, use Equation 1, substituting the flow rate of the retrofit in-line flow restrictor for the flow rate of the existing dipper well. An efficient retrofit in-line flow restrictor should provide a maximum flow rate of 0.3 gpm.

Water Savings

Determine the expected water savings by subtracting the water use after retrofit from the current water use.

Payback

To calculate the simple payback from retrofitting an existing dipper well, identify the following information and use Equation 3 below:

- Equipment and installation cost of the retrofit in-line flow restrictor.
- Water savings as calculated in Equation 1.
- Facility-specific cost of water and wastewater.

Equation 2:

Payback (years) = Equipment and Installation Cost ($) / (Water Savings (gallons/year) X Cost of Water and Wastewater ($/gallon))

Dipper Well Replacement with Metering Faucet

Though retrofitting an existing dipper well with a flow restrictor is likely the most cost-effective choice for a facility, significant water savings may also be achieved by replacing a dipper well faucet with a metering faucet.

Current Water Use

To estimate the current water use of an existing dipper well, use Equation 1.

Water Use After Replacement with Metered Faucet

To estimate the water use after replacing an existing dipper well with a push-button, metered faucet identify the following information and use Equation 3 below:

- Flow rate of the metering faucet [in gallons per cycle (gpc)].
- Average cycles used per hour.
- Average operating hours per day of the facility.
- Days of facility operation per year.

Equation 3:

Water Use of a Metering Faucet (gallons/year) = Flow Rate per Cycle (gallons/cycle) X Use per Hour (cycles/hour) X Daily Use Time (hours/day) X Days of Operation per Year (days/year)

Water Savings

Determine the expected water savings by subtracting the water use after faucet replacement from the current water use.

Payback

To calculate the simple payback from replacing an existing dipper well with a push-button, metered faucet, use Equation 2, substituting the cost of replacing the existing faucet with a new metering faucet for the cost of the in-line flow restrictor.

Dipper Well Replacement with Energy Star Qualified Commercial Dishwasher

Though retrofitting an existing dipper well with a flow restrictor is likely the most cost-effective choice for a facility, significant water savings may also be achieved by replacing a dipper well with an Energy Star qualified commercial under-counter dishwasher *and* altering the practices of those individuals responsible for utensils.

Current Water Use

To estimate the current water use of an existing dipper well, use Equation 1.

Water Use After Replacement with Energy Star Dishwasher

To estimate the water use after replacing an existing dipper well with an Energy Star qualified commercial under counter dishwasher, identify the following information and use Equation 4 below:

- Water use per rack washed. A high-temperature, Energy Star qualified commercial under-counter dishwasher uses 1.0 gallons per rack or less. A low-temperature model uses 1.7 gallons per rack or less.[61]
- Average estimate of racks washed per day.
- Days of facility operation per year.

[61] U.S. Environmental Protection Agency, Energy Star program. Commercial Dishwashers Key Product Criteria. www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers

Equation 4:

Water Use of an Energy Star Qualified Commercial Under-Counter Dishwasher (gallons/year) = Water Use per Rack (gallons/rack) X Racks Washed per Day (racks/day) X Days of Operation per Year (days/year)

Water Savings

Determine the expected water savings by subtracting the water use after dishwasher installation from the current water use.

Payback

To calculate the simple payback from replacing an existing dipper well with an Energy Star qualified commercial under counter dishwasher, use Equation 2, substituting the cost of installing an Energy Star qualified dishwasher for the cost of the in-line flow restrictor. Purchasing and installing a new Energy Star qualified commercial under-counter dishwasher can cost approximately $6,000.[62]

Additional Resources

Arizona Water. *Implementing a Water Management Plan Checklist for Facility Managers*. Page 8. www.azwater.gov/AzDWR/StatewidePlanning/Conservation2/Documents/documents/ImplementingaWaterManagementPlanChecklistforManagers.pdf

East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD8-FOOD9. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

Fisher Nickel Inc. 2005. *Best Practices – How to Achieve the Most Efficient Use of Water in Commercial Food Service Facilities*. Page 11. www.energystar.gov/ia/business/healthcare/fisher_nickel_feb_2005.pdf

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U.S. Environmental Protection Agency, Energy Star program. Commercial Dishwashers Key Product Criteria. www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers

[62] U.S. Environmental Protection Agency, Energy Star program. Energy Star Life Cycle Cost Estimate for Energy Star Qualified Commercial Dishwasher(s). www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorCommercialDishwasher.xls

U.S. Environmental Protection Agency, Energy Star program. Energy Star Life Cycle Cost Estimate for Energy Star Qualified Commercial Dishwasher(s). www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorCommercialDishwasher.xls

Steam Cookers

Overview

Steam cookers, also known as food steamers, are commercial kitchen appliances used to prepare foods in a sealed vessel that limits the escape of air or liquids below a pre-set pressure. There are two types of steam cookers: boiler-based and boilerless (without a central boiler connection).

Boiler-based steamers

Boiler-based steam cookers are connected to a central boiler, which delivers steam to the heating compartment. Steam that does not condense on the food escapes as a mixture of steam and condensate through a drain or venting. In addition, some water is continuously bled off from the steam cooker to help reduce and manage scale build up. Most manufacturers indicate that water supplied to the steam cooker should be under 50 parts per million (ppm) of total dissolved solids (TDS), otherwise bleed off must be increased. Boiler-based steam cookers also use large amounts of water to further condense the steam and to cool (temper) the condensate water to around 140^{o}F before it enters the sewer system. Most boiler-based steam cookers offer a standby setting that maintains the boiler in a ready-to-use state. In many instances, the condensate cooling (tempering) water will continue to flow even when the steam cooker is in standby mode, particularly if the condensate cooling water is controlled by a valve that must be manually turned on and off. Some boiler-based steam cookers, but not all, do allow for the condensate cooling water to be turned off while the steamer is in standby mode. Steamers that are timer-controlled will automatically switch into standby mode at the end of the set cook time, minimizing the amount of water wasted while the unit is not in use.

Boilerless (connectionless) steamers

Boilerless steam cookers can be either completely unconnected to any water supply or can be connected to a water supply just to keep the water reservoir full. Unconnected (connectionless) boilerless steam cookers have an individual reservoir where water is heated below the steam trays to create the steam. These types of steam cookers are manually drained and refilled and do not require a dedicated drain for condensate or the addition of cooling (tempering) water. A small amount of steam is vented through the top of the steam cooker, but what is not vented or condensed on the food returns as condensate to the reservoir. Connected boilerless steam cookers have a float valve that maintains the water level in the reservoir, but unlike the boiler-based steam cookers, there is no continuous flow of water. The connected boilerless steam cookers are usually as efficient as the connectionless models.

To address efficiency and advances in commercial steam cookers, Energy Star has developed voluntary criteria to qualify energy- and water-efficient steam cookers to earn the Energy Star label[63].

[63] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC

Operation, Maintenance, and User Education

For optimum steam cooker efficiency, consider the following:

- Use batch production as opposed to staged loading of food pans (i.e., do not repeatedly open the door to load and unload food pans).
- Where possible, fill the steam cooker to capacity instead of cooking one pan in a multi-pan steamer.
- Keep the doors closed while the steamer is operating.
- Use only as many steamer compartments as needed.
- Use a timer to ensure that the steam cooker returns to standby mode after use.
- Turn the steam cooker off during long periods of non-use. This will reduce water and energy use associated with keeping the steam cooker in stand-by mode.
- Repair any leaks. Remove any deposit buildup from the boiler on boiler-based models.

Retrofit Options

When using a boiler-type steam cooker, a condensate return system may be installed to direct the condensate back into the central boiler system for reuse. This process will improve both water and energy efficiency, because the condensate can be used as boiler makeup water. Packaged condensate return systems can be purchased from most steam equipment suppliers; plumb them directly into an existing system. Insulating condensate return lines will further improve their efficiency.

There are currently no retrofit options available on the market to increase the water efficiency of boilerless steam cookers.

Replacement Options

Steam cookers come in several sizes with varying numbers of boiler pans. Choose a steam cooker that is of the appropriate size for the food service needs of the facility. A larger than necessary steam cooker may waste water and use excessive energy to heat unused compartment space.

When purchasing a new steam cooker or replacing an existing one, choose models that are Energy Star qualified[64]. Energy Star steam cookers meet cooking efficiency and maximum idle rate requirements and can typically save about 90 percent of the water used by a traditional steam cooker.

It should be noted that the cost differential between connectionless and boiler-based steamers is small. However, boiler-based steamers must have both water and sewer hookups and an RPZ backflow preventer, which can add several thousand dollars to the total installed cost of the steamer. In addition, the backflow preventer must be tested annually.

Savings Potential

[64] www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC

Energy Star qualified steam cookers can achieve a 90 percent reduction in water use and use half as much energy as standard steam cookers.[65] Traditional boiler-based steam cookers may use as much as 40 gallons of water per hour. Switching to an Energy Star qualified steam cooker can reduce that water use to 3.0 gallons of water per hour or less. Assuming the steam cooker is used and operating 6.5 hours per day, 360 days per year[66], an Energy Star qualified steam cooker may save as much as 86,000 gallons and 3,000 kilowatt-hour (kWh) per year[67].

Several methods and tools can be used to calculate facility-specific water, energy, and cost savings for replacing an existing boiler-based steam cooker with an Energy Star qualified model. In addition to the equations below, you can use one of the Food Service Technology Center's life cycle and energy cost calculators[68]

Current Water Use

To estimate the current water use of a steam cooker, identify the following information and use Equation 1 below:

- Flow rate of the existing steam cooker.
- Average daily use time.
- Days of food service operation per year.

Equation 1:

Water Use of Steam Cooker (gallons/year) = Flow Rate per Hour (gallons/cycle) X Daily Use Time (hours/day) X Days of Operation per Year (days/year)

Water Use After Retrofit or Replacement with Energy Star Qualified Steam Cooker

To estimate the water use after retrofitting a boiler-based system or replacing an existing steam cooker, use Equation 1, substituting the flow rate of the new recirculating configuration or the Energy Star qualified steam cooker for the flow rate of the existing steam cooker.

Equation 2:

Water Use of Retrofitted System or Energy Star Qualified Steam Cooker (gallons/year) = Flow Rate per Hour (gallons/cycle) X Daily Use Time (hours/day) X Days of Operation per Year (days/year)

[65] ibid.
[66] East Bay Municipal Utility District. 2008. "Turning up the Heat on Commercial Kitchen Water Savings". www.energystar.gov/ia/partners/downloads/meetings/water_Richard_Harris.pdf
[67] U.S. EPA., Energy Star Life Cycle Cost Estimate for Qualified Electric Steam Cookers. <www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Commercial_Steam_Cooker.xls>.
[68] www.fishnick.com/saveenergy/tools/calculators/

Water Savings

Determine the expected water savings by subtracting the water use after steam cooker retrofit or replacement from the current cooker water use.

Potential Future Water Savings for California

A 2005 report by the Food Service Technology Center[69] estimated that approximately 25,000 compartment food steamers were installed in the state of California. As of 2005, the FSTC went on to estimate that the boilerless (connectionless) equipment only represented less than 5 percent of that total, the remainder being boiler-based units. The FSTC concluded that about 60 percent of the installed base were viable candidates for replacement with the very efficient units, or about 15,000 steamers[70], and, if replaced, could yield an estimated 3,750 acre-feet of annual water savings.

Payback

To calculate the simple payback from retrofitting or replacing an existing steam cooker, identify the following information and use Equation 3 below:

- Purchase and installation cost of the retrofit or replacement steam cooker.
- Water savings as calculated in Equation 2.
- Facility-specific cost of water and wastewater.

Equation 3:

Payback (years) = Equipment and Installation Cost ($) / (Water Savings (gallons/year) X Cost of Water and Wastewater ($/gallon))

CASE STUDY – IRVINE RANCH WATER DISTRICT

In 2006, the Irvine Ranch Water District (IRWD) initiated a Restaurant Retrofit Package Program to install water conservation devices in restaurants that have been in operation at least five years. The targeted devices were connectionless food steamers and pre-rinse spray valves (1.6 gallons per minute). The goal of the program was to install 50 of each device in restaurants throughout the IRWD service area. IRWD was awarded an Enhanced Conservation Program grant from the Metropolitan Water District in December 2006. IRWD added to this funding and

[69] Fisher-Nickel, Inc. and Koeller and Company, 2005. Evaluating the Water Savings Potential of Commercial “Connectionless” Food Steamers, Final Report, June. This report describes the very comprehensive field study of actual steamer installations and their water and energy consumption. Funded by Pacific Gas & Electric, East Bay Municipal Utilities District, and the Metropolitan Water District of Southern California, the field work tracked water and energy consumption at 12 different food service operations in northern and southern California.

[70] It should be noted that not all boiler-based units could be replaced, due the need in some establishments for high production capacity, something the boilerless steamers are not yet equipped to provide.

leveraged existing Southern California Edison (SCE) energy rebates for food steamers to drive down the customer cost.

IRWD staff inspected customer's existing steamers to determine program eligibility. The new steamer and pre-rinse spray valves were installed by an installation company contracted with AccuTemp. The customer was invoiced for the installation cost and disposal costs for their old inefficient steamer, which totaled approximately $750 per retrofit. IRWD was invoiced by AccuTemp for the total price of each retrofit. IRWD then invoiced MWD for reimbursement from the grant funds. Upon installation verification, the program participant signed over release of the SCE rebate to IRWD, which was then submitted to SCE for reimbursement. The program had a total of three customers participate, installing a combined total of five steamers.

Lifetime water savings per installed steamer amounted to 2.47 acre feet over the 10 year lifetime of the equipment. Therefore, the five steamers installed through the program saved a total of 12.35 AF over the 10 years.

Additional Resources

Alliance for Water Efficiency. *Food Steamers Introduction*. www.allianceforwaterefficiency.org/1Column.aspx?id=642&terms=steam

East Bay Municipal Utility District. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. 2008. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

Fisher-Nickel, Inc. and Koeller and Company, 2005. Evaluating the Water Savings Potential of Commercial "Connectionless" Food Steamers, Final Report, June.

Food Service Technology Center. *Steamers*. www.fishnick.com/savewater/appliances/steamers/

Sydney Water, 2001. *Save Water, Money, and the Environment – Kitchens.*

http://www.sydneywater.com.au/Publications/FactSheets/SavingWaterKitchens.pdf

Sydney Water, 2006. The Conserver: *Water Cuts are on the Menu at McDonalds.* http://www.sydneywater.com.au/Publications/CaseStudies/HiltonConserver13.pdf

Sydney Water, 2007. The Conserver: *No Water Wasted at the Mandarin.* http://www.sydneywater.com.au/Publications/CaseStudies/MandarinShoppingCentreConserver12.pdf

U.S. EPA's Energy Star Program. *Commercial Steam Cookers*.

www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC#buying

Steam Kettles

Overview

Steam kettles are often selected for use in large food service facilities because, as with steam tables, temperatures can be more easily controlled, thereby preventing scorching the food. However, they should be installed only where large-volume food preparation justifies the water and energy use.

Steam kettles are either boiler-based or self-contained cooking appliances that use circulating steam to perform tasks similar to traditional stockpots, including boiling pasta and simmering sauces. Steam kettles may be preferable to traditional stockpots due to their rapid, uniform cooking and ease of control.

Steam kettles have a double wall that covers at least half of the height of the sides of the kettle. Steam is circulated within this double wall, or "jacket," and it then condenses to transfer heat to the food product by means of conduction. Steam kettles range in size from 0.5 gallon to more than 200 gallons each.[71] Steam kettles may also be designed with tilting capability, strainers, and covers.

Boiler-based steam kettles rely on an external central boiler to deliver steam. These types of steam kettles are commonly found in industrial facilities with centrally located boilers. Boiler-based steam kettles require a regular "blow down" to remove condensate on the steam supply line and can consume more than 100,000 gallons of water per year. Returning condensate to the boiler as makeup water can reduce this water consumption.[72]

Self-contained steam kettles rely on their own heat source to generate steam under pressure (Figure 7X). Self-contained steam kettles use less water and energy than boiler-based steam kettles, because they do not require significant blow down water. Boiler water must be dumped at the end of the day to prevent mineral build up. They also require de-liming on a regular basis and regular manual venting and refilling.[73]

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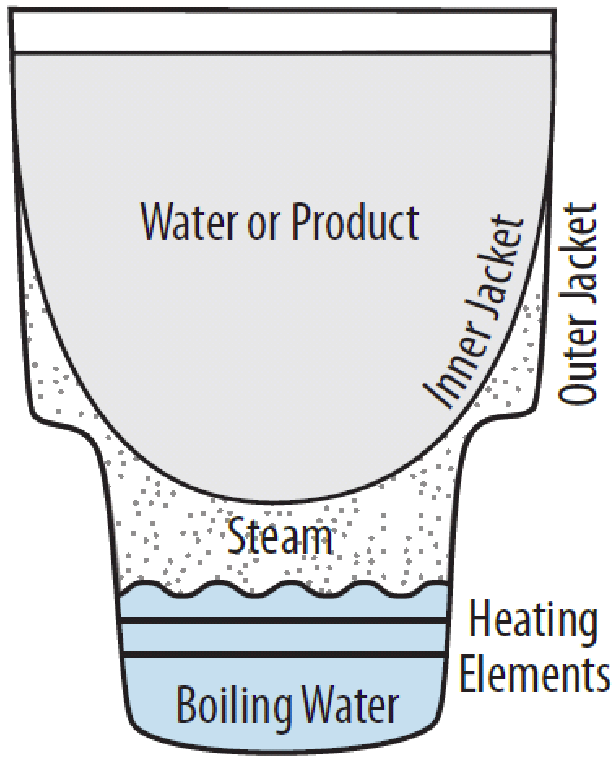
[71] Cornell University New York State Agricultural Experiment Station. 2007. Steam Kettles in Food Processing: Small Scale Food Entrepreneur. www.nysaes.cornell.edu/necfe/pubs/pdf/FactSheets/FS_SteamKettles.pdf

[72] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Page FOOD6.

[73] Cornell University New York State Agricultural Experiment Station. 2007. Steam Kettles in Food Processing: Small Scale Food Entrepreneur. www.nysaes.cornell.edu/necfe/pubs/pdf/FactSheets/FS_SteamKettles.pdf

Figure X. Self-Contained Steam Kettle



The American Society for Testing and Materials (ASTM International) developed a performance test for direct steam and self-contained gas or electric steam kettles. *ASTM F1785-97*, Standard Test Method for Performance of Steam Kettles, measures the energy consumption and cooking performance of steam kettles. This test method can be used to choose an appropriately sized kettle based on the operation's food output and can maximize kettle efficiency.

Operation, Maintenance, and User Education

For optimum steam kettle efficiency, consider the following:

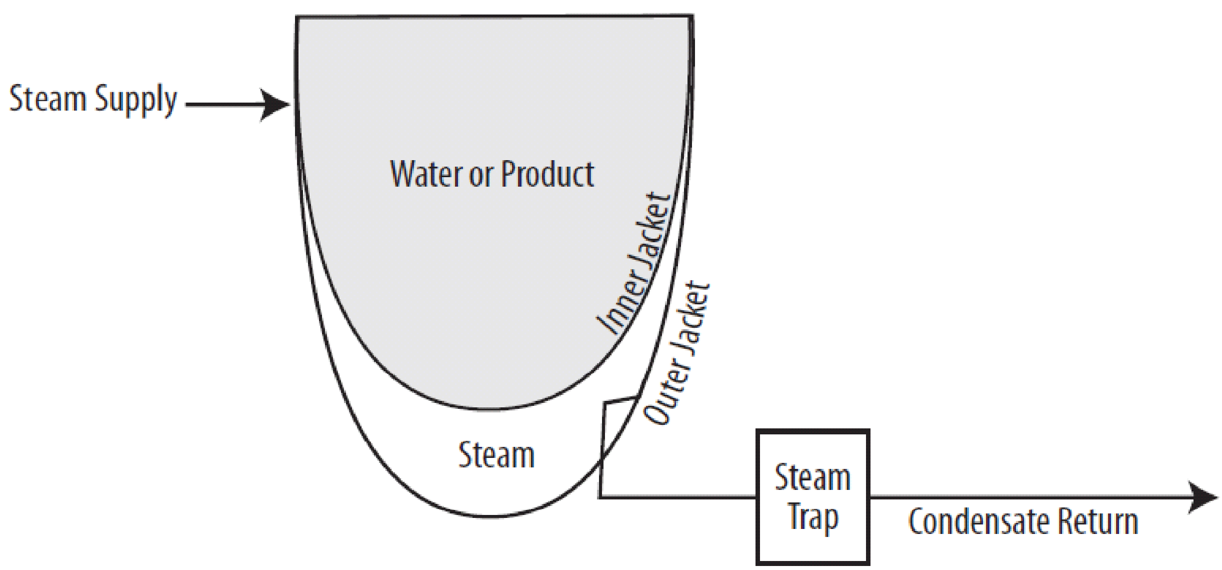
- Regularly monitor self-contained steam kettle water levels and maintain control components to ensure efficient operation.
- Turn the steam kettle down or off between uses.
- Secure the steam kettle lid whenever possible to reduce the amount of energy required for simmering and boiling.
- If using a boiler-based steam kettle, ensure that the central boiler system is maintained properly in accordance with the *Boiler and Steam Systems BMP*.

Retrofit Options

The major water-saving potential for boiler-based steam kettles is for the condensate to be retained and returned to the boiler.

A condensate return system can be installed to direct the condensate back into the central boiler system for reuse (Figure X). This process will improve both water and energy efficiency, because the condensate can be used as boiler makeup water. Packaged condensate return systems can be purchased from most steam equipment suppliers; plumb them directly into an existing system. Condensate return systems cost about $3,000. There are additional costs for piping and other installation requirements. Insulating condensate return lines will further improve efficiency.

Figure X. Boiler-Type Steam Kettle



There are currently no retrofit options available on the market to increase the efficiency of self-contained steam kettles.

Replacement Options

When purchasing a new steam kettle or replacing an old one, consider the steaming needs of the kitchen. For smaller steaming needs, consider self-contained steam kettles without an external boiler, which use less water and energy than boiler-based steam kettles. If daily operations require a boiler-based steam kettle, consider a model with a condensate return system. Choose a steam kettle with a properly sized steam trap to prevent inadvertent dumping of condensate.

Savings Potential

Retrofitting or replacing existing steam kettles can yield operational water savings. For a boiler-based steam kettle, water savings achieved by returning the condensate to the boiler can be substantial. However, actual water savings are difficult to approximate because the water use of a steam kettle varies based upon its size and the pressure of the steam. According to the East Bay Municipal Utility District, condensate return systems cost approximately $3,000 and have an estimated product life of 10 years.[74]

Current Water Use

To estimate the water use of a steam kettle, identify the following information and use Equation 1 below:

- Flow rate of the existing steam kettle calculated using the capacity of the kettle (gal) and the pressure of the steam (psi)
- Average daily use time in the food service operation.
- Days of food service operation per year.

Equation 1:
Water Use of Boiler-Based Steam Cooker (gallons/year) = Flow Rate per Hour (gallons/cycle) X Daily Use Time (hours/day) X Days of Operation per Year (days/year)

Water Use After Retrofit or Replacement

To estimate the water use after retrofitting or replacing an existing steam kettle, use Equation 1, substituting the flow rate of the new configuration or new system for the flow rate of the existing steam kettle.

Water Savings

Determine the expected water savings by subtracting the water use after steam kettle retrofit or replacement from the current kettle water use.

Payback

To calculate the simple payback from replacing an existing steam kettle, identify the following information and use Equation 2 below:

- Purchase and installation cost of the replacement steam kettle.
- Water savings as calculated above..

[74] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Page FOOD6.

- Facility-specific cost of water and wastewater.

Equation 2:

Payback (years) = Equipment and Installation Cost ($) / (Water Savings (gallons/year) X Cost of Water and Wastewater ($/gallon))

Additional Resources

Cornell University New York State Agricultural Experiment Station. 2007. Steam Kettles in Food Processing: Small Scale Food Entrepreneur. www.nysaes.cornell.edu/necfe/pubs/pdf/FactSheets/FS_SteamKettles.pdf

East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

Food Service Technology Center. 2009. Steam Kettles. http://www.fishnick.com/equipment/appliancetypes/steamkettles

Robert M. Kerr Food & Agricultural Products Center. Food Technology Fact Sheet – Steam Kettle Hookup. www.fapc.okstate.edu/files/factsheets/fapc120.pdf

Sydney Water, 2001. *Save Water, Money, and the Environment – Kitchens.*

http://www.sydneywater.com.au/Publications/FactSheets/SavingWaterKitchens.pdf

Sydney Water, 2007. The Conserver: *No Water Wasted at the Mandarin.* http://www.sydneywater.com.au/Publications/CaseStudies/MandarinShoppingCentreConserver12.pdf

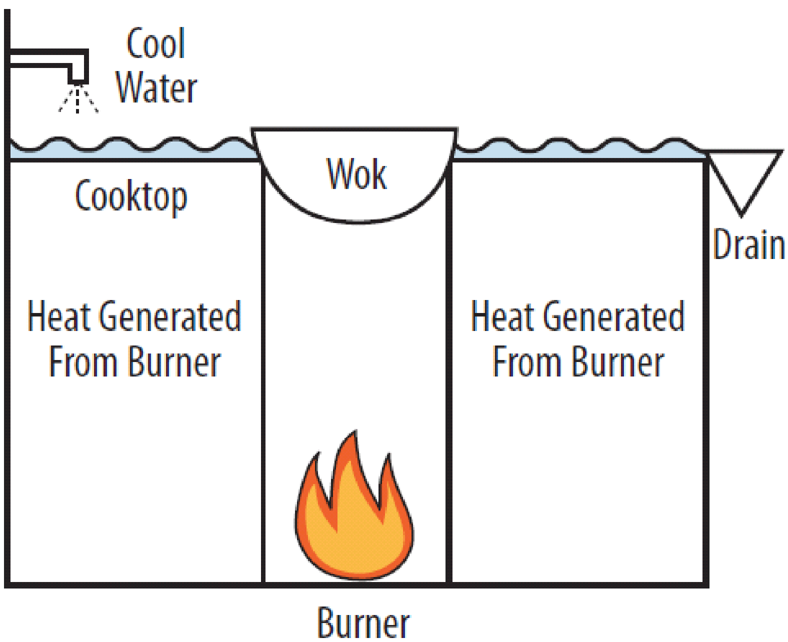
U.S. Department of Energy, Energy Efficiency & Renewable Energy, Federal Energy Management Program. 2009. Best Management Practice: Commercial Kitchen Equipment. www1.eere.energy.gov/femp/program/waterefficiency_bmp11.html

Wok Stoves

Overview

A wok stove is a Chinese pit-style stove that has a wok (or multiple woks) recessed into the stove top, allowing heat to be fully directed onto the bottom of the wok. Conventional wok stoves use water for both cooling and cleaning.[75] In a conventional wok stove, the burner chimney and ring are affixed to the top of the stove; as a result, heat is trapped under the cook top. Water jets are installed to enable cooling water to flow at approximately 1.0 gpm per burner across the cook top to absorb the heat. Figure 7X illustrates the design of a water-cooled wok stove.

Figure X. Water-Cooled Wok Stove

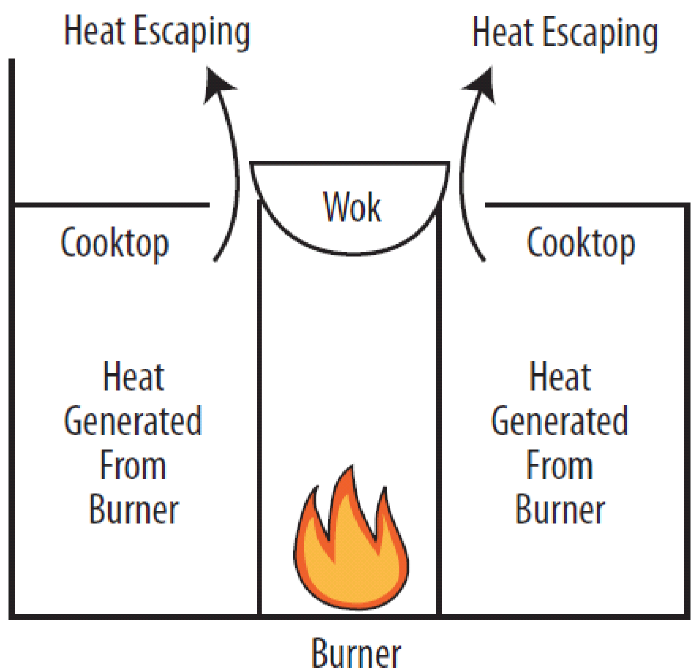


[75] Sydney Water. Wok Stoves. www.sydneywater.com.au/Publications/Factsheets/Wok_stove_fact_sheet.pdf

Wok Stoves

Waterless wok stoves, a relatively new technology, are cooled with air, and thus do not require the use of cooling water. These wok stoves function by creating an air gap between the burner chimney and ring and the top of the stove so that the heat can be released directly from beneath the cook top and vented to the kitchen exhaust (Figure X). Waterless wok stoves can further reduce water use if they are outfitted with a rinsing spout that shuts off the water supply when it is not needed for wok cleaning.

Figure X .One Type of Air-Cooled Wok Stove



Another new wok stove technology connects to the building chilled water loop or uses a point-of-use chiller. These systems provide chilled water to the wok stove to reduce the temperature of the cook top. This type of wok stove has an internal backup water-using system in the event that the recirculated chilled water is not available.

Some conventional wok stoves are outfitted with a reservoir to provide water used for cooking, which is typically left running even when it is full. Waterless wok stoves may have a mechanism to limit both the flow rate and duration of flow to this reservoir.[76]

By replacing conventional wok stoves with waterless models and/or reducing the flow rate and duration of rinse and reservoir spouts, facilities could save 90 percent of the water required for cooking and cleaning.

Operation, Maintenance, and User Education

For optimum wok stove efficiency, consider the following:

[76] Alliance for Water Efficiency. 2010. Waterless Wok Introduction. www.allianceforwaterefficiency.org/1Column.aspx?id=700

- Encourage cooking staff to turn off rinse and reservoir spouts when not in use.
- Inspect and ensure that the shutoff valves for the rinse and reservoir spouts are in working order.
- Shut off the cooling water when the wok stove is not in use, especially at the end of each day.
- Routinely check cooling water lines for leaks and corrosion.

Retrofit Options

If retrofitting an existing conventional wok stove, check to see if rinse spouts can be replaced with spouts that automatically shut off or that can switch off when pushed back away from the wok.

Replacement Options

When purchasing a new wok stove or looking to replace an existing conventional wok stove, look for models that are considered waterless, which will be air-cooled instead of water-cooled. Waterless wok stoves may use about 2 percent more energy than a conventional wok stove,[77] but they can save more than 90 percent of the water used. Also, look for waterless models that have automatic shutoff rinse and reservoir spouts and/or knee-operated timer taps to limit both the flow rate and duration of the flow.

Savings Potential

During the course of a 12-hour day, a conventional wok stove with one burner can use more than 700 gallons of water. In addition to the water used for cooling, the woks must also be rinsed between uses, which can require 500 to 800 gallons of water per day, particularly if the rinsing spout is left constantly running. Studies have shown that daily average water use of a conventional wok stove is 1,400 to 2,000 gallons per day.[78] The savings could add up to more than $3,500 in avoided water and sewer costs each year, which could provide payback for the cost of the new equipment in as few as one to two years.[79]

Water savings can be achieved through two mechanisms: eliminating the use of cooling water by switching from a water-cooled to an air-cooled waterless wok stove *or* by reducing the flow rate and duration of use of rinse and reservoir spouts. To estimate facility-specific water savings and payback, use the following information:

<u>Wok Stove Retrofit</u>

[77] International Association of Plumbing and Mechanical Officials. 2010. Green Newsletter. 2010's Top-5 New and Innovative Water Efficient Products. <http://forms.iapmo.org/newsletter/green/2010/05/2010_Top5.asp

[78] Sydney Water. Wok Stoves. <www.sydneywater.com.au/Publications/Factsheets/Wok_stove_fact_sheet.pdf>.

[79] Estimate assumes an annual savings of approximately 500,000 gallons; from Sydney Water. Wok Stoves. www.sydneywater.com.au/Publications/Factsheets/Wok_stove_fact_sheet.pdf. Also assumes a water and sewer rate of $7.16 per 1,000 gallons; from Raftelis Financial Consulting. 2008. *Water and Wastewater Rate Survey*. American Water Works Association.

Woks must be rinsed between uses and reservoir spouts are often filled to provide water used in cooking. These rinse and reservoir spouts can require 500 to 800 gallons of water per day, particularly if they are left continuously running. Reducing the flow rate of rinse and reservoir spouts and the duration of their use can significantly reduce this water use. Use the following information to estimate water savings and payback potential that may be achieved with this type of retrofit:

Current Water Use

To estimate the current water use of the existing wok stove rinse and reservoir spouts, identify the following information and use Equation 1 below:

- Flow rate of each rinse and reservoir spout.
- Average daily use time of rinse and reservoir spouts.
- Days of food service operation per year.

Equation 1:

Water Use of a Wok Stove Rinse and Reservoir Spout (gallons/year) = Flow Rate (gpm) X Daily Use Time (minutes/day) X Days of Facility Operation (days/year)

Water Use After Retrofit

To estimate the water use of more efficient rinse and reservoir spouts, use Equation 1, substituting the flow rate of the retrofit rinse and reservoir spouts.

Water Savings

Determine the expected water savings by subtracting the water use after retrofit of the spouts from the current water use.

Payback

To calculate the simple payback from retrofitting an existing wok stove with more efficient rinse and reservoir spouts, identify the following information and use Equation 2 below:

- Equipment and installation cost of the retrofit rinse and reservoir spouts.
- Water savings as calculated using Equation 1.
- Facility-specific cost of water and wastewater.

Equation 2:

Payback (years) = Equipment and Installation Cost ($) / (Water Savings (gallons/year) X Cost of Water and Wastewater ($/gallon))

Wok Stove Replacement

During the course of a 12-hour day, a conventional water-cooled wok stove can use more than 700 gallons of water. Switching to a waterless wok or one that uses recirculated chilled water can eliminate the use of single-pass cooling water, thereby reducing the wok stove's total water use by as much as 90 percent, resulting in savings of over 250,000 gallons per year. Waterless wok stoves cost approximately $10,000 to $12,000, excluding installation. As such, it is unlikely that a conventional food service operation can recoup the initial cost of the equipment in an acceptable period of time. Use the following information to estimate water savings and payback potential that may be achieved by replacing a conventional wok stove with a waterless wok stove or one that uses recirculated chilled water:

Current Water Use

To estimate the water used for cooling of a waterless wok stove, identify the following information and use Equation 3 below:

- Flow rate of the cooling water. This flow rate is typically 1 gpm.
- Average daily use time.
- Days of food service operation per year.

Equation 3:

Water Use of Wok Stove Cooling Water (gallons/year) = Flow Rate (gallons/minute) X Daily Use Time (minutes/day) X Days of Facility Operation (days/year)

Water Savings

Determine the expected water savings by subtracting the water use after replacement with a waterless wok from the current water use.

Payback

To calculate the simple payback from replacing an existing conventional wok stove with a waterless unit, identify the following and use Equation 2 above:

- Equipment and installation cost of the replacement waterless wok stove or one that uses recirculated chilled water. Units that use chilled water cost between over $10,000, excluding installation. Verify costs before deciding to replace and existing conventional wok stove.
- Water savings as calculated using above.
- Facility-specific cost of water and wastewater.

Additional Resources

Alliance for Water Efficiency. 2010. Waterless Wok Introduction. www.allianceforwaterefficiency.org/1Column.aspx?id=700

City West Water Limited. Woking the Way to Water Savings. www.citywestwater.com.au/business/programs_and_assistance_woking_the_way_to_water_savings.aspx

Food Service Technology Center, 2010. *Wok Water Saver Performance Test*, FSTC Report 50130940, for Pacific Gas & Electric Company, March.

International Association of Plumbing and Mechanical Officials. 2010. Green Newsletter. *2010's Top-5 New and Innovative Water Efficient Products*. http://forms.iapmo.org/newsletter/green/2010/05/2010_Top5.asp

Sydney Water, 2005. *Save Water, Money, and the Environment – Wok Stoves.*

http://www.sydneywater.com.au/Publications/FactSheets/SavingWaterKitchens.pdf

Sydney Water, 2001. *Save Water, Money, and the Environment – Kitchens.*

http://www.sydneywater.com.au/Publications/FactSheets/SavingWaterKitchens.pdf

Washing and sanitation

Overview

Washing floors in food-service establishments can use large quantities of water. The common practice has been to mop the kitchen floor with soapy water, then use a high-pressure hose with hot water to rinse the soapy water into the floor drain. This process uses large amounts of water, as well as energy to heat the water, and has a tendency to splash dirty water onto clean equipment. Some literature reports that water use for floor cleaning in a large commercial kitchen can be in the range of 1,000 to 1,500 gallons a day.

One of the items used to perform cleaning in food service operations is the wash-down sprayer. These sprayers consist of hoses and nozzles used for a variety of cleaning purposes, including washing countertops, floors, mats, and other kitchen areas. Wash-down sprayers use large volumes of water to provide a high-pressure stream capable of cleaning dirt and residue from surfaces.

A wash-down sprayer features a nozzle attached to a hose, which, in turn, is connected to the potable water supply. Wash-down sprayers typically deliver flow rates of 7 gpm,[80] while heavy-duty hoses used without nozzles can deliver higher flow rates from 9 to 20 gpm.[81]

Because wash-down sprayers are not water efficient for cleaning tasks, using another cleaning method could be a viable alternative. These cleaning methods (e.g., mopping or sweeping) are able to perform the same tasks yet require significantly less water or no water at all. If implementing new cleaning methods is not feasible, replacement options exist that use lower flow rates than wash-down sprayers, including pressure washers and water brooms.

Operation, Maintenance, and User Education

For optimum wash-down sprayer efficiency, consider the following:

- Only use wash-down sprayers to clean floors, countertops, and other surfaces. Do not use wash-down sprayers to clean dishware, which should be cleaned with pre-rinse spray valves.
- Any conventional floor cleaning system with a hot-water hose should, at a minimum, have a self-closing valve. If the wash-down sprayer does not have such a valve, shut off the water supply when the sprayer is not in use.
- For floor washing applications, consider using a broom and dust pan to clean up solid waste and/or using a mop and squeegee instead of a wash-down sprayer.
- Use floor-cleaning machines that are equipped with a water tank.

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[80] Food Service Technology Center. Water Conservation Measures for Commercial Food Service. www.fishnick.com/savewater/bestpractices/Water_Conservation_in_CFS.pdf

[81] U.S. Environmental Protection Agency's Energy Star program. *Best Practices—How To Achieve the Most Efficient Use of Water in Commercial Food Service Facilities*. www.energystar.gov/index.cfm?c=healthcare.fisher_nickel_feb_2005

Retrofit Options

If a high-flowing wash-down sprayer hose is used without a nozzle, consider installing a self-closing nozzle. This nozzle can reduce a 10-20 gpm flow to 7 gpm or less and prevent water waste when the wash-down sprayer is not in use.

Replacement Options

There are several replacement options for wash down sprayers. For certain applications, wash down sprayers may be replaced with mopping or sweeping, which require little or no water.

Pressure washers serve as a viable replacement option for facilities that rely on the washing capability of wash-down sprayers. Pressure washers typically operate at flow rates of 3 gpm or less at high pressure and often outperform wash-down sprayers in cleaning ability.

For surface cleaning applications, water brooms can replace existing wash-down sprayers. Water brooms have wide spray patterns with multiple jets that can clean more efficiently than a wash-down sprayer and use significantly less water.[82]

Savings Potential

Water savings can be achieved through retrofit or replacement. Existing high flowing wash-down sprayers can be retrofitted with a self-closing nozzle. Wash-down sprayers can be replaced with a pressure washer or water broom.

<u>Wash-Down Sprayer Retrofit</u>

Installing a self-closing nozzle on a high-flowing wash-down sprayer to reduce the water flow can result in sprayer water savings between 40,000 to 280,000 gallons per year. Nozzle retrofits cost approximately $100; therefore, a facility saving 40,000 gallons per year could recoup the initial cost of the retrofit equipment in less than one year.[83] To estimate facility-specific savings and payback use the following information:

Current Water Use

To estimate the current water use of an existing wash-down sprayer without a nozzle, identify the following information and use Equation 1 below:

- Flow rate of the existing, high-flowing wash-down sprayer without a nozzle. Most high-flowing wash-down sprayers have flow rates between 9 and 20 gpm.[84]
- Average daily use time in the food service operation.
- Days of food service operation per year.

Equation 1:

[82] Food Service Technology Center. Water Conservation Measures for Commercial Food Service. www.fishnick.com/savewater/bestpractices/Water_Conservation_in_CFS.pdf

[83] Assumes a water and sewer rate of $7.16 per 1,000 gallons. Raftelis Financial Consulting. 2008. *Water and Wastewater Rate Survey.* American Water Works Association.

[84] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD8-FOOD9. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

Water Use of a Wash Down Sprayer or Water Broom (gallons/year) = Flow Rate (gallons/minute) X Daily Use Time (minutes/day) X Days of Facility Operation (days/year)

Water Use After Retrofit

To estimate the water use after installing a nozzle on an existing wash-down sprayer without a nozzle, use Equation 1, substituting the flow rate of the new nozzle. Self-closing nozzles often flow at a rate of 7 gpm.[85]

Water Savings

Determine the expected water savings by subtracting the water use before nozzle retrofit or replacement from the current wash-down water use.

Payback

To calculate the simple payback for the wash-down sprayer retrofit, identify the following information and use Equation 2 below:

- Equipment and installation cost of the self-closing nozzle. Self-closing nozzles typically cost $100.
- Water savings as calculated using Equation 1.
- Facility-specific cost of water and wastewater.

Equation 2:

Payback (years) = Equipment and Installation Cost ($) / (Water Savings (gallons/year) X Cost of Water and Wastewater ($/gallons))

<u>Wash-Down Sprayer Replacement</u>

Replacing a wash-down sprayer with a pressure washer or water broom can result in water savings between 100,000 and 400,000 gallons per year. Pressure washers and water brooms typically cost in the range of $100 to $200; therefore, a facility saving 100,000 gallons per year could recoup the initial cost of the retrofit equipment in less than one year.[86] To estimate facility-specific savings and payback use the following information:

Current Water Use

To estimate the current water use of an existing wash-down sprayer, use Equation 1.

Water Use After Replacement

[85] Food Service Technology Center. Water Conservation Measures for Commercial Food Service. www.fishnick.com/savewater/bestpractices/Water_Conservation_in_CFS.pdf
[86] Assumes a water and sewer rate of $7.16 per 1,000 gallons. Raftelis Financial Consulting. 2008. *Water and Wastewater Rate Survey.* American Water Works Association.

To estimate the water use of a replacement pressure washer or water broom, use Equation 1, substituting the flow rate of the new device. Water brooms can use as little as 2 gpm.[87] Pressure washers flow at similar flow rates using high water pressure.

Water Savings

Determine the expected water savings by subtracting the water use after replacement from the current wash-down water use.

Payback

To calculate the simple payback for the wash-down sprayer replacement, use Equation 2, substituting the cost of the pressure washer or water broom for the cost of the retrofit self-closing nozzle.

Additional Resources

American Water Works Association (Raftelis Financial Consulting). 2008. *Water and Wastewater Rate Survey*.

East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD8-FOOD9. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook>.

Food Service Technology Center. *Water Conservation Measures for Commercial Food Service.* www.fishnick.com/savewater/bestpractices/Water_Conservation_in_CFS.pdf

Food Service Technology Center. *Water, Water Everywhere and Not a Drop to Waste.* www.fishnick.com/saveenergy/greensheets/GreenSheet_Water_Waste_1.pdf

Sydney Water, 2001. *Save Water, Money, and the Environment – Kitchens.*

http://www.sydneywater.com.au/Publications/FactSheets/SavingWaterKitchens.pdf

Sydney Water, 2006. The Conserver: *Water Cuts are on the Menu at McDonalds.* http://www.sydneywater.com.au/Publications/CaseStudies/HiltonConserver13.pdf

Sydney Water, 2007. The Conserver: *No Water Wasted at the Mandarin.* http://www.sydneywater.com.au/Publications/CaseStudies/MandarinShoppingCentreConserver12.pdf

U.S. Environmental Protection Agency's Energy Star program. *Best Practices—How To Achieve the Most Efficient Use of Water in Commercial Food Service Facilities.* www.energystar.gov/index.cfm?c=healthcare.fisher_nickel_feb_2005

[87] Food Service Technology Center. Water Conservation Measures for Commercial Food Service. www.fishnick.com/savewater/bestpractices/Water_Conservation_in_CFS.pdf

7A2: Fabric Cleaning and Washing Equipment

Overview

General

The type of equipment used in commercial laundry operations depends upon the type of laundry facility, the total quantity and type of laundry to be cleaned, and the frequency that cleaning is needed. Several different CII applications exist, each of which uses a different type of wash equipment:

- Self-service (coin- or card-operated) commercial laundromats provide a centralized location where individual consumers can bring their personal laundry. These types of laundry facilities typically use commercial single-load, residential-style washers and multi-load washers not commonly found in homes.
- On-premises laundries - OPLs (institutional), on the other hand, are on-site facilities dedicated to washing fabrics used at the location. They are typically found in facilities such as hotels, food and beverage manufacturers, hospitals, nursing homes, incarceration facilities, athletic facilities, and universities.
- Industrial laundries are typically centralized contract laundries that launder fabrics from other businesses, usually in high volume, such as uniform, diaper, and linen services, as well as other specialized apparel and fabrics.

Industrial laundries and on-premises laundries tend to use large, multi-load washers and washer extractors. These same operations may also use tunnel washers. Specific types of commercial laundry equipment are discussed in more detail below.

Recent advances in commercial laundry equipment include the availability of more efficient equipment, water recycling (internal and external to the machines), and ozone technologies. Each has provided options for reducing water use in commercial laundry operations.

Technical Feasibility

All of the practices, products and technologies described within this report section have been in existence for an extended period of time and found to be technically feasible. In each case, however, economic feasibility must be evaluated within the context of the physical condition and demands of the specific property or building being considered for high-efficiency fabric cleaning operations.

Commercial Coin- and Card-Operated Washers

Commercial coin- and card-operated single-load washers are similar to conventional, residential-style clothes washing machines. Top loading, soft mount (not bolted to the floor) machines have dominated this market, although they are being phased out and replaced by more efficient, front-loading machines. Multi-load machines are now appearing in many laudromats (supplementing single-loaders) as a means to achieve economies of scale (reduced machine footprint, greater water and energy efficiency, and increased revenue per square foot of store).

Single-Load Clothes Washers

The Energy Policy Act (EPAct) of 2005 and subsequent rulings require that commercial coin- or card-operated single-load, soft-mount residential-style laundry equipment meet the following requirements[88]:

> Top loading machine: Water factor (WF) of 8.5 gallons per cycle per cubic foot of capacity and a modified energy factor (MEF) of at least 1.6 cubic feet per kilowatt-hour (kWh) per cycle.

> Front loading machine: WF of 5.5 gallons per cycle per cubic foot of capacity and an MEF of at least 2.0 cubic feet per kilowatt-hour (kWh) per cycle

To address efficiency and advances in commercial clothes washers, Energy Star has developed voluntary criteria to further qualify high-efficiency clothes washers to earn their Energy Star label. As of January 8, 2013, Energy Star qualified washers (**http://www.energystar.gov/products**) must not exceed a WF of 4.5 gallons per cycle per cubic foot of capacity and must have an MEF of no less than 2.2[89].

Multi-Load Washers

In addition to the single-load machines, some commercial laundromats are also equipped with coin- or card-operated multi-load capacity washers. These types of machines are not regulated for water use by EPAct 2005 or DOE. Multi-load machines may be top- or front-loaded, hard mount (bolted to the floor) or conventional soft mount machines with capacities often exceeding 80 pounds per load (as compared to less than 20 pounds per load for a conventional single-load machine). Unlike the conventional machines, multi-load machines must be programmed to control settings (e.g., number of cycles, water levels per cycle). These settings can dictate the amount of water used by the machine and can be adjusted to improve efficiency.

[88] These updated requirements are effective January 8, 2013. See: www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers.html

[89] For information on Energy Star-qualified commercial clothes washers see www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CCW

Typical installation of multi-load clothes washing machines

Washer Extractors

Washer extractors are similar to multi-load washers, but they can be significantly larger, with capacities ranging from 30 to 800 pounds of laundry per load. Commonly used in OPLs[90], washer extractors remove water and detergent from clothes using high-speed, centrifugal force spin cycles and are only configured with a horizontal front-loading axis. Washer extractor efficiency is usually measured in gallons of water per pound of fabric, as opposed to gallons per cubic foot for commercial coin- or card-operated washers. Today's high-efficiency washer extractors reuse water multiple times within the wash-rinse cycle to achieve both water and energy efficiency.

Washer-extractors are designed to wash everything from relatively clean hotel towels and bedding to heavily soiled items from nursing homes and commercial kitchens. One significant difference between a washer extractor and a coin- or card-operated commercial washer is the ability to significantly vary the number of wash cycles. For example, washing lightly soiled sheets at a hotel may only require a three-cycle operation consisting of wash (detergent), bleach and rinse cycles. More heavily soiled laundry may require additional cycles including a first flush, an alkali cycle to adjust the pH, a wash cycle, a bleach cycle, several rinse cycles, another pH adjustment to return the pH to neutral, and a final rinse cycle. With each cycle, some machines have the ability to adjust water levels and the amount of hot or cold water used. This example illustrates the importance of the equipment operator separating laundry by its level of soil to determine the amount of water used for the total wash operation. Most washer extractors require two to four gallons of water per pound of fabric cleaned, depending upon the machine, the number of wash cycles used, and the water level settings. Equipment costs vary depending upon washer capacity, and range from $3,000 to $20,000.

Table Y shows the average volume of laundry produced by each of the most common OPL operations.

Table Y. Laundry Production in Common Operations

Type of On-Premise Laundry Operation	Pounds of Laundry	
	per person/day	per room/day
Hospitals		25
Nursing Homes		25
Motels		23
Hotels		36
University dormitories	20	
Jails	10	

[90] Koeller and Company, 2005. *Evaluation of Potential Best Management Practices – On-Premise Laundries*, for the CUWCC, November.

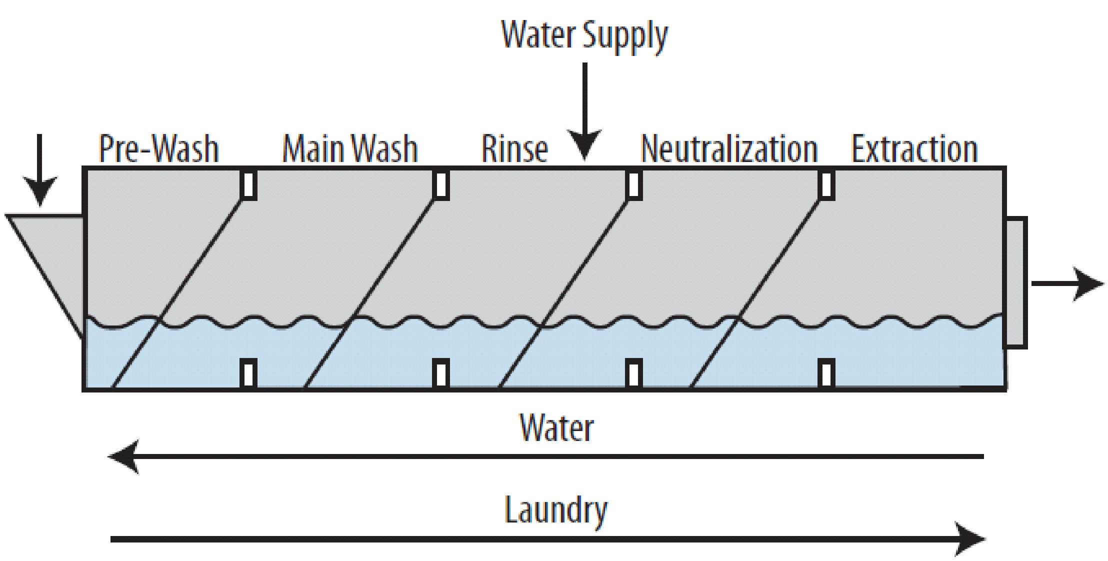
Prisons	12	

Source: Koeller and Company, 2005

Tunnel Washers

Since their introduction in the late 1960s, tunnel washers have become progressively more reliable. Though extremely expensive (many in excess of $1 million), they are now common in major hotel, hospital, cruise ship and other high-volume laundry applications[91]. Tunnel washers are large volume, continuous batch washers with long chambers and a series of compartments through which the laundry is pulled for soaking, washing, and rinsing. In addition to being used in some OPLs, tunnel washers are also used in off-site industrial laundry operations serving institutional users, such as hospitals, prisons, hotels, motels, and restaurants. They are capable of handling up to 2,000 pounds of laundry per hour. Tunnel washers are more water-efficient because the water moves in a counter-flow direction to the laundry, starting with the last rinse, so water is used through several cycles of the wash before being sent to the drain (Figure X). Tunnel washers are costly to purchase and install, but are capable of saving more water than washer extractors and require less operation and maintenance labor. Tunnel washers typically use two gallons of water or less per pound of fabric.

Figure X. Tunnel Washer



Ozone Laundry Systems

[91] Wikipedia, 2011. Tunnel Washers. en.wikipedia.org/wiki/Tunnel_washer

Ozone laundry systems can be used in a variety of OPLs. With these systems, ozone is injected into the wash as a powerful oxidant that reacts with dirt and organic materials. It also provides disinfection and whitening properties. Ozone can reduce the amount of detergents and other chemicals needed, lessening the amount of rinsing required.

Ozone systems are especially attractive where water/sewer costs are less than $4.00 per thousand gallons, and where annual laundry volume is relatively small. Ozone laundry systems are best suited for wash classifications in the medium and light range, generally not for heavy soil. Although some manufacturers claim that satisfactory results have been obtained in heavy soil laundering, most manufacturers will not venture into applications with large percentages of heavy soil or they exclude the mix of heavy soil from their savings calculations. Care must be taken at the laundry not to attempt to treat the heavy soil portion with ozone, as it must be laundered with conventional chemistry and high-temperature water.

Studies indicate that a minimum of 15 percent to 20 percent water and sewer savings can be achieved in many applications. Isolated opportunities may yield 30 percent to 35 percent savings in water consumption and sewer discharges. Some manufacturers claim savings up to the 50 percent - 60 percent range. Caution is very important in estimating savings with ozone laundry systems. Ozone laundry systems can cost between $10,000 and $25,000; paybacks are cited of less than two years.

Since ozone works best in ambient water temperatures, the water is not heated. Therefore, the water heating energy savings over conventional laundry systems is approximately 80 percent in most applications. Actual energy savings realized will depend upon the proportion of loads that must be washed with standard chemistry in high temperature, such as food and beverage linen, mop heads and bar rags. Other benefits include chemical savings, less wear and tear on linens, shorter wash cycles and potential labor savings.

Rinse Water Recovery Technologies

One of the concepts utilized in laundries is rinse water recovery. This type of system works by diverting water recovered from rinse-only cycles into a large holding tank near the laundry wash line. Whenever a washer calls for water in a soak, suds or wash cycle, the water stored in the rinse water holding tank is pumped into the washers. One manufacturer has been successful in installing their system in several institutional properties, such as Veterans Administration hospitals and state prisons, but these systems are not found in typical commercial laundry applications. They involve high initial cost and very long payback periods, often making them unattractive in commercial settings.

Operation and Maintenance

To maximize the efficient operation of commercial laundry machines, consider the following:

- Operate washers only with full loads. For washer extractor and tunnel washer applications, use a laundry scale to weigh loads to ensure the machine is filled to capacity.

- Separate and wash laundry based upon the extent to which materials are soiled. Also consider separating laundry by the number of cycles needed.
- In consumer applications (laundromats), install only front loading high efficiency machines (single load and multi-load) and set those machines to maintain the manufacturer-rated WF (or less).[92]
- Work with the equipment manufacturer and supplier to provide an ongoing service and maintenance program.
- Consult service personnel and the laundry's supplier of chemicals for the wash equipment to ensure that equipment is operating at optimal efficiency.
- Use detergents specially formulated for high-efficiency clothes washers.
- Install a computer-controlled wash and/or rinse water reclamation system in situations where the washers are not already equipped for internal water re-use and where permitted by local codes. These systems can save as much as 25 percent of a washer's potable water demand by diverting rinse water to a storage tank for later reuse as wash water. However, note the disadvantages mentioned earlier for such systems.
- Avoid excessive backflushing of filters or softeners; backflush only when necessary.

Retrofit Options

There are two main retrofit options to reduce water use associated with existing laundry equipment— water reuse/recycling and ozone systems.

Water Reuse/Recycling

Simple or complex recycle systems can be added to coin- or card-operated, multi-load washers, and washer extractors to recycle a portion or all of the water for reuse in the next wash. Simple recycle systems recover discharge from the final rinse in a multi-cycle operation for use in the first rinse of the next cycle. The water from these systems rarely needs treatment prior to reuse, so potential water savings are generally between 10 to 35 percent. Complex recycle systems treat the reclaimed water from wash and rinse cycles for use in all cycles of the next load and can save more than 85 percent of water used[93]. Complex recycle systems usually require water treatment before reuse and are costly to install and maintain.

It is important to evaluate space constraints when considering water reuse/recycling options. Space may not be available to accommodate additional recycling equipment or storage tanks. Recycling may also require adjustments in chemicals and detergents. Therefore, contact the chemical supply vendor during the planning process.

Ozone Systems

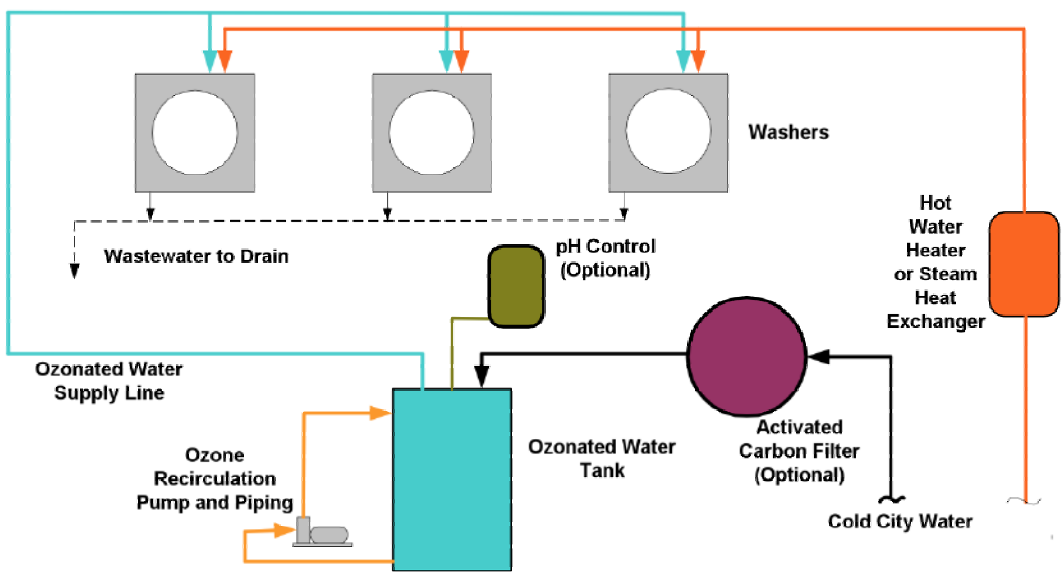
Ozone systems can be installed on all types of existing commercial laundry machines as retrofits, although they are not as common as a retrofit for tunnel washers. As noted earlier,

[92] East Bay Municipal Utility District. 2008. *WaterSmart Guidebook: A Water-Use Efficiency Plan Review Guide for New Businesses.* <www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook>.

[93] Koeller and Company, 2005. *Evaluation of Potential Best Management Practices – On-Premise Laundries*, for the CUWCC, November.

ozone systems work well on lightly soiled laundry, but are not recommended for heavily soiled laundry. In these applications, conventional washing, detergents, and hot water work best. See the figure below for ozone system configuration.

Ozone Laundry Systems



Replacement Options

When installing new laundry equipment or replacing existing equipment, consider the following:

- Select new coin- or card-operated, single-load clothes washer models that are Energy Star-qualified (http://www.energystar.gov/products). Energy Star-qualified washers use significantly less energy, water, and detergent compared to standard models.
- When installing new multi-load washers, choose models that use no more than 6.0 gallons per cycle per cubic foot of capacity.

- When installing new or replacing old washer extractors, choose machines with built-in water recycling capabilities that can store the rinse water from the previous load for use in the next load. These types of washer extractors can use less than 2.5 gallons of water per pound of fabric.
- For very large industrial or commercial laundries, consider replacing old washer extractors or multi-load washers with tunnel washers if large volumes of laundry will be processed.
- Ensure that large commercial laundry equipment is easily programmable so it uses no more water than required for the degree of soiling of the items being washed.
- Choose new machines that support remote diagnosis by the manufacturer to minimize maintenance costs and time associated with troubleshooting equipment problems.

Savings Potential

Water savings can be achieved through retrofitting existing laundry equipment to recycle wash water or reduce the amount of water required for rinsing, or by replacing existing laundry equipment with more efficient equipment. To estimate facility-specific water savings and payback, use the following information:

Coin- or Card-Operated Washer or Multi-Load Washer Retrofit

Use the following information to estimate water savings and payback potential that may be achieved with recycling or ozone retrofits. Water savings can vary based upon the water use and use patterns of the existing laundry equipment and the type of retrofit selected.

Water Use

To estimate the current water use from a commercial coin- or card-operated washer or multi-load washer, identify the following information and use Equation 1 below:

- Washer's water factor (WF) in gallons per cycle per cubic foot of capacity. Coin- or card-operated washers installed since the early 1990's will have a WF of 9.5 or less.
- Capacity of the washer.
- Average number of cycles per load.
- Average number of loads per year.

Equation 1:
Water Use of a Commercial Coin- or Card-Operated Washer or Multi-Load Washer (gallons/year) = Water Factor (gallons/cycle/ft^3 capacity) X Washer Capacity (ft^3) X Number of Cycles (cycles/load) X Number of Loads (loads/year)

Water Savings

Studies have documented water savings for retrofits with a simple recycling system, retrofits with a complex recycling system, and ozone system retrofits. To estimate water savings that may be achieved from retrofitting existing laundry equipment, multiply the water use of the existing laundry equipment (Equation 1) by the savings potential for the appropriate retrofit option indicated in the Table X (Equation 2).

Table X. Potential Water Savings From Commercial Laundry Retrofit Options

Retrofit Option	Water Savings Potential[94]
Retrofit with simple recycling system	10–35%
Retrofit with complex recycling system	85–90%
Retrofit with ozone system	10–25%

Equation 2:

Water Savings from Commercial Laundry Retrofit (gallons/year) = Current Water Use (gallons/year) X Water Savings Potential (%) from Retrofit in Table X

__Washer Extractor or Tunnel Washer Retrofit__

Existing washer extractors or tunnel washers can also be retrofitted to recycle and reuse a portion of the wash or retrofitted with an ozone system.

Water Use

To estimate the current water use from a washer extractor or tunnel washer, identify the following information and use Equation 3 below:

- Washer's water efficiency in gallons per pound of fabric.
- Average number of pounds of fabric per load.
- Average number of loads per year.

Equation 3:

Water Use of a Washer Extractor or Tunnel Washer (gallons/year) = Water Efficiency (gallons/pound of fabric) * Pounds of Fabric per Load (pounds /load) X Number of Loads (loads/year)

Water Savings

To calculate water savings that can be achieved from retrofitting an existing washer extractor or tunnel washer, multiply the water use of the existing laundry equipment as calculated using Equation 3, by the savings potential for the appropriate retrofit option indicated in the Table X above.

__Coin- or Card-Operated Washer or Multi-Load Washer Replacement__

Coin- or card-operated washer or multi-load washers can be replaced with more efficient laundry equipment. Look for washers with the Energy Star designation.

[94] East Bay Municipal Utility District. 2008. *WaterSmart Guidebook: A Water-Use Efficiency Plan Review Guide for New Businesses.* <www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook>.

Current Water Use

To estimate the current water use of a coin- or card-operated washer or multi-load washer, use Equation 1.

Water Use After Replacement

To estimate the water use of a more-efficient, replacement commercial coin- or card-operated washer or multi-load washer, substitute the water factor and washer capacity of the replacement equipment into Equation 1. Energy Star qualified coin- or card-operated washers will have a WF of 6.0 or less. An efficient multi-load washer will have a WF of 8.0 or less.

Water Savings

Calculate the expected water savings by subtracting the water use after replacement from the current water use.

<u>Washer Extractor or Tunnel Washer Replacement</u>

Existing washer extractors or tunnel washers can be replaced with more efficient laundry equipment.

Current Water Use

To estimate the current water use from a washer extractor or tunnel washer, use Equation 3.

Water Use After Replacement

To estimate the water use of a more-efficient, replacement washer extractor or tunnel washer, substitute the new washer's water efficiency in Equation 3. Existing washer extractors can be replaced with machines with built-in water recycling capabilities that use less than 2.5 gallons of water per pound of fabric. Efficient tunnel washers typically use two gallons of water or less per pound of fabric.

Water Savings

Calculate the expected water savings by subtracting the water use after replacement from the current water use.

Additional Resources

Alliance for Water Efficiency. Commercial Laundry Facilities Introduction. www.allianceforwaterefficiency.org/commercial_laundry.aspx *AND*

www.allianceforwaterefficiency.org/uploadedFiles/Resource_Center/Library/non_residential/EBMUD/EBMUD_WaterSmart_Guide_Laundries_Dry-Cleaning_Operations.pdf

DeBrum, Marc, Clear Water Tech, LLC, 2011. Ozone Laundry System Reduces Hotel's Operational Costs by 40%.

www.airbestpractices.com/sustainability-projects/water-conservation/ozone-laundry-system-reduces-hotels-operational-costs-40

Del Ozone, 2011. *Recapture Ozone Laundry Costs in 12 to 24 months.*

www.delozonelaundry.com/our-program/roi-of-ozone.php

East Bay Municipal Utility District. 2008. *WaterSmart Guidebook: A Water-Use Efficiency Plan Review Guide for New Businesses*. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

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Sydney Water, 2001. *Save Water, Money, and the Environment – Laundries.*

www.sydneywater.com.au/Publications/FactSheets/SavingWaterLaundries.pdf

U.S. Department of Energy, 2000. Federal Energy Management Program (FEMP), BMP 13. May. www1.eere.energy.gov/femp/program/waterefficiency_bmp13.html U.S. Environmental Protection Agency's Energy Star Program. *Energy Star Products*. www.energystar.gov/products

Vancouver Island Health Authority, 2010. New Tunnel Washer System at Cumberland Regional Laundry Facility.

www.viha.ca/about_viha/news/news_releases/cumberland_laundry.htm

VWR International, 2011. Lab Animal Science. www.vwrsp.com/programs/animal_science/page.cgi?tmpl=smc

Water Energy Laundry Consulting, 2011. Tunnel Washers.

laundryconsulting.com/equipment/washers/tunnel-washers/

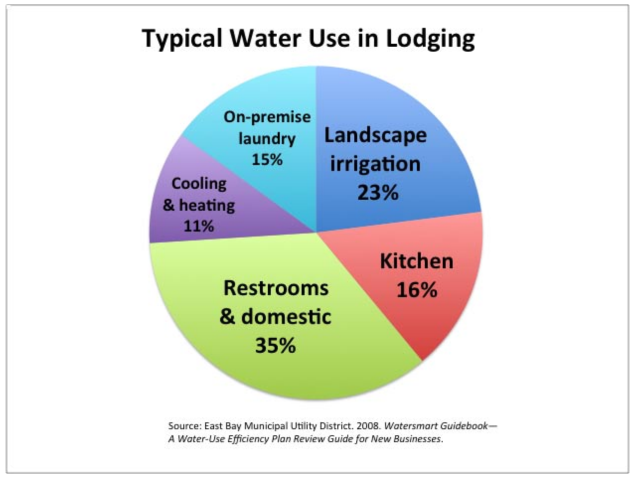
Water Energy Laundry Consulting, 2011. Ozone Laundry Systems.

laundryconsulting.com/solution/green-laundry-technology/ozone-laundry-systems/

Wikipedia, 2011. Tunnel Washers. en.wikipedia.org/wiki/Tunnel_washer

7A3 Hospitality: Lodging - Hotels and Motels

Introduction



In California, the lodging industry encompasses approximately 6,500 establishments, each with an average of roughly 150 rooms[1]. The largest lodging facilities may be part of a mixed-use property and also include residential apartments, retail stores, recreation facilities, landscaping, and office space at the same site, but this is not typical of most establishments.

Each activity within a hotel or motel has its own special need for water. Smaller facilities have guest-room water demands similar to those of the larger properties, but do not usually recreation facilities and heavily irrigated landscapes. Typically, the largest lodging properties require water for guest rooms, on-premise laundries, HVAC systems, public restrooms, food service, recreation, landscape, and maintenance.

Restrooms and Plumbing

Appropriate water-saving technologies exist with all restroom fixtures, both in the public areas and guest rooms. Refer to report **Section XXX, General Building Sanitary and Safety Applications** for a discussion of water use efficiency opportunities and best management practices for restrooms and other operations in lodging facilities.

If available, and where codes and health departments permit, non-potable, treated water may be used for fixture flushing (toilets and urinals only) and landscape irrigation applications. Refer to report **Sections XXX Commercial Landscape and VII.C.6 Alternate Water Sources** for information and best management practices related to these topics.

In guest rooms, additional BMPs to be considered are:

- Prohibit multiple showerhead installations in a shower stall.
- Substitute showers for bathtubs. Where bathtubs are necessary, use low-volume tubs.

Cooling and Heating Systems

Water use related to cooling and heating amounts to 11 percent of total water consumption in the typical lodging facility. Cooling towers and boilers are the primary systems accounting for this use. Refer to report **Sections XXX Building Systems – Thermodynamic Processes** for information and best management practices related to this topic.

[1] California Hotel and Lodging Association, www.calodging.com

On-Premise Laundries

On-premise laundries account for 15 percent of all water consumption in the typical lodging property. Refer to report **Section XXX Fabric Cleaning and Washing Equipment and Technologies** for a discussion of water use efficiency opportunities and best management practices for on-premise laundries in lodging facilities.

Floor Cleaning

Best management practices for floor cleaning include:

- Discourage the use of open hoses for cleaning. While wet methods may be used, install self-closing nozzles, limiting flow to 5 gpm. Also refer to report **Section XXX Commercial Food Service, Washing and Sanitation** for further information on floor cleaning, available equipment, and best management practices.
- Install drains close to areas where liquid discharges are expected.
- Arrange equipment for easy use of a mop and squeegee system or floor-cleaning machine.

Ice Machines

Ice machines installed on guest room floors as well as in the central kitchen use water for ice and sometimes for cooling the compressor. Best management practices include:

- Select ENERGY STAR qualified ice-making machines that are air-cooled, using remote heads to expel warm air outside the workspace and customer areas. Air-cooled machines are preferred over cooling-tower loops.
- Select energy-efficient flake or nugget machines rather than cube-ice machines. If cube-ice machines are used, those that meet CEE Tier 2 or 3 efficiency standards are preferred.
- Also refer to report **Section XXX Commercial Food Service, Commercial Ice Machines** for more information on available equipment and their efficiencies.

Kitchen Operations

On-site kitchens in typical lodging facilities consume about 16 percent of the potable water use by the facility. For best management practices and equipment options associated with food service, refer to report **Section XXX Commercial Food Service.**

Submetering

Separate metering of water-using systems and building areas is recommended where possible in order to ensure that the costs of water use and wastewater disposal are accurately tracked. Tracking actual use through a building management system connected to a series of submeters can disclose operating issues (leaks, equipment malfunctions) that might have previously remained undiscovered. For a full discussion of submetering and best management practices associated with that topic, refer to report Section XXX **Building Meters, Submeters, and Management Systems.**

Landscape

Landscape irrigation represents 23 percent of water use in the typical lodging property. It is important to ensure the use of climate-appropriate plant materials in the landscape and to install and monitor efficient irrigation systems that apply only the amount of water necessary. For further information and best management practices related to landscape and landscape irrigation, refer to report **Section XXX Commercial Landscaping.**

Other

Other recommended best management practices for lodging facilities include:

- Install automatic shutoff and solenoid valves on all hoses and water-using equipment.
- Encourage guests to engage in "green" practices for bed linens and towels to avoid unnecessary laundry use.
- Conspicuously mark fire-protection plumbing so no connections will be made other than those for fire protection.
- Install flow-detection meters on fire services to reveal unauthorized water flows.

CASE STUDY – San Francisco Hotel

Significant water savings and reductions in maintenance service calls resulted from a major toilet retrofit project in the Park 55 Wyndham Hotel in downtown San Francisco. The hotel was originally constructed in 1984 and opened for business as a Ramada Inn. With 1,012 guest rooms and 1,030 guest room toilet fixtures, the Parc 55 is one of the largest hotels in that city. At the time of construction, all guest rooms were fitted with 3.5 gallons per flush gravity-fed toilet fixtures.

In late 2007, hotel management undertook the toilet replacement project by selecting a pressure-assist HET to replace the older non-efficient gravity-fed fixtures. The fixture selected functions at 1.0 gallon per flush and was ideally suited to guest room use. In December 2007, the physical replacement of fixtures began, concluding in October 2008, a rate of about 100 replacements per month.

At the conclusion of the retrofit project and after the 2008 holiday season, the per unit (or per guest room toilet) reductions attributable to the retrofit program were determined as follows:

Water Consumption – "Before" and "After" Replacement

	Water Consumption
"BEFORE" - Water use prior to retrofit project (22 months – January 2006 to October 2007)	4,707 units per month[95] = 3,521,000 gallons per mo.
"AFTER" – Water use following retrofit project (8 months November 2008 to June 2009)	3,474 units per month = 2,598,000 gallons per mo.
Water use reduction – 1,030 guest room toilet fixtures[96]	1,233 units per month =

[95] A unit is equal to 100 cubic feet or 748 gallons, and is used for utility billing purposes.
[96] Savings based upon a nominal 90% occupancy

	923,000 gallons per month
Water use reduction – per guest room toilet fixture	893 gallons per month = 10,700 gallons per year (29 gallons per day)

The daily per fixture water savings of 29 gallons amounts to a savings of approximately $170,000 annually on water and sewer charges at 2009 rates in San Francisco.

The secondary major benefit to the replacement program was the reduction in service calls upon hotel maintenance (and associated labor cost reductions), due to improved flush performance and fixture reliability, and elimination of frequent repairs. Annually, the replacement is projected to reduce maintenance labor by several hundred hours per year.

Additional Resources

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7A4: Medical and Laboratory Equipment & Processes

Hospitals, dental offices, laboratories, aquariums, and research facilities are found in most large communities. All of these facilities have water uses such as restrooms, landscape, and often cooling towers and boilers that are common to many types of facilities. They also have equipment and operations not commonly found in other facilities, including:

1. Sterilizers
2. Instrument, glassware, cages, racks, and bottles
3. Vacuum systems
4. Hood systems
5. Vivarium and Aquarium operations
6. X-ray film developers.

This section will discuss each of these six types of equipment or operations.

Sterilizers

Description of Sterilizer Types - Sterilization of surgical instruments, fluids, pharmaceuticals, equipment, and bandages is an integral part of modern medical and laboratory practice. Over the years, different sterilization techniques have been used,

1. chemical (ethylene oxide, peroxides, ozone, etc.)
2. radiation
3. dry heat
4. steam sterilization.

Since the first three techniques do not require significant amounts of water, this discussion focuses on steam sterilizers. Steam sterilizers and autoclaves may be divided into four categories. The first three are for medical and laboratory type facilities and include (1) table top, (2) gravity, and (3) vacuum type systems. The fourth are autoclaves used in industrial operations, and they are not covered in this discussion.

Steam sterilizers have two major configurations: tabletop and freestanding. Tabletop-type sterilizers have a filled water reservoir and a heating element to make steam. They use little water. Freestanding sterilizers include both gravity and vacuum type systems. In both, steam is injected into a closed chamber housing the instruments or equipment to be sterilized. Steam used for this purpose must be "clean steam" meaning that the water used to make the steam has been demineralized. Both types have application in the medical, pharmaceutical, and in science and engineering laboratories.

In the gravity type, steam pushes air out of the chamber filling the top of the chamber with steam. The air is said to be “drained” by gravity since it weighs more than the steam. With the vacuum type, a vacuum pump draws the air out. The vacuum type dries the sterilized materials more quickly than the vacuum type.

In both cases, the sterilizer chamber is surrounded by an outer chamber that is also filled with steam to help keep the whole cavity hot. As the steam in the outer chamber condenses, it is discharged through a steam trap to the sanitary drain.

Steam sterilizers are common in hospitals and biological or medical laboratories. The California Urban Water Conservation Council report, PBMP-Year One-Chapter VI-Sterilizer Savings Assessment reports that there over 8,400 medical steam sterilizers in California.

Figure 1 Front of Typical Steam Sterilizer

Figure 2 Sterilizer Being Loaded with Surgical Packs

Water Use by Sterilizers

Freestanding-type sterilizers, which are the most common found in medical facilities, use large quantities of water in their operation. Table-top sterilizers, on the other hand, use only small amounts of water, and the other types use little if any.

Freestanding sterilizers use water in three ways. The first is the consumption of steam, which, in most cases, represents is the least amount of water use. Only a few gallons (5 to 12 gallons depending on model and size) get used per complete sterilization cycle.

A major water use for older sterilizers is associated with plumbing code regulations that prohibit water hotter than 140^{o}F from being discharged to a sanitary sewer. The sterilizer steamtraps only discharge a couple of quarts of water at the most when opened and this occurs infrequently during the day. Since the water from the steam trap that discharges the condensate from condensed steam from the outside steam jacket is at 112^{o}F.

For models made before the mid 1990s, water was simply plumbed to run continuously down the drain, commonly with flow rates of 0.3 to 1.5 gallons per minute. The purpose of this water was to be available any time the steam trap opened to cool the condensate as it entered the drain. Since the mid 1990's, tempering kits have been included as standard devices. These kits have solenoid valves connected to thermal sensors that only open and allow water to flow when condensate is actually flowing. Retrofit kits are available for older models.

Based on the California Urban Water Conservation Council report, PBMP-Year One-Chapter VI-Sterilizer Savings Assessment and work done at the University of Washington in Seattle, adding a water tempering kit to older models can reduce water use for this purpose from 68 to 98 percent and can save 1,500 to 3,000 gallons a day. The installed cost for these retrofit kits ranges from 2,2,500 to $5,500 per kit.

Figure 3. Example of a Retrofit Water Tempering Device

The most water efficient and energy efficient practice is to return the condensate to the boiler. Unfortunately, most hospitals are not equipped to do this. Another method used in several U.S. Green Building Council LEED certified facilities is to use the building's chilled water system to cool the condensate. An even more water efficient strategy was is to install individual boilers on each autoclave so the condensate can be returned directly, but since these boilers typically use electricity, energy costs rise.

The way in which a vacuum is created significantly impacts the amount of water used for this operation. In the past, a simple venturi system was used to create a vacuum (Figure 4.).

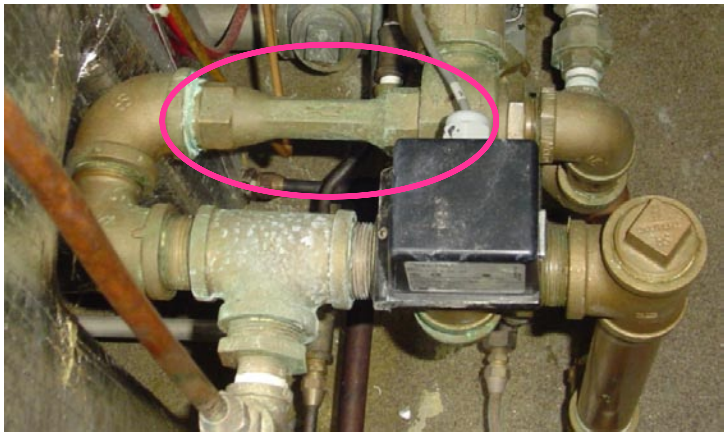


Figure 4. Venturi Vacuum System on a Sterilizer

These systems can use 6 to 18 gallons per minute according to the California Urban Water Conservation Council report, PBMP-Year One-Chapter VI-Sterilizer Savings Assessment. Liquid ring vacuum systems can reduce water use by about 75 percent. The retrofit liquid ring vacuum systems cost over $20,000 installed. Table 1 summarizes the impact installing a liquid ring vacuum pump on total water use.

Table 1. Comparison of Vacuum System Water Use for Steam Sterilizers*
Based on 10 uses a day, and 250 days per year

Venturi Ejector Water Use (gpm)	Gallons Used per Cycle	Venturi Gallons per Year	Liquid Ring Gallons per Year
6	**189**	**495,000**	**123,750**
11	**363**	**907,500**	**226,875**
18	**594**	**1,485,000**	**371,250**

*Source: California Urban Water Conservation Council report, PBMP-Year One-Chapter VI-Sterilizer Savings Assessment

In Europe, another technology is emerging that would bring this water use to zero. Cisa, an Italian firm now markets a dry vacuum system for sterilizers. Called the “Aquazero," it has not yet been approved by the U.S. Food and Drug Administration 510K regulations, so it not available in America at this time for medical facilities. (*www.cisagroup.it/site/prodotti/english/.../**aquazero/aquazero**.pdf). In research facilities and industrial operations, however, dry vacuum systems are in use, reducing water use to zero. The systems cost more than liquid ring pumps. (See section on vacuum systems).)*

Best Management Practices (BMP's) for Sterilizers

- If possible, choose something other than a free-standing steam sterilizer, such as a chemical, radiation, or dry heat sterilizer or even a table-top steam sterilizer.
- Ensure that free-standing steam sterilizers are equipped with water tempering devices, that the steam is returned to the boiler, or that it is condensed using a chilled water condenser.
- Where not cost prohibitive, consider stand-alone boilers on each autoclave.
- Prohibit the use of venturi vacuum systems on vacuum sterilizers.
- Use dry vacuum systems whereever allowed by the FDA 510K regulations.

Vacuum Systems

Vacuum systems are used throughout the medical and scientific community as well as in all types of industries. The most rudimentary “vacuum pump" is a venturi system, also called an aspirator system. Aspirators are found in many high school and college laboratoriesthat only use them for a few hours each semester. Because of their infrequent use, these pumps are not the focus of this BMP, but using aspirator or venturi systems on frequently used equipment, such as steam sterilizers, is an extremely wasteful practice. (See section on sterilizers.)Mechanical pumps may be used for medical, dental, and other low vacuum laboratory applications of 0.01 mbar (.0074 millimeters of mercury). The end use determines that size of the pump. Dental offices pumps range from 1.0 to 4.0 horsepower (hp), while a central vacuum pump in a medical facility requires 5.0 to 20.0 hp.

Vacuum pumps can use water in two ways:

1. for pump cooling - use only air cooled pumps or those connected to a cooling tower loop or chilled water systems (See Thermodynamic Processes), or
2. for creating a seal.

Vacuum pumps can either be “dry” or “wet”—based on how the vacuum seal is generated. Wet pumps use a closed impeller that is sealed with water to generate the vacuum. Dry pumps do not use water to generate the seal for the vacuum, so they do not connect to a water supply. Instead, they create vacuums with turbines (fans) or use positive displacement devices, such as vane pumps, claw pumps, or piston pumps.

Dry systems tend to be the most energy efficient. A review of product literature shows energy savings in the range of 25 to 50 percent. However, dry systems cost more to purchase. A typical dental liquid ring pump, for example, costs about $2,000, while dry systems cost from $5,000 to $7,500 for the same dental clinic. In addition, dry pumps must be vented since they use air instead of water as the moving agent.

Figure 5. A Dry Vacuum System at a Dental Office

The amount of water that may be saved is significant. Literature shows that a typical dental liquid ring vacuum uses approximately one-half-gallon minute per horsepower, so a two-horsepower pump would use approximately 1.0 gpm. An office that is open for eight hours uses 480 gallons. For larger medical installations, the relationship of water to horsepower is similar, but the pumps are much larger.

Central vacuum systems serve the entire hospital with vacuum. These systems should always be dry with air cooling or with cooling that is part of the chilled water loop. Any type of pass-through cooling should be eliminated.

Some special laboratory facilities that produce acid fumes may have to use a liquid ring pump to prevent corrosion of the pump. In these cases, water recirculation systems may be used. In these systems, a pump recirculates water through the pump, and that water is cooled either by air or a chilled water loop. A portion of the water must be continuously discharged to keep the chemicals from building up. Typically, these units can reduce water use by 50 percent to 75 percent depending on the chemicals involved.

Best Management Practices (BMPs) for Vacuum Systems

- Use dry vacuum systems for all medical and dental processes.
- Eliminate pass through cooled equipment.
- Only use liquid ring pumps for conditions where acid fumes and other very corrosive materials are being handled.
- If a liquid ring vacuum pump must be used, consider a non-potable source of water such as an on-site source or recycled water.

Laboratory Fume Hoods

A fume hood is a ventilated enclosure where hazardous materials can be handled safely to limit exposure. Fume hoods draw contaminants within the work area away from the user to minimize contact, and they exhaust fumes through a ventilation system to remove contaminants from the building. Most hood exhausts can be directed to the outside without additional treatment. These hoods do not use water to clean the exhausted gases. In some cases though, contaminants that pose a hazard or pollution risk must be removed using either a dry or wet "scrubber system."

Figure 6. A Typical Hood System in a Lab

The type of system chosen will depend on the substances in need of removal. Table 2 summarizes some of these choices.

Perchloric acid, a corrosive liquid, poses a specific hazard. While not combustible, under some circumstances it may act as an oxidizer and present an explosion hazards. Organic materials are especially susceptible to spontaneous combustion if mixed or contacted with perchloric acid.

Special perchloric acid wash-down system hoods must be used to control these fumes and wash perchloric acid deposits from the duct linings. To prevent corrosion and reduce explosive perchlorate build-up, perchloric acid fume hoods use a system of nozzles to wash down the fume hood and exhaust system surfaces after each period of use. Older perchloric acid hoods ran water continuously. The flow of water in newer hoods can be controlled to operate only when the hood vent fan is operating. In all cases, the hood should be operated according to instructions for that hood.

Table 2. Fume Hood Scrubber Systems				
Filtering mechanism	**How does it work?**	**How is contaminant removed?**	**Does it use water?**	**What are the special considerations?**
Wet scrubber	Packed bed system which is wetted with recirculated scrubbing liquor dissolves contaminants in air and releases cleaned air	Scrubbing liquor with dissolved contaminants is blowndown and the liquor is periodically replenished with fresh water	Yes	None
Inert adsorbents	Inert adsorbents, such as activated carbon, activated alumina, and molecular sieves, adsorb contaminants	Spent adsorbent must be changed or regenerated regularly	No	Adsorbent systems are not effective in removing high concentrations of contaminants (i.e., spills inside the hood). These systems require a consistent check on contaminant concentrations and maintenance of the adsorbent.
Chemically active adsorbents	Inert adsorbents impregnated with a strong oxidizer, such as potassium permanganate, which react with and destroy organic vapors	Spent adsorbent must be changed or regenerated regularly	No	Adsorbent systems are not effective in removing high concentrations of contaminants (i.e., spills inside the hood). These systems require a consistent check on contaminant concentrations and maintenance of the adsorbent.

Wet scrubbers simply pass water over a packed medium as the exhaust gas is forced or drawn through the packed medium with fans. The water and solution of reactive chemicals are recirculated through the systems. Water is evaporated in the process, and some water must be bled off to prevent the buildup of chemicals and salts in the system. Figure 7 shows the pumps and back side of a hood scrubber system.

Figure 7. Fume Scrubber for a Microelectronics Lab

Best Management Practices for Laboratory Hoods

- Use dry hoods to the maximum extent possible.
- Only choose scrubber systems if that is the only type of system that will work.
- If a hood scrubber system must used, be sure it is a type that recirculates water.
- Control scrubber blowdown with a conductivity controller or other appropriate control device.
- Use an alternate, non-potable source of water for the scrubber wherever possible.

Instrument, Glassware, Cage, Rack, and Bottle Washers

Laboratory and medical facilities must wash a variety of types of equipment of all sizes and types, including glassware in labs, surgical instruments in hospitals, and animal cages at vivariums and animal research facilities. In all cases, the articles being washed must be thoroughly cleaned and disinfected. In many cases, the equipment or instruments are then sterilized in a steam sterilizer.

For ***glassware washers***, no specific efficiency standards have been set, but major manufacturers are beginning to offer more energy and water efficient models. In the interim the consider following these best management:

Operation, Maintenance, and User Education: For optimum glassware washer efficiency:

- Only run glassware washers when they are full. Fill each glassware washer rack to maximum capacity.
- Operate the glassware washer near or at the minimum flow rate recommended by the manufacturer.
- Use detergents that clean most effectively so rinsing is simpler.
- If the number of rinse cycles can be chosen, select as few rinse cycles as possible, considering the cleanliness requirements of the glassware.

Retrofit Options: Consider installing a water recycling system that reuses rinse cycle wastewater as wash water in the next load.

Replacement Options: When purchasing a new glassware washer or replacing an existing one, look for models with these features:

- Cycle selection that allows users to optimize rinse cycles for both effective and efficient cleaning.
- Reuse of final rinse water as wash water for the next load.
- Water intake monitoring to adjust the amount of water used based on load size.

Washer - Disinfectors are used to clean surgical and medical instruments before they are sterilized. They are typically found in central sterilizations operations in hospitals. These operations are usually abbreviated as "Central Sterile" or "CS" operations. There are stand-alone batch washers for smaller operations and large tunnel washers that resemble conveyor dishwashers in operation. A search of product literature shows that water and energy conservation have become major selling points for the current generation of surgical and medical instrument washer - disinfectors. Better instrumentation and computer control along with better design are cited as the reasons for these increases in efficiency.

Figure 8. Batch and Conveyor (Tunnel) Washer - Disinfectors in Central Sterile

Until standards for water efficiency are established, the ***best management practices*** for this type of operation is to only operate when needed and search the literature for water and energy efficiency when purchasing new equipment.

Cage, Rack, and Bottle Washers are found in vivariums and animal research facilities. The equipment ranges from conveyor washers for mice and rat cages that closely resemble conveyor dishwashers to large compartment washers that can hold carts of cages or large primate cages. The following Best Management Practices information is provided as part of the U. S. Environmental Protection Agency's "Labs for the 21st Century" program.

Figure 9. Small Cage Washer

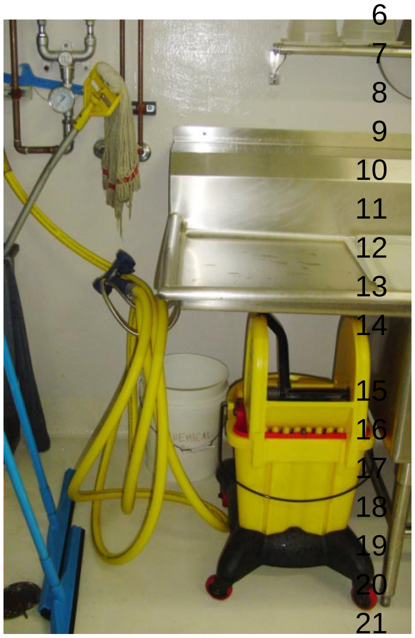
Vivarium Equipment

- *Replace older inefficient cage and rack washers with more efficient models. Look for models that recycle water through four cleaning stages using a counter-current rinsing process. In counter-current rinsing, the cleanest water is used only for the final rinsing stage. Water for early rinsing tasks (when the quality of rinse water is not as important) is water that was previously used in the later stages of rinsing operations.*
- *Retrofit existing cage and rack washers to make use of counter-current flow system to reuse final rinse water from one cage-washing cycle in earlier rinses in the next washing cycle.*
- *Use tunnel washers for small cage cleaning operations.*
- *Sterilize and recirculate water used in automatic animal watering systems instead of discharging water to the drain. Consider using water that cannot be recycled for drinking due to purity concerns in other non-potable applications, such as cooling water make-up or for cleaning cage racks and washing down animal rooms. (http://www1.eere.energy.gov/femp/program/waterefficiency_bmp12.html#dss)*

Vivariums and Aquariums

Aquariums, vivariums (research mice facilities), and large animal research facilities are found at most universities and pharmaceutical research facilities.

Vivariums and other animal care facilities require regular cleaning and care. The washing of cages, bottles, and feeding containers is covered under the section on washing and disinfecting.



The care and washing of the facilities and floors often requires hose down. Using squeegees and brooms to first clean an area significantly reduces the amount of water needed for floor washing. For large animals, slotted floors with manure rakes are sometimes used. Choosing hose nozzles with the minimum flow rates that accomplish the cleaning, increasing pressure to reduce water use, and using floor cleaning equipment can all help reduce water use, as will designing floors and walls to be easily cleanable.

Automatic animal watering systems provide drinking water to laboratory animals. There are two types of automated animal watering equipment. They differ in their method of bacterial build-up prevention: flushing animal watering systems and recirculating animal watering systems. Flushing animal watering systems use a periodic, high-pressure flow to "flush" and remove bacteria from piping. Residual chlorination is typically used to further control bacterial growth. Recirculating animal watering systems control bacteria, by means of a constant flow of water treated with ultraviolet disinfection or other methods before distribution for animal watering. Flushing systems use more water than recirculating systems because water is discharged to the drain after the flushing cycle is complete.

Automatic water systems require regular observation of the systems and the animals. If not maintained properly, they pose the risk of cage flooding or clogged valves. They do not allow for monitoring of animal water intake. Before choosing an automatic watering system, these issues should be considered.

For optimum animal watering system efficiency, consider the following:

- For animal watering systems that use flushing, minimize the number of flushing cycles, while ensuring sufficient control of bacterial growth.
- Consider collecting and reusing wastewater from animal watering systems for other purposes within the facility, matching an end use with the level of water quality that exists or that can be achieved through water treatment.

Aquariums are common in any research facility working with fish and aquatic plants and animals. For smaller systems, good filtration systems significantly reduce water use.

For larger aquariums, the principles are the same but the equipment is much larger and special treatment systems are sometimes needed as seen in Figure 10's sea foam remover and Figure 11's large sand filtration systems. Large aquariums often capture the backwash from these larger filters, treating and filtering it to recover as much water as possible.

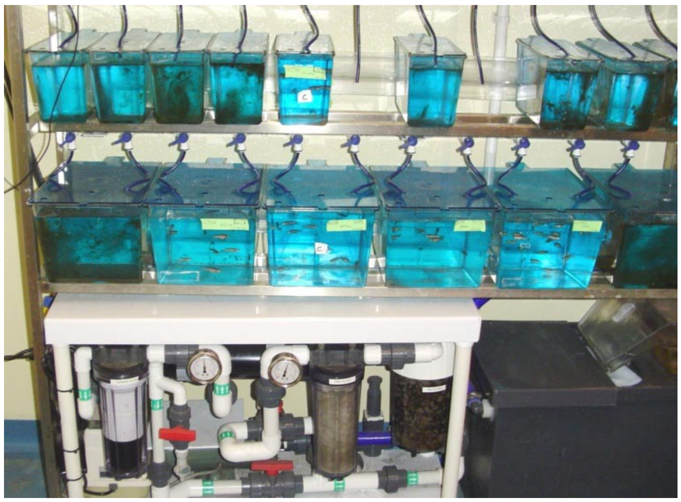


Figure 10. Filtration System for Ichthyology Lab Aquariums

Figure 11. Sea Foam "Fractionator"

Figure 12. Large Aquarium Sand Filters

Best Management Practices for Aquariums include the proper use of filtration equipment, using water treatment systems to remove specific contaminants that may be unique to the situation, and proper care and cleaning of aquarium surfaces.

Photographic and X-Ray Equipment

Traditional film processing is extremely water-intensive, with water required for both the image development and printing process. Old 35-mm film could use as much as 30 gallons of water per roll developed. The requirements in the late 1970s to recover silver and other heavy metals at film process centers began the process of reducing water use. Modern 35 mm film processing equipment, such as that found at pharmacies and department stores, uses only a few ounces of water to develop a role film.

Digital technology represents a much more significant development since it has eliminated the need for film development. Water conservation considerations for film development, including large frame X-ray film development, must be tempered by the fact that extensive use of wet processes may not even exist in 20 years except for special "artistic" endeavors. Dry printing processes similar to laser printing are also available that do not use water.

In old X-ray equipment, water is sometimes also used for equipment cooling. Some X-ray film processing machines require a constant stream of cooling water flowing at a rate of 0.5 to 2.5 gallons per minute (gpm) to as much as 3.0 to 4.0 gpm[97] to ensure acceptable image quality. Cooling water with a flow rate as low as 0.5 gpm can discharge more than 250,000 gallons of water annually. In the past, special "WaterSaver" recirculation equipment that only operates the cooling system and the film rinse purge systems when needed was available, but with the advent of modern digital technology and the rapid disappearance of old film type equipment, sales of this equipment have plummeted.

The new digital X-ray technology is rapidly replacing the old film based equipment because of its medical value for radiology. Just like home digital pictures can be enhanced to see specific detail, digital x-rays can, and they can be sent by e-mail to family physicians and others.

New medical digital equipment is very expensive, potentially costing more than a million dollars to convert a large medical center radiology department to digital equipment. Water savings alone would not be a major cost savings for this conversion. It is being driven by the need of medical facilities to have the most up-to-date equipment.

Best Management Practices for Photographic and X-Ray Equipment

- If old film type equipment is being used, install a WaterSaver kit.
- Encourage the switch to digital equipment.

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Van Gelder, Roger, and John Leaden. 2003. *Field Evaluation of Three Models of Water Conservation Kits for Sterilizer Trap Cooling at University of Washington*. University of Washington. <http://www.p2pays.org/ref/50/49036.pdf>.

Water Conservation at Tufts New England Medical Center (NEMC). www.h2e-online.org/pubs/tuftsh2o. doc

7A5: Office Buildings

Introduction

Office buildings may combine residential apartments, hotels, retail stores, and office space into a mixed use structure. Each has its own special needs for water. Typically, large buildings require water for HVAC (cooling), restrooms, food service, and maintenance.

Restrooms and Plumbing

High-efficiency plumbing fixtures and fittings are critical to achieving water use efficiency, since restrooms and related domestic uses are the primary water consumers office buildings.

Appropriate water-saving technologies exist with all restroom fixtures, both in the public areas and tenant spaces. Refer to report **Section XXX General Building Sanitary and Safety Applications** for a discussion of water-use efficiency opportunities and best management practices for restrooms and other operations in office buildings.

If available, and where codes and health departments permit, non-potable, treated water may be used for fixture flushing (toilets and urinals only) and landscape irrigation applications. Refer to report **Sections XXX Commercial Landscape and XXX Alternate Water Sources** for information and best management practices related to these topics.

Cooling and Heating Systems

Water use related to cooling and heating amounts to about 28 percent of total water consumption in the typical office building. Cooling towers and boilers are the primary systems accounting for this water use.

Cooling Systems

Modern office buildings need to remove heat generated by the occupants, as well as from computers, lights, kitchens, and other operations. Energy-efficient equipment may reduce such waste heat, which is usually removed by a central refrigeration system and compressor. The compressor may be air- cooled or connected with a circulating loop to a cooling tower or evaporative condenser. As warm water from the compressor is directed through the cooling tower, some water evaporates, cooling the remaining water, which returns to cool the equipment. Measures to reduce water waste in cooling towers include:

- Operating towers at a minimum of five cycles of concentration using potable water, depending upon the chemistry of the make-up water used, including considerations for reclaimed water or other on-site sources of quality water. In certain cases, where source water quality is high, CCs of as much as 15 may be achieved.
- Providing adequate training to cooling-tower operators and maintenance personnel.
- Performing a life cycle cost analysis, including all operating, capital, and maintenance costs, to determine the cost effectiveness of a cooling tower vs. air cooling.
- Equipping cooling towers with conductivity controllers, make-up and blowdown water

meters, and overflow alarms.

- Using dry cooling or once-through cooling with non-potable water where feasible.
- Using high-efficiency drift eliminators that reduce drift loss to less than 0.002 percent of circulating water volume for cross-flow towers and 0.001 percent for counter-flow towers.
- Evaluating the processes in the plant for maximum energy efficiency and waste-heat recovery, since a more efficient building will reject less heat to the cooling tower.

Heating Systems

Steam boilers and hot-water boilers provide heat and hot water in some buildings. Closed-loop systems return water and steam condensate to the boiler for reuse, saving energy and water. Open-loop systems expend the water or steam without return to the boiler. Several water-efficiency actions are available to optimize water use.

- Install make-up meters on feed-water lines:
    - to steam boilers and water boilers of more than 100,000 Btus per hour.
    - to closed-loop hot-water systems for heating.
- Install recirculating hot-water systems for large buildings.
- Equip steam boilers of 200 boiler horsepower (hp) or greater with conductivity controllers to regulate top blowdown.
- Install condensate-return meters on steam boilers of 200 boiler hp or greater in closed loop systems.
- Operate closed-loop steam systems at twenty cycles of concentration or greater (5 percent or less of make-up water).
- Install code-compliant steam-distribution lines and equipment with steam traps.
- Ensure that boiler-temperature and make-up meters are clearly visible to operators.
- Ensure that discharge pipes are easy to inspect for flow. Provide visible indicators that will show whether the valve has activated, thereby reducing plumbing leaks due to repeated openings of water-temperature- and pressure-relief valves (TPRVs).

Refer also to report **Sections XXX Building Systems – Thermodynamic Processes** for further information and additional best management practices related to this topic.

Water Treatment

Water treatment is used in many commercial operations, including food services, laundries, pharmacies, and food service operations, all of which can be present within a multi-tenant office building. The types of treatment and best management practices associated with those types are fully described within **Section XXX Water Treatment Processes**. However, the most important measures to improve the efficiency of water treatment include the following:

- For all filtration processes, install pressure gauges to determine when to backwash or change cartridges, followed by backwash based upon pressure differential.
- Set recharge cycles by volume of water treated or by using conductivity controllers for all ion-exchange and softening processes.
- Avoid the use of clock timers for softener-recharge systems.

- Use water treatment only when necessary.

Kitchen

On-site commercial kitchens in office facilities can account for a significant proportion of the potable water use by the facility. For best management practices and equipment options associated with food service, refer to report **Section XXX Commercial Food Service.**

Ice Machines

Ice machines use water for ice and sometimes for cooling the compressor. Best management practices include the following:

- Select Energy Star qualified ice-making machines that are air-cooled, using remote heads to expel warm air outside the work space and customer areas. Air-cooled machines are preferred over cooling-tower loops.
- Select energy-efficient flake or nugget machines rather than cube-ice machines. If cube-ice machines are used, those that meet Consortium for Energy Efficiency (CEE) Tier 2 or 3 efficiency standards[98] are preferred; avoid products that are water cooled.
- Refer to report **Section XXX Commercial Food Service, Commercial Ice Machines** for more information on available equipment and their efficiencies.

Floor Cleaning

Best management practices for floor cleaning include:

- Discourage the use of open hoses for cleaning. While wet methods may be used, install self-closing nozzles, limiting flow to 5 gpm. Also refer to report **Section XXX Commercial Food Service, Washing and Sanitation** for further information on floor cleaning, available equipment, and best management practices.
- Install drains close to areas where liquid discharges are expected.

[98] CEE, 2011. http://www.cee1.org/com/com-kit/files/IceSpecification01Jul2011.pdf

Submetering

Wherever feasible, meter indoor water use separately from outdoor water use. In addition, separate metering of individual units (tenants), building water-using systems (e.g., cooling towers), or building areas (e.g., food service, landscape) is recommended wherever feasible to ensure that the costs of water use and wastewater disposal are equitably distributed among the tenants and accounted for accurately.

Tracking actual use through a building management system connected to a series of submeters can disclose operating issues (e.g., leaks, equipment and process malfunctions) that might have otherwise remained undiscovered. For a full discussion of submetering and best management practices associated with that topic, refer to report **Section XXX Building Meters, Submeters, and Management Systems.**

Landscape

Landscape irrigation represents 27 percent of water use at the typical office building site. It is important to ensure the use of climate-appropriate plant materials in the landscape and to install and monitor efficient irrigation systems that apply only the amount of water necessary. Wherever possible, meter indoor water use separately from outdoor water use. For further information and best management practices related to landscape and landscape irrigation, refer to report **Section XXX Commercial Landscaping.**

Other

Other recommendations include:

- Installing automatic shutoff and solenoid valves on all hoses and water-using equipment.

Additional Resources

East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD8-FOOD9. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

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- http://www.sydneywater.com.au/Publications/FactSheets/BestPracticeGuidelinesForWaterConservationInCommercialOfficeBuildingsAndShoppingCentresPart4WaterSavingChecklist.pdf

U.S. Environmental Protection Agency, Energy Star program. *Best Practices—How To Achieve the Most Efficient Use of Water in Commercial Food Service Facilities.* www.energystar.gov/index.cfm?c=healthcare.fisher_nickel_feb_2005

7A6: Prisons and Correctional Facilities

Correctional facilities are a major component in the institutional water use sector. They fall into the following North American Industrial Classification System Codes.

Table 2. NAICS* Codes for Correctional Facilities	
NAICS	**Description**
922140	Correctional boot camps
922140	Correctional institutions
922140	Detention centers
922140	Honor camps, correctional
922140	Houses of correction
922140	Jails (except private operation of)
922140	Penitentiaries
922140	Prison farms
922140	Prisons
922140	Reformatories
922150	Pardon boards and offices
922150	Parole offices, publicly administered
922150	Probation offices, publicly administered
922150	Public parole offices
922150	Public probation offices
922150	Rehabilitation services, correctional, government
** NAICS - North American Industrial Classification System*	

California houses over 290,000 prisoners and detainees in Federal, State, and local facilities. According to the California Department of Corrections and Rehabilitation, about 170,000 of these people reside in state facilities. California is home to approximately 500 correctional facilities. Table 1 shows the types of facilities based on State and Federal records.

Table 1. Correctional Facilities in California*	
Type of Facility	**Number in State**
Federal	15
State Prisons	33
State (Other Facilities)	28
Local Facilities	540+
TOTAL	**625+**
*Source: Ca l i f o r n i a D e p a r t m e n t o f C o r r e c- t i o n s a n d R e h a b i l i t a t i o n - Corrections Year at a Glance 2011, and **CALIFORNIA COUNTY JAILS & STATE PRISONS CORRECTIONAL FACILITIES -Jail.org**	

Prisons are much like small cities. They have living, eating, medical, laundry, manufacturing, boilers and cooling towers, and industrial operations. Table 2 summarizes types of water use found in prisons and provides the references to applicable sections in the document that describe best management practices for that use.

Table 2. Water Uses Found at Prisons and Correctional Facilities	
Type of Use	**Section Describing BMP for Use**
Employee restroom facilities	***Chapter and Section numbers will be added when the document is set and the table of contents finalized.***
Medical/dental facilities	
Food service	
Inmate restroom facilities	
Inmate showering facilities	
Laundries and clothes washers	
Cooling towers and boilers	
Water treatment	
Cogeneration and energy facilities	
Wastewater treatment	
Prison industries	
Prison farms, greenhouses, and gardens	
Pools and recreational facilities	
Landscape irrigation	
Vehicle washing	
Educational facilities	
Leaks, metering, and unaccounted for water	
Reclaimed water	
Alternate on-site sources of water	

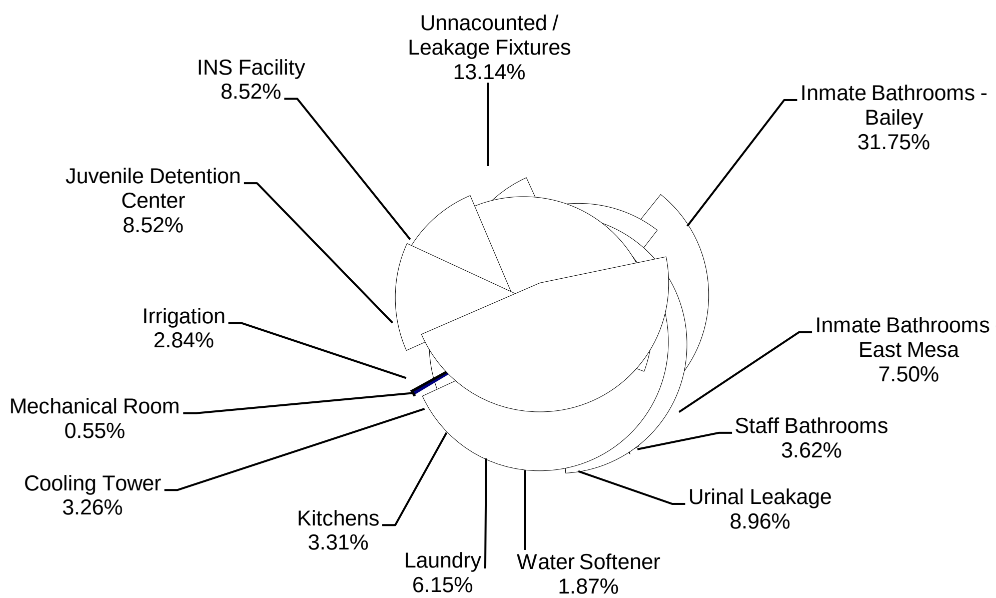
Some ways that water is used in prison is unique in its wastefulness. In his book, **Unquenchable: America's water crisis and what to do about it**, author Robert J. Glennon talks about toilet telegraphs, the use of toilets to reduce boredom, a toilets as a means of disposing of contraband, often causing minor flooding. In fact, he reports that toilets are sometimes flushed 100 times a day. The main point is that prisoners are locked in their cells for over 20 hours a day with plenty of time to invent ways to use (WASTE) water. Audits of prisons by Water Management Inc. have shown that prisoners often flush the toilets in their cells fifteen to twenty times a day. For regular sanitation uses, one person should flush five to six times a day.

One best management practice unique to prisons is the use of flush valves that limit the number of flushes that a can occur in a given amount of time, thus eliminating much of this excessive flushing. A number of California prisons have used these valves, saving significant volumes of water.

The Otay Water District has made a concerted effort to work with correctional facilities in their service area in San Diego County: the R.J. Donovan Correctional Facility, a State Prison, and the George F. Bailey Detention Center & East Mesa Detention Facilities. Before the water conservation effort, the Donovan facility used over 885 acre-feet per year (290 million gallons per year). For the Donovan facility, the audit showed that just the potential indoor savings were in the range of 84 million gallons per year (Table 3.), a 29 percent reduction in indoor use. With all measures in place – indoor, outdoor, and managerial – water use had declined to under 450 acre-feet per year (145 million gallons per year) or a 45 to 50 percent drop by 2010.

For the George F. Bailey Detention Center & East Mesa Detention Facilities, reductions were similar. Based on the first nine months of water use for 2010 compared to a similar period in 2009, water use has decreased more than fifty percent. Figure 1 shows the breakdown of indoor water use and facility operations water use for the detention facilities. Measures taken include all those found in Table 3 for the Donovan facility.

Figure 1. Bailey and East Mesa Water Distribution



Source: Information provided by William Granger and Rhianna Pensa, Otay Water District, San Diego County, California

Table 3. Proposed Water Conservation Measures at the Donovan State Prison

Measures	Quantity	Gallons/ Year Savings	Annual Savings	Installed Cost	Payback with Incentives
Inmate Bathroom Fixtures – Facility 1-4					
I-CON Electronic Bathroom Controls	2,092	57,834,260	$421,039	$1,851,420	4.0
I-CON Electronic Shower Controls	176	13,094,010	$114,812	$155,760	1.0
I-CON Electronic Faucet Controls	500	5,840,000	$51,207	$442,500	8.3
Inmate Bathroom Fixtures- Facility 5					
Replace commercial toilets	26	1,790,592	$12,714	$26,185	1.9
Replace urinal flush valves	4	156,160	$1,109	$2,026	1.8
Install flow reducers for faucets	44	78,022	$554	$2,577	4.7
Common Area Bathrooms Facility 1-5					
Replace common area toilets	267	2,797,729	$19,865	$237,700	10.7
Replace common area urinals	23	468,096	$3,324	$9,965	3.0
Replace common area faucet aerators	265	68,270	$591	$4,770	8.1
Laundry					
Ozone Laundry System	1	1,750,000	$38,704	$151,429	2.8
Kitchen					
Kitchen Pre Rinse Spray Nozzles	8	175,200	$1,789	$0	-
Total		**84,052,339**	**$665,706**	**$2,884,331**	**4.6 years**

Source: Information provided by William Granger and Rhianna Pensa, Otay Water District, San Diego County, California

The California Department of Corrections and Rehabilitation has implemented a system-wide initiative to reduce water use as part of the State mandate Executive Order S-06-08 that declared a state of drought in California. CDCR set a goal of reducing water consumption by 20 percent statewide, and the results have been significant. The following is a report released by the California Department of Corrections and Rehabilitation in 2009 (See actual news release at the end of this segment). The prison system continues to make progress.

News Release from the CDCR April 3, 2009

California Prisons Reduce Water Consumption by 21 Percent Through Comprehensive Drought Response Plan

SACRAMENTO – Today the California Department of Corrections and Rehabilitation (CDCR) announced it has achieved a 21 percent annual reduction in its water usage, saving 2.4 billion gallons of water– enough to fill approximately 65,000 swimming pools.

1 CDCR's water conservation program began in 2006 with a pilot project to install "flush meters" on toilets in selected
prisons. In 2008, under the direction of Governor Schwarzenegger's Executive Order S-06-08 declaring that California is in
2 a state of drought, CDCR set a goal of reducing water consumption by 20 percent statewide. On February 27, 2009
Governor Schwarzenegger declared a state of emergency on water shortage in response to three years of drought
conditions.

3 "As California's largest state agency and a major water user, Corrections has taken steps to drastically reduce water consumption and prepared a comprehensive drought response plan in anticipation of another dry summer," said CDCR Secretary Matthew Cate. "CDCR's expansive water savings program has reviewed water usage in our 33 prisons and correctional facilities across the state. We are reducing water consumption on a massive scale through a combination of methods including conservation, elimination of nonessential use, retrofits, and increased efficiencies. Through the efforts of our wardens and staff across the state, we have achieved the Governor's goal for our agency of reducing consumption by 20 percent, and are continuing to search for new and innovative means to lessen the impact of the drought."

To comply with the Governor's Executive Order, CDCR has enacted the following measures:

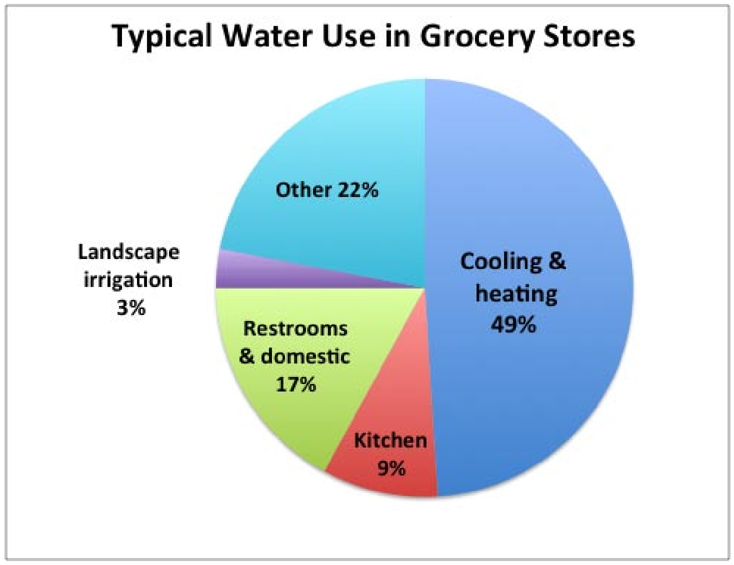
- Flush meters have been installed at nearly one-third of all adult institutions, with more under construction in 2009. Institutions with flush meters result in a 27 percent average annual savings of water, versus 17 percent for institutions without flush meters.
- Institutions are now reporting monthly water consumption to CDCR Headquarters.
- Prisons and other facilities have enacted low-or-no-cost water conservation methods.
- Headquarters has distributed a "Best Management Practices Water Management & Conservation" document to all institutions that covers:
  - eliminating nonessential water use;
  - modifying practices for water efficient landscaping;
  - leak detection and repair – building systems and equipment;
  - water-efficient irrigation; and
  - laundries and vehicle washing.
- On-site Water Consumption Surveys have been initiated at prisons.
- CDCR has identified other opportunities for additional water savings through operational modifications and best practices in inmate housing, kitchens, grounds and laundries.
- Additional water conservation projects have been launched.

"This is just the beginning," said Deborah Hysen, CDCR's Chief Deputy Secretary, Facility Planning, Construction and Management Division which oversees the effort. "Through a centralized reporting process and basic surveys we are conserving more water than ever before. As the drought continues we hope to enact additional water savings programs."

CDCR's water conservation efforts are part of its agency-wide environmental resource conservation program. CDCR is on-track to achieve the goal laid out by the Governor of reaching a 20 percent reduction in energy usage by 2015. These savings will be realized through the use of solar photovoltaic power plants, implementing peak load reduction programs, and by installing the latest in lighting technology. CDCR has been recognized as a national leader and as the first state government agency member of the Climate Registry.

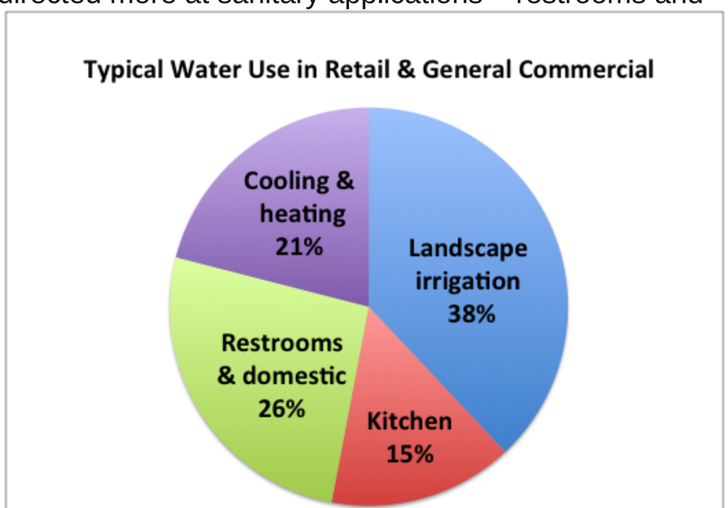
7A7: Retail, Grocery Stores and Food Markets

Introduction



Grocery stores and food markets typically use water for a variety of operations: spraying fresh vegetables with cold water, ice machines, deli operations, food preparation and restaurant service, restrooms, photo processing, floor cleaning, and cooling refrigeration equipment with cooling towers and evaporative condensers. Ice is often used in vegetable displays to maintain product freshness and to enhance aesthetic appeal.

In the general retail sector, water use is directed more at sanitary applications – restrooms and cleaning – and, in most cases, landscape.



Source: East Bay Municipal Utility District. 2008. *Watersmart Guidebook— A Water-Use Efficiency Plan Review Guide for New Businesses.*

Multi-tenant commercial structures, such as mixed-use strip malls that are also occupied by medical activities, such as dentists, physicians, and clinics), distribute water differently (**Section XXX Medical Processes**).

Cooling and Heating Systems

Water use related to cooling and heating accounts for 49 percent of total water consumption in the typical grocery store. Freezers, refrigeration and cooler operations, and comfort air conditioning equipment are often linked to remote refrigeration equipment. According to recent studies of grocery stores in California, half the water used at facilities with cooling towers is used by the cooling towers themselves. In other parts of the South and Southwest, air cooling, typically with multiple rooftop units, is more common[99]. The use of multiple rooftop units allows a grocery to continue to operate even if one or two units are down for repair. The use of air-cooling also eliminates the cost of building and operating a cooling tower. However, air-cooled units are generally less energy-efficient than systems using cooling towers, especially under full- or base-

[99] Refer to Section VII.C.2 on Thermodynamic Processes for further information.

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load conditions.

In the general retail sector, water use for cooling and heating is estimated at 21 percent of total use. However, the same recommendations and best management practices apply.

Refer to report **Sections XXX Building Systems – Thermodynamic Processes** for a full discussion and information and best management practices related to this topic.

Kitchen Operations

In addition to traditional groceries, some grocers offer prepared food for take-out and eat-in. Preparation of food for sale and the resulting scullery operations are areas that use large amounts of water. Selecting energy-efficient kitchen equipment helps reduce waste heat, which also has implications for water use.

Water consumption for dishwashing and other scullery operations can be reduced through the following best management practices:

- Use only efficient pre-rinse spray valves (1.6 gpm maximum) for dish rinsing.
- Use strainer (scrapper) baskets in place of garbage disposals (grinders).
- Install ENERGY STAR automatic dishwashers meeting efficiency standards set by the Consortium for Energy Efficiency (CEE).
- Install steam doors on dishwashers.

For food preparation, several best practices offer opportunities for improved water efficiency.

1. Select combination ovens that use no more than 15 gallons of water per hour and comply with the California energy rebate list.
2. Instead of steam tables, install dry heating tables.
3. Thaw food in refrigerators. Avoid thawing food under running water.
4. Return and reuse condensate from all boiler-type steam kettles.
5. Size steam traps for proper operation to avoid dumping condensate.
6. Insulate condensate-return lines.
7. Use pasta cookers with a simmer mode and automatic over-flow-control valves. Restrict flow to 0.5 gpm.
8. Use connectionless or boilerless steamers consuming no more than 3 gallons per hour.
9. Install in-line restrictors that reduce “dipper well” flows to under 0.3 gpm where permitted.

For further information on these and other best management practices in the kitchen, refer to report **Section XXX Commercial Food Service.**

Ice Machines

Ice machines may be located in vending areas for customers, as well as in the central kitchen of a grocery or food market. These machines use water for the ice itself and sometimes for cooling the compressor. These best management practices apply:

- Select ENERGY STAR qualified ice-making machines that are air-cooled, using remote heads to expel warm air outside the workspace and customer areas. Air-cooled machines are preferred over cooling-tower loops.
- Select energy-efficient flake or nugget machines rather than cube-ice machines. If cube-ice machines are used, those that meet CEE Tier 2 or 3 efficiency standards are preferred.
- Refer to report **Section VII.A.1 Commercial Food Service, Commercial Ice Machines**

for more information on available equipment and their efficiencies.

Restrooms and Plumbing

Appropriate water-saving technologies exist with all restroom fixtures. Refer to report **Section XXX, General Building Sanitary and Safety Applications** for a discussion of water use efficiency opportunities and best management practices for restrooms and other operations in lodging facilities.

If available, and where codes and health departments permit, use non-potable, treated water for fixture flushing (toilets and urinals only) and landscape irrigation applications. Refer to report **Sections XXX Commercial Landscape** and XXX **Alternate Water Sources** for information and best management practices related to these topics.

Floor Cleaning

Best management practices for floor cleaning include:

- Discourage the use of open hoses for cleaning. While wet methods may be used, install self-closing nozzles, limiting flow to 5 gpm. Refer to report **Section XXX Commercial Food Service, Washing and Sanitation** for further information on floor cleaning, available equipment, and best management practices.
- Install drains close to areas where liquid discharges are expected.
- Arrange equipment for easy use of a mop and squeegee system or floor-cleaning machine.

Submetering

Separate metering of water-using systems and building areas is recommended where possible to ensure accurate tracking of the costs of water and wastewater disposal, particularly in multi-tenant commercial applications where tenancy is divided among disparate users with widely different water use demands. Accountability for individual water use and the associated water and sewer costs by each tenant often leads to the implementation of water efficient practices by those tenants, reducing overall property water consumption.

Tracking actual water use through a building management system connected to a series of submeters can rapidly disclose operating issues such as leaks and equipment malfunctions that might have remained undiscovered for a period of time. For a full discussion of submetering and best management practices associated with that topic, refer to report **Section XXX Building Meters, Submeters, and Management Systems.**

Other

Other recommended best management practices for grocery and retail facilities include:

- Install automatic shutoff and solenoid valves on all hoses and water-using equipment.
- Use self-contained “mini labs” that require no plumbing or washing for on-site photo processing.
- Conspicuously mark fire-protection plumbing so no connections will be made other than those for fire protection.
- Install flow-detection meters on fire services to reveal unauthorized water flows.

Additional Resources

East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD8-FOOD9. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

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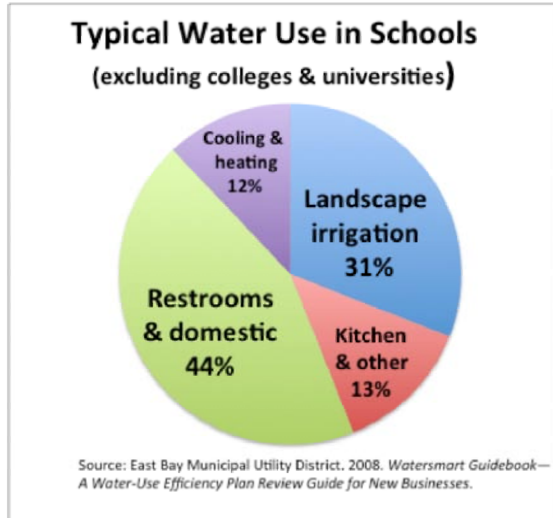
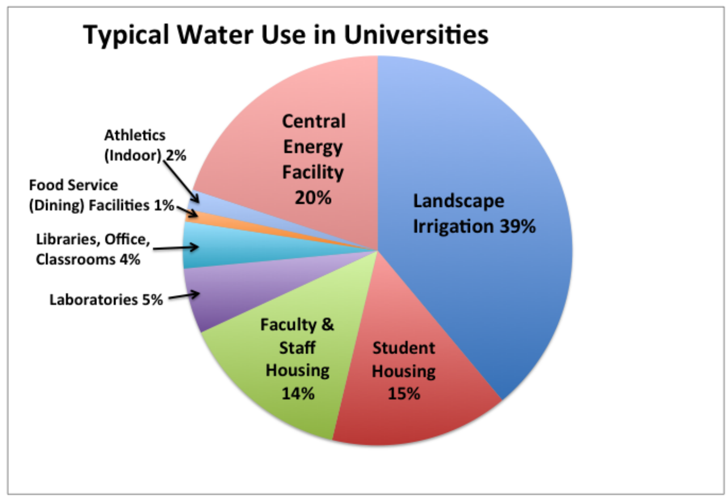
- http://www.sydneywater.com.au/Publications/FactSheets/BestPracticeGuidelinesForWaterConservationInCommercialOfficeBuildingsAndShoppingCentresPart2TechnicalWaterSavingInformation.pdf
- http://www.sydneywater.com.au/Publications/FactSheets/BestPracticeGuidelinesForWaterConservationInCommercialOfficeBuildingsAndShoppingCentresPart3AlternativeWaterSources.pdf
- http://www.sydneywater.com.au/Publications/FactSheets/BestPracticeGuidelinesForWaterConservationInCommercialOfficeBuildingsAndShoppingCentresPart4WaterSavingChecklist.pdf

7A8: Schools and Educational Facilities





Introduction

Schools, colleges, universities, and vocational institutions use water in many ways, including some that are similar to those of the following sectors: lodging, food service, laundry, and office buildings. They have in common many of the water-using systems and equipment common in those sectors, such as restrooms and sanitary functions, food service equipment, image processing, water purification, on-premise laundries (colleges and universities), vacuum systems, cooling towers and boilers, and cleaning, as well as the industrial processes taught in many of the vocational schools and classes. This discussion highlights the key water-using elements of typical schools.

Restrooms and Plumbing

Restrooms and related domestic uses are the major water consumers in schools. Appropriate water-saving technologies exist with all restroom fixtures. Refer to report **Section XXX, General Building Sanitary and Safety Applications** for a discussion of water use efficiency opportunities and best management practices for restrooms and other operations in school facilities.

If available, and where codes and health departments permit, non-potable, treated water may be used for flushing toilets and urinals and landscape irrigation applications. Refer to report **Sections XXX Commercial Landscape and XXX Alternate Water Sources** for information and best management practices related to these topics.

Cooling and Heating Systems

Water use related to cooling and heating, mostly in cooling towers and boilers, accounts for about 12 percent of total water consumption in the typical school.

Cooling Systems

Modern schools need to remove heat generated by the occupants, as well as the computers, research laboratories, lights, kitchens, and other operations, usually by means of a central refrigeration system and compressor. The use of energy-efficient equipment may reduce such waste heat. The compressor may be air- cooled or connected with a circulating loop to a cooling tower or evaporative condenser. As warm water from the compressor is directed through the cooling tower, some water evaporates, cooling the remaining water, which returns to cool the equipment. Measures to reduce water waste in cooling towers include:

- Operating towers at a minimum of five cycles of concentration (CC) when using potable water, depending upon the chemistry of the make-up water used, including considerations for reclaimed water or other on-site sources of quality water. In certain cases, where source water quality is high, CCs of as much as 15 may be achieved.
- Providing adequate training to cooling-tower operators and maintenance personnel.
- Performing a life-cycle cost analysis, including all operating, capital, and maintenance costs, to determine the cost effectiveness of a cooling tower vs. air cooling.
- Equipping cooling towers with conductivity controllers, make-up and blowdown water meters, and overflow alarms.
- Using dry cooling or once-through cooling with non-potable water where feasible.
- Using high-efficiency drift eliminators that reduce drift loss to less than 0.002 percent of circulating water volume for cross-flow towers and 0.001 percent for counter-flow towers.
- Evaluating the processes in the plant for maximum energy efficiency and waste-heat recovery, since a more efficient building will reject less heat to the cooling tower.

Heating Systems

Steam boilers and hot-water boilers provide heat and hot water in some buildings. Closed-loop systems return water and steam condensate to the boiler for reuse, saving energy and water. Open-loop systems expend the water or steam without return to the boiler. Several water-efficiency choices are available:

- Install recirculating (including demand-based) hot water distribution systems for large buildings.
- Equip steam boilers of 200 boiler horsepower (hp) or greater with conductivity controllers to regulate top blowdown.
- For closed-loop systems, install condensate-return meters on steam boilers of 200 boiler hp or greater.
- Operate closed-loop steam systems at twenty cycles of concentration or greater (5 percent or less of make-up water).
- Install code-compliant steam-distribution lines and equipment with steam traps.
- Install make-up meters on feed-water lines:
    - to steam boilers and water boilers of more than 100,000 Btus per hour.
    - to closed-loop hot-water systems for heating.
- Ensure that boiler-temperature and make-up meters are clearly visible to operators.
- Ensure that discharge pipes are easy to inspect for flow. Provide visible indicators that will show whether the valve has activated, thereby reducing plumbing leaks due to repeated openings of water-temperature- and pressure-relief valves (TPRVs).

Refer also to report **Sections XXX Building Systems – Thermodynamic Processes** for further information and additional best management practices related to this topic.

On-Premise Laundries

On-premise laundries exist in nearly every major college and university in California. Refer to report **Section XXX, Fabric Cleaning and Washing Equipment and Technologies** for a discussion of water use efficiency opportunities and best management practices for on-premise laundries in schools.

Special Facilities

- For laboratories, choose dry-vacuum systems rather than liquid-ring pumps. For vacuum and compressor systems, use air-cooled, radiator-cooled, chilled-loop, or cooling-tower systems. Sterilizers in laboratories should be equipped with water tempering devices. Water used by cage, glassware, and bottle washers in laboratories should comply with the requirement outline elsewhere in this report. For further details on these and other items of laboratory equipment, refer to report **Sections XXX Medical and Laboratory Equipment and Processes** and **XXX Water Treatment Processes.**
- For vocational facilities dedicated to vehicle repair, refer to report **Section XXX Auto and Truck.**
- For photography and medical and other imaging, try to use digital technologies that allow images to be displayed on electronic video screens and stored in computer files. Where film imaging is required, use self-contained "mini-lab" developing units that require no special plumbing or washing to develop the film. For paper or film image copies use laser or ink-jet printing.

Floor Cleaning

Best management practices for floor cleaning include:

- Discourage the use of open hoses for cleaning. While wet methods may be used, install self-closing nozzles, limiting flow to 5 gpm. Also refer to report **Section XXX Commercial Food Service, Washing and Sanitation** for further information on floor cleaning, available equipment, and best management practices.
- Install drains close to areas where liquid discharges are expected.
- Arrange equipment for easy use of a mop and squeegee system or floor-cleaning machine.

Submetering

Separate metering of water-using systems and building areas is recommended where possible to ensure that the costs of water use and wastewater disposal are accurately tracked. Tracking actual use through a building management system connected to a series of submeters can disclose operating issues such as leaks and equipment malfunctions that might have remained undiscovered. For a full discussion of submetering and best management practices associated with that topic, refer to report **Section 7.8.8 Building Meters, Submeters, and Management Systems.**

Residence Halls (college and university)

For college and university on-campus residence halls, refer to the report section on **Hotels and Motels** as well as **XXX on laundry facilities** and **XXX General Building Sanitary and Safety**

Applications.

CASE STUDY – UNIVERSITY OF CALIFORNIA, IRVINE

UC Irvine (UCI) is the first of the University of California campuses to participate in the Strategic Energy Partnership (SEP), joining with the local water utility to reduce potable water use. Through joint funding with the Irvine Ranch Water District (IRWD), UCI's Plumbing Shop retrofitted 70 toilets in high-traffic restrooms with High-Efficiency Toilets (HETs). The HETs use 1.28 gallons per flush compared to the 3.0 gallons per flush used by the targeted toilets. This retrofit equates to a 57 percent reduction in potable water consumption per toilet, totaling 2.6 million gallons and $11,800 in annual savings.

UCI has also taken advantage of the Metropolitan Water District of Southern California's "Save Water – Save A Buck" program to retrofit 83 urinals with High-Efficiency Urinals (HEUs). The HEUs flush with one pint (0.125 gallons) of water compared to the 1.5 and 3.5 gallons per flush used by the targeted urinals that were removed. This resulted in an average 95 percent drop in potable water consumption per urinal, totaling 3.4 million gallons and $15,700 in annual savings.

To determine the value of the water savings, UCI and IRWD commissioned a third party to calculate the average usage and savings per fixture based on the campus population and number of fixtures on campus. With this report and an audit of all the restrooms on campus, UCI developed a work plan to replace the most inefficient toilets and urinals in the restrooms that get the most traffic and estimated the water savings resulting from such replacements. The result was an average savings per fixture that IRWD could use to calculate the incentive value and UCI could use to calculate the annual savings in their operating budget for water.

Additional Resources

East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages FOOD8-FOOD9. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook

Food Service Technology Center. *Water Conservation Measures for Commercial Food Service.* www.fishnick.com/savewater/bestpractices/Water_Conservation_in_CFS.pdf

Food Service Technology Center. *Water, Water Everywhere and Not a Drop to Waste.* www.fishnick.com/saveenergy/greensheets/GreenSheet_Water_Waste_1.pdf

Sydney Water, 2007. The Conserver: *Helping Schools Save Water Without Compromising Quality.* http://www.sydneywater.com.au/Publications/CaseStudies/EarlyleakdetectionschoolsConserver12.pdf

Sydney Water, 2003. The Conserver-Business Bulletin: *Simple Measures-Big Savings, University of Wollongong.* http://www.sydneywater.com.au/Publications/CaseStudies/UniversityofWollongong1Conserver3.pdf

Sydney Water, no date. The Conserver-Business Bulletin: *Invisible Modification Reduces Residential College's Water Consumption by 40 Percent.* http://www.sydneywater.com.au/Publications/CaseStudies/StAndrewsCollegeConserver3.pdf

Sydney Water, 2007. The Conserver: *Mission Accomplished, Sydney Institute.* http://www.sydneywater.com.au/Publications/CaseStudies/TAFENSWSydneyInstituteConserver12.pdf

Sydney Water, 2005. Save Water, Money, & the Environment: *Saving Water in Community Swimming Pools or Leisure Centres.*

U.S. Environmental Protection Agency, ENERGY STAR program. *Best Practices—How To Achieve the Most Efficient Use of Water in Commercial Food Service Facilities.* www.energystar.gov/index.cfm?c=healthcare.fisher_nickel_feb_2005

7A9: Vehicle Washing

Background

This section addresses vehicle washing. It includes commercial carwashes open to the public, fleet operations, including car, truck and bus washes, and washes for trucks and light vehicles that leave industrial sites to enter the public thoroughfare. Stand-alone businesses providing these services, categorized under NAICS 811192, include mobile carwash systems and detailing shops that offer hand washing. Some businesses, like car dealerships, vehicle rental companies, convenience stores, or service stations often have the same equipment, but they are not listed under this NAICS classification. Similarly, quarries, cement or asphalt companies with wheel or truck wash equipment are classified under their principal business type rather than this code.

According to the 2007 Business Census, businesses falling under the NAICS 811192 category provided $1 billion of economic activity and almost 24,000 jobs in California. While water use data is not aggregated on a statewide basis for this industry, some municipal water agencies track customer water use by class on gallons per vehicle (gpv) basis. These data provide an estimate of statewide water demand when multiplied by the average number of washes per business type.

This section only addresses the wash equipment associated with cleaning the exterior of the vehicle. Water uses and best management practices associated with domestic uses of water found at the businesses can be found in the General Building Sanitary and Safety Applications section, and water uses associated with businesses that are co-located with a carwash can be found in sections appropriate to that business. In addition, some vehicle washes have landscaped areas, and the water uses associated with those landscapes are addressed in that section.

In 2006, the CUWCC estimated that the total water use for all commercial vehicle washes would be approximately 60,000 acre-feet by 2020 based upon the growth rate in dedicated vehicle wash businesses from the 1997 to 2002 California business census figures. This estimate included commercial vehicle washes available to the general consumer and vehicle wash systems at car dealerships. It did not include washing of vehicles leaving industrial sites for which there are no centralized data sources.

Description

The most common types of vehicle washes are divided into three classes by the International Carwash Association: conveyor, in-bay automatic, and self-serve.[100] This section deals with general and particular patterns of water use and best management practices applicable to all three types of vehicle washes. In a conveyor vehicle wash, separate spray arches and/or brushes perform these steps. In in-bay automatic washers, all processes are performed through

100 Brown, Water Conservation in the Professional Carwash, International Carwash Association, 2000

a set of nozzles, except in those cases where brushes are used in the wash cycle. Self-service vehicle washes use a hand-held wand, though there may also be a brush for the wash cycle. Truck and bus washes use the same types of equipment only on a larger scale, typically combining the spray wands of a self-service or tunnel with the arches of a conveyor wash.

How Water is Used

Water use in vehicle washes is controlled by type of equipment, water pressure, speed, nozzle size, and presence or lack of an on-site reclamation system. Typically, car washes are divided into specific stages in which water is delivered by different equipment, at different rates, and of different quality. The four basic phases are pre-wash, wash, application of finish products, and rinse. In some vehicle washes, the drying stage presents an opportunity to save water and reclaim it for use in the earlier stages of the wash.

Pre-wash cycles are usually performed by a handheld spray wand or fixed nozzles designed to knock loose dirt and grit off a vehicle prior to the wash cycles. The wash cycle(s) use detergent or surfactants and high-pressure sprays or brushes. In the conveyor or in-bay automatic washes, the brushes may be in the form of strips of cloth on a spinning axle or a curtain of cloth that is pulled from side-to-side over the vehicle. Reclaimed water, when used, is typically used in the pre-wash and/or wash cycles.

Rinse cycles may use high- or low-pressure sprays, and in some cases, they may include water treated for greater clarity. When reverse osmosis water treatment is used for the rinse water, the reject water may be reclaimed for use in the pre-wash or wash cycles.

Water Use and Best Management Practices by Type of Vehicle Wash

Self-Service Carwash

Self-service vehicle washes are typically coin-operated with spray wands and brushes operated by the customer. The wash facility typically contains four to six wash bays and a central equipment room that houses water process equipment. The customer controls whether and for how long to use low-pressure or high-pressure settings, as well as whether to use a spray wand or brush. As a result,, the carwash owner/operator does not have direct control over the water use at the facility. With a fixed pricing structure for the initial purchase of several cycles plus the ability to purchase additional time (usually at a 25¢ per unit), however, the customer has a direct monetary incentive to move as quickly as possible, thus conserving water. Studies of vehicle wash water use efficiency have shown that on average, self-service carwashes use the least amount of water, 15 gallons per vehicle (gpv).

In addition to water used in the pre-soak and wash cycles, many self-service operations also offer a spot-free rinse. As with in-bay automatics, reject water from the RO unit may be used in landscape watering if landscape exists.[101] Because customers wash their own vehicles unattended, self-service operators sometimes find evidence of dumping of oils or other organic

[101] However, since reclaim is not typically used in self-service washes, except where required by law, reuse of RO reject water is not typically an option in self-service carwashes.

materials in the wastewater. Such dumping is expensive, difficult to remedy, destructive of filters, and it provides a disincentive to the use of reclaimed water in self-service washes.

In-Bay Automatic

"In-bay automatics" have a wash bay in which the customer stays in the vehicle as spray nozzles, brushes, or a combination of both carry out the individual cycles. The vehicle remains stationary during the process, and the carwash machinery is moved over the vehicle by a gantry. In-bay automatics have the greatest variety in basic design with some machines comprising an entire moveable arch, others having vertical and horizontal arms suspended from the gantry, and yet others with spinning arms attached to the gantry.

Nozzle size, number and alignment, flow rates, and timing all affect water use in the in-bay automatic vehicle washes. Since all of the water flows to one pit, and all of the chemicals mix together, reclaim systems can be more costly and a bigger challenge to maintain than in conveyor carwashes. Many in-bay automatic operations also offer a spot-free rinse, which is typically obtained with reverse osmosis (RO) or deionization (DI) equipment. The Water Treatment Systems section contains a more detailed discussion of water treatment systems found in commercial carwashes.

As with the conveyor vehicle wash, in-bay automatics that use brushes or cloth use less water than frictionless or "touch-free" vehicle washes. Some in-bay automatics also reduce water use by using laser sensors to identify the length of the vehicle, thus limiting the gantry movement and timing of wash based upon the sensor signals. The International Carwash Association study of 2002 found average in-bay automatic water consumption per vehicle to be 42.9 gallons, although differences in equipment produce great variability among sites.

Conveyor

The conveyor wash, which is usually installed in a tunnel, includes a series of cloth brushes or curtains and arches from which water is sprayed while the vehicle is pulled through the tunnel on a conveyor chain. Some "touchless" carwashes use only spray nozzles. In full service conveyor carwashes, hand drying usually follows the conveyor; likewise, the pre-soak is often done by hand, sometimes with held wands similar to those found at self-service carwashes.

In friction carwashes, the wash cycle is accomplished with brushes or soft cloth curtains. Conveyors with friction components use less water than frictionless washes because the brushes or curtains pick up water and detergent from the pre-soak of vehicles as the day proceeds.[102]

[102] Kobrick, J.D., et. al., 1997. *Water uses and conservation opportunities in automatic carwashes: A City of Phoenix study,* June.

The most recent national survey of carwash businesses reported that 73 percent of conveyors use friction components in the wash.[103] California specific data were not available and, thus, not separated out in the report.

Timing is a critical component in carwash water efficiency. In properly calibrated conveyors, nozzles are timed to turn on as the vehicle passes under the arch and to shut off as the vehicle exits each arch. Each arch is on for a matter of seconds, so conveyors can process 90 or more vehicles per hour. Proper nozzle alignment and pressure also help to maintain efficiency.

Further water efficiency may be obtained by the orientation of blowers after the final rinse. When properly aligned, they push water back into the tunnel after the final rinse arch. As a result, water that would otherwise be carried out of the tunnel flows back into sump, where it can be reused in carwashes with reclaim systems. Because of the speed of the conveyors and the more prevalent use of reclaim systems (56% of sites) conveyor systems use an average of 34 gpv.

Many full-service conveyor carwashes offer towel drying as one of the services. In many older vehicle washes, the sinks for washing the towels are designed to have a constant flow of water through them. Installing a float ball valve to stop the flow of water when it reaches an optimum level is an effective water efficiency measure. Replacing older flow-through sinks or replacing top loading washing machines with front loading machines will cut water consumption by 40% or more. Some conveyor washes, referred to by the industry as “exterior-only,” do not offer drying or detailing services, thus eliminating this water use.

Truck, Bus and Fleet Washes

The type of equipment used to wash trucks, buses, utility vehicles, and heavy equipment is similar to that described above except larger in scale. Industrial or construction-related uses often must remove greater amounts of dirt and grease. As a result, they use more water per vehicle than a typical carwash. Some commercial truck wash operations are coin operated, charging customers by the length of the vehicle, usually at a cost per foot of length. Due to differences in vehicle size and shape, hand held wands are prevalent in truck washes. One modified type of equipment is a drive through arch, similar to those found in conveyors, but where the driver controls the speed at which they move under the arch. These systems are referred to as “drive through tunnels,” though sometimes the arch is found without a surrounding building. Electronic or magnetic sensors turn the arch on and off as the vehicle enters and leaves the arch. Thus, the speed of the vehicle driving under the arch influences the amount of water used.

Fleet washing of light passenger vehicles (such as in an auto dealership or at a rental agency) is typically done with either in-bay automatic or hand held wands and brushes. The Irvine Ranch Water District (District) surveyed 24 automobile dealerships to determine the carwashing equipment being used.[104] They found that 87.5 percent of automobile dealers have on-site

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[103] Billings, A., ed, 2000. *Almanac for the Year 2000,* Auto Laundry News, Vol. 48, No. 14.
[104] Sanchez, Fiona, 2006. Personal communication, Conservation Manager, Irvine Ranch Water District, April 28.

vehicle wash facilities in their service areas: 62.5 percent had self-service type wands; 20.8 percent had in-bay automatics or drive-through type washes[105]; and 4.2 percent had conveyors. The ICA study did not include fleet washes, but it would be reasonable to estimate that they use about the same amount of water per vehicle as their commercial counterparts.

Another sector of the market, which is not well studied, entails the water used by detailing or handwashing businesses. A survey of commercial vehicle washes in 1999 found that 5 percent of respondents operated hand washes.[106] Anecdotal observation suggests that hand washing and detailing businesses have grown as a sector of the carwash industry, although there are no firm numbers on water use or size of market.

Reclaim

On site capture and re-use of water in vehicle washes is referred to as reclaim water. Specific equipment and steps in the process of reclaim include capture of the water in pits or troughs below the cars, treatment of the water through filtration and disinfection, storage of the reclaim water and delivery of the reclaim water to specific cycles in the vehicle wash. The types of equipment used include paper filters, sand filters, or centrifugal filters. Disinfection and odor control is carried out by use of ozone, chlorine injection, or UV systems. For additional details on the uses and management of water treatment equipment please refer to that section of the report.

The data from the 2002 ICA study showed that the lowest amount of water recycled in a carwash was 9 percent of total gpv, and the highest being 82 percent of water used per vehicle[107]. This large range in percentages of reclaim water demonstrates the difficulty in providing accurate estimates without more details on the types of reclaim systems anticipated and the associated costs of making modifications to the existing facility.

A 2006 Potential Best Management Practice Report by the CUWCC indicated that a statewide requirement of reclaim systems in all new Conveyor and In-Bay Automatic vehicle wash systems has a potential for water savings totaling 22,877 acre-feet per year (AFY) in 2020. In-bay automatics make up more than two-thirds of the potential savings at 16,580 AFY, and conveyors represent 6,297 AFY potential savings, in 2020. Because of difficulties in the use of reclaim systems in self-service carwashes as discussed earlier, this category was not included in the estimated savings.

[105] No studies of water use in drive-through facilities have been published, but due to the slower speed of the vehicle proceeding through a drive-through arch, an industry representative anticipates water use to resemble an in-bay automatic more than a conveyor. Bill Sartor, former Chair of ICA, personal communication, April 2006.
[106] Billings, ibid, 2000.
[107] Brown, ibid., 2002, p. 39.

Self Serve and Reclaim

Reclaim systems are not usually used by self-service carwashes due to the relatively few gallons per vehicle used by self-service customers. However, a closed-loop reclaim system is used in self-service carwashes where there is no discharge to the sanitary sewer and all discharge is restricted.[108] In these situations, it is not uncommon for the self-service to be staffed on-site to prevent customers from dumping oil or other materials, which would damage the reclaim equipment in the pits.

In Bay Automatics and Reclaim

Reclaim equipment companies generally acknowledge that in-bay automatics provide a more expensive challenge to reclaim systems, since all chemical products, from cleaning to finish, as well as oil and grease and contaminants from the road winds up in the same separator tank. The water needs to be treated to remove all constituents that would interfere with its eventual reuse in the wash. The 2002 ICA water use study also found a wide variation in reclaim usage rates in in-bay automatics with a low of 12 percent per wash and a high of 82 percent per vehicle washed. The 2002 study found that 25 percent of in-bay automatic washes in the United States have a reclaim system[109].

Conveyors and Reclaim

In conveyor systems, the length of the tunnels can provide opportunities to reclaim rinse water separately from wash water, necessitating different levels of treatment. This flexibility can create more cost-effective reclaim opportunities. For example, more difficult-to-treat chemicals that are used in small quantities, such as those in waxes or finish products, may be routed away from the principal reclaim system. Likewise, final rinse water may be reclaimed and reused with less treatment. The wide variety of ways that reclaim can be performed in conveyor carwashes results in a broad range of reclaimed water usage measured as a percentage of total water used per vehicle in the 2002 ICA study. The lowest amount of reclaim water used in a conveyor wash with reclaim was 9 percent per wash and the highest was 74 percent. The 2002 study also found that 56 percent of conveyor washes in the United States have a reclaim system[110].

Large Vehicles and Reclaim

Reclaim also has an important role in industrial uses and for large vehicles as noted above. The controlled access to such facilities allows for more innovative treatment of the water, such as longer residence times and use of enzymes. Rainfall can be captured to replenish systems, so closed-loop systems can approach 100 percent nonpotable water use. A bus wash reclaim system in Seattle, for example, which was partially funded by the Seattle Public Utilities,

[108] Anderson, ibid., 1999.

[109] Brown, ibid., 2002.
[110] Brown, C., 2002. *Water Use in the Professional Carwash Industry,* International Carwash Association.

achieved in excess of 80 percent efficiency and saved more than 200 gallons per vehicle. Similar results could be expected for other large vehicle reclaim systems, but studies on this sector have not been performed.

Other considerations

Vehicle wash operators typically pay a sewer discharge rate that covers the costs of treating the materials that have come off the vehicles, such as grit, oils and metals, and the detergents or cleaning products the facility has added. Thus oil and grit separation tanks are standard features of a vehicle wash, and reclaim equipment has added value because it helps reduce the volume of discharge per vehicle.

Recycled water from municipal sources is not typically delivered to commercial car washes. However in California, Marin Municipal Water District (MMWD) has done so. MMWD currently serves two commercial car washes with recycled water. Two issues have dominated use of recycled water in these car washes: pathogens and spotting on cars due to TDS. To address DPH concerns about pathogens, the car washes have been equipped with a device that automatically delivers periodic chlorine shock treatment. Also, ozonation systems are commercially available to address this issue. Spotting was addressed initially with an RO system, but MMWD reduced its recycled water TDS such that spotting on cars is now effectively managed with ion exchange and/or surfactants.

7B: Industrial Sectors

7B1: Best Management Practices for Industrial Operations

Introduction: Industrial operations are unique, even more so , than commercial and institutional operations. Although the processes are generally the same in a specific type of industry, the uniqueness comes in the configuration or layout of the actual facility and the design of equipment, which is often proprietary. As a result, "cookie cutter" assumptions on payback or the implementation of a specific BMP are impractical. The following three concepts should serve as guiding principles when considering industrial facilities:

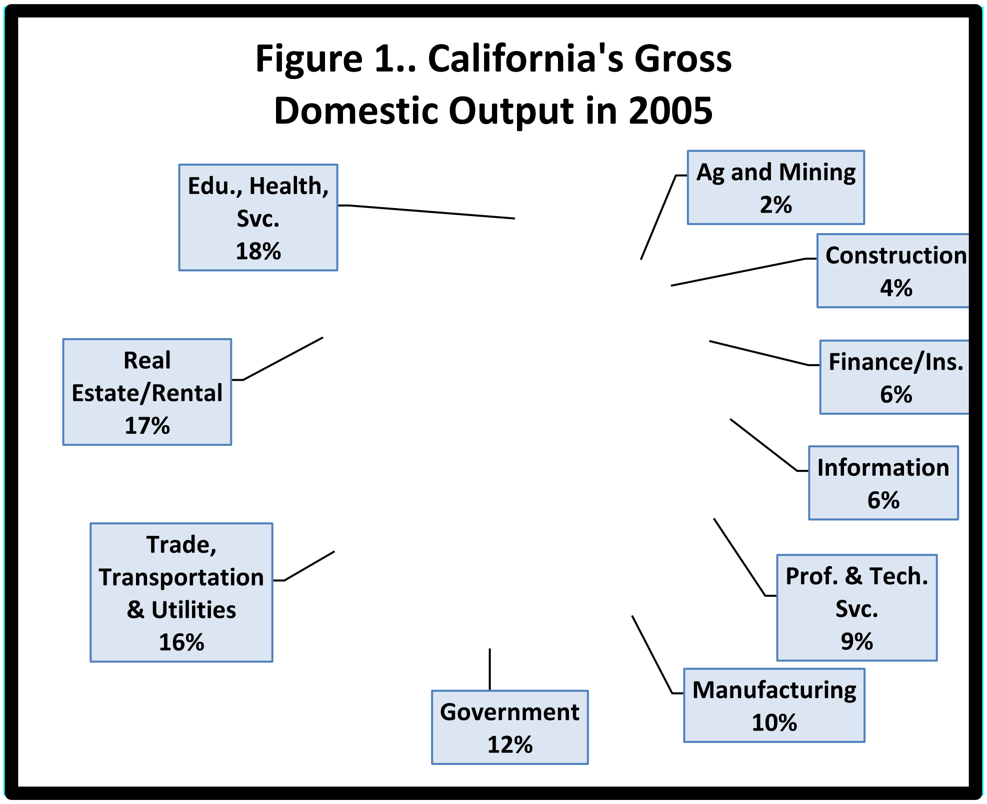
1. **One size does not fit all** – For any given industry, there may be a dozen potential BMPs. Not all will be applicable. In many cases, establishing one BMP will make another one inapplicable because they will "be saving the same water."
2. **Every plant is unique** - Analyzing potential payback is unique to each plant and situation. Unlike many commercial situations, manufacturing plants vary in manufacturing techniques and design, even in the same industry. As a result, what may work at one vegetable processing plant may not be applicable at another.
3. **The list should be used only as a guide** - The intent of the manufacturing BMPs is to provide a list of possible measures that plants can adopt for their specific situation.

Purpose: The purpose of this chapter is to:

1. Look at the importance of industrial operations to the State of California.
2. Examine how water is used in general.
3. Look at six example cases of how water is used in selected major industrial sectors in the State.
4. Present detailed descriptions of best management practices in each of these industries that are applicable to all industries.

The six industries chosen provide examples of water-using operations that are generally found in other industries.

California Industries: California leads the nation in commercial output. In fact, if California were its own country, it would rank as the eighth largest economy in the world. According to U.S. Department of Commerce information, the state's economic output in 2008 was $1.85 trillion. Figure1. shows the distribution of that output over the various economic sectors in California.



The manufacturing sector employed 1.197 million Californians in 2009 and produced over $443 billion in total shipments based on the U.S. Census of Manufacturers. Figures aa, bb, and cc summarize employment and shipments by each of the major sectors. Value added, approximately the difference between raw materials and shipment, represents the "worth" added by the manufacturing process. Value added in 2009 was $225 billion while workers earned over $63.6 billion, which averages to a little over $53,000 dollars annually for each worker.

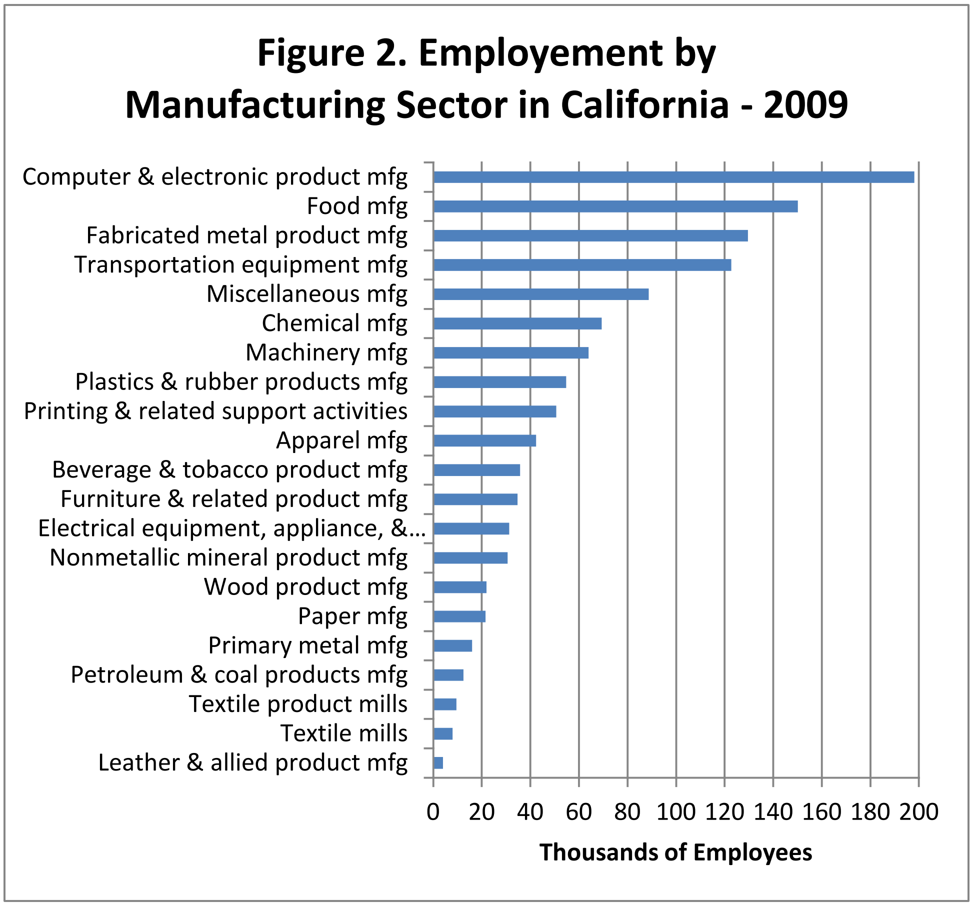


Figure 2. Employement by Manufacturing Sector in California - 2009

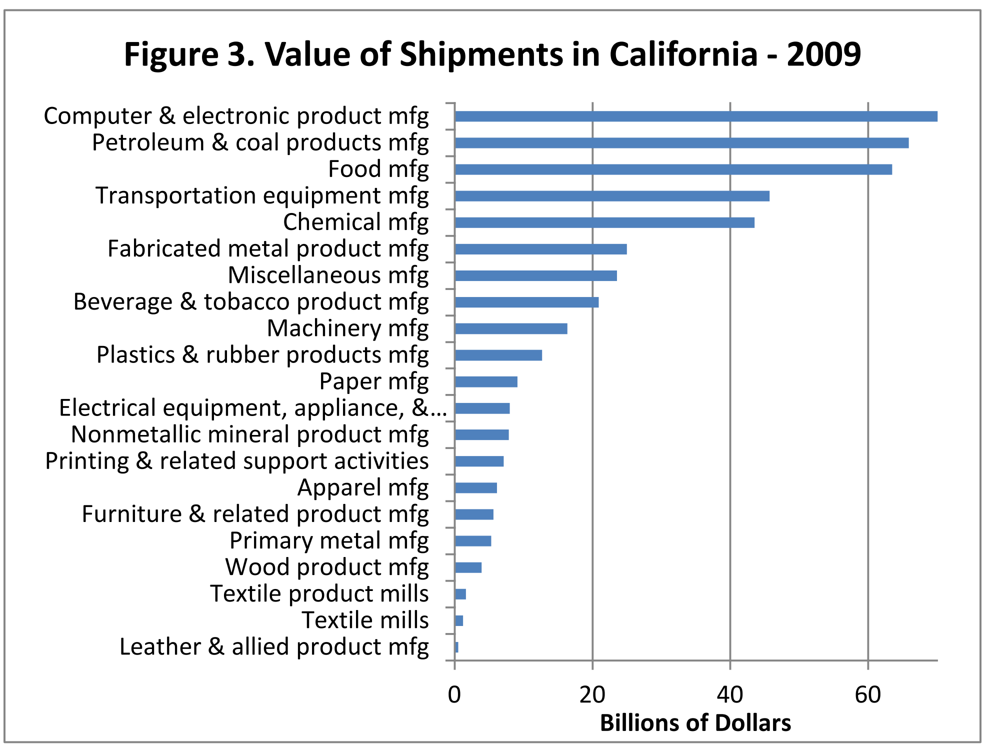
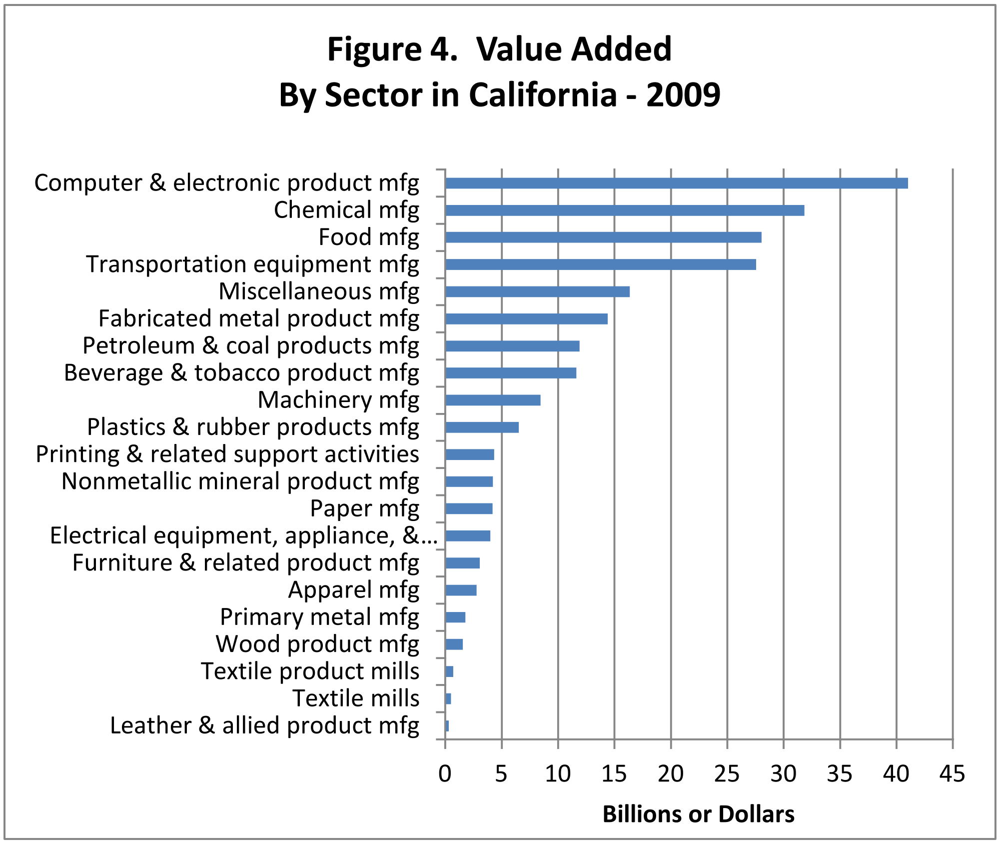


Figure 3. Value of Shipments in California - 2009



For purposes of this analysis, the beverage industry will be included in the food - processing sector. Prior to the 1990s the system to classify commercial activities was known as the Standard Industrial Classification system (SIC). The new North American Industrial Classification System (NAICS) has replaced the SIC system. In the new system, beverages were separated from the food processing system and combined into a new category of Beverages and Tobacco under the NAICS code of 312 with Beverages being 3121 and Tobacco being 3122. Because of confidentiality concerns, the US Department of Commerce does not list California dollar production at the four-digit level, but combines it at the 312 level including tobacco. However, it does give employment information at the four-digit level. This information shows that 99 percent of employees work in the beverage sector; therefore, NAICS 312 is used to represent this sector in the above material. The new NAICS codes also better delineated the Computer and Electronics Manufacturing sector to reflect current market conditions.

Table 1. compares old SIC codes to new NAICS codes.

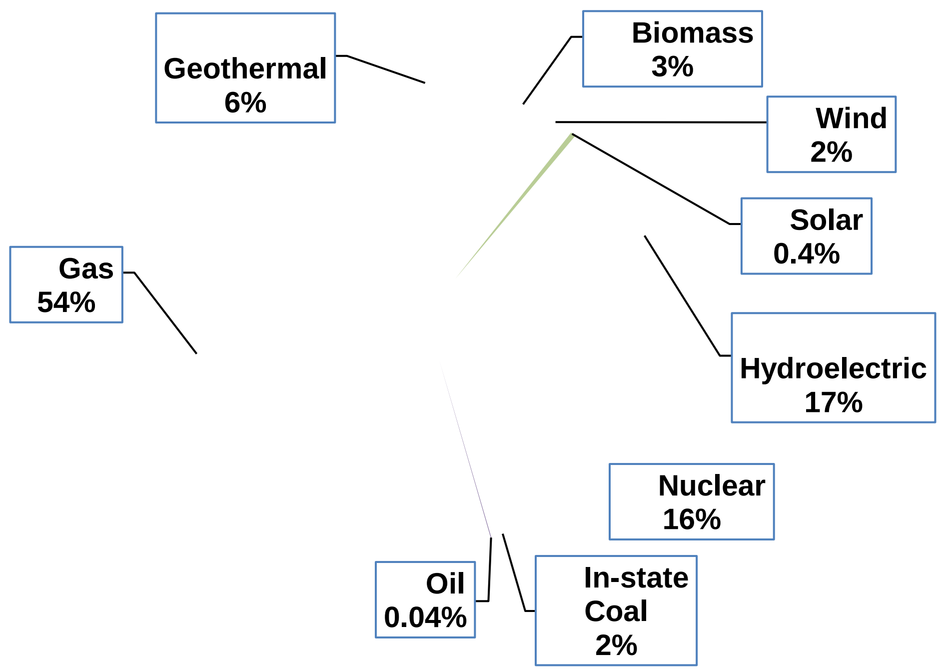
Table 1. Comparison of Federal Industrial Sector Codes		
Industrial Sector	**NAICS***	**SIC***
Food mfg	**311**	**20**
Beverage & tobacco product mfg	**312**	**20**
Textile mills	**313**	**22**
Textile product mills	**314**	**22**
Apparel mfg	**315**	**23**
Leather & allied product mfg	**316**	**32**
Wood product mfg	**321**	**24**
Paper mfg	**322**	**26**
Printing & related support activities	**323**	**27**
Petroleum & coal products mfg	**324**	**29**
Chemical mfg	**325**	**28**
Plastics & rubber products mfg	**326**	**30**
Nonmetallic mineral product mfg	**327**	**32**
Primary metal mfg	**331**	**33**
Fabricated metal product mfg	**332**	**34**
Machinery mfg	**333**	**35**
Computer & electronic product mfg	**334**	**36**
Electrical equipment, appliance, & component mfg	**335**	**36**
Transportation equipment mfg	**336**	**37**
Furniture & related product mfg	**337**	**25**
Miscellaneous mfg	**339**	**39**
***NAICS - North American Industrial Classification, SIC - Old System Numbers**		

Table 2. summarizes the ranking of the industrial sectors in California by value of shipments, employment, and value added. This information shows that from an economic perspective, the major industries are computers and electronics, chemicals, food processing, transportation equipment, fabricated metals, and petroleum.

Table 2. California Industrial Economic Ranking by Three Indicators			
Rank	**Value Added**	**Value of Shipments**	**Employment**
1	Computer & electronic products	Computer & electronic products	Computer & electronic products
2	Chemicals	Petroleum & coal products	Food processing
3	Food processing	Food processing	Fabricated metal product
4	Transportation equipment	Transportation equipment	Transportation equipment
5	Miscellaneous	Chemicals	Miscellaneous
6	Fabricated metal product	Fabricated metal product	Chemicals
7	Petroleum & coal products	Miscellaneous	Machinery
8	Beverage & tobacco	Beverage & tobacco	Plastics & rubber products
9	Machinery	Machinery	Printing
10	Plastics & rubber products	Plastics & rubber products	Apparel
11	Printing	Paper	Beverage & tobacco
12	Nonmetallic mineral products	Electrical equipment, appliance, etc.	Furniture
13	Paper	Nonmetallic mineral products	Electrical equipment, appliance, etc.
14	Electrical equipment, appliance, etc.	Printing	Nonmetallic mineral products
15	Furniture	Apparel	Wood products
16	Apparel	Furniture	Papers
17	Primary metals	Primary metals	Primary metals
18	Wood product	Wood products	Petroleum & coal products mfg
19	Textile product mills	Textile product mills	Textile product mills
20	Textile mills	Textile mills	Textile mills
21	Leather & allied product	Leather & allied product	Leather & allied product
Source: U.S. Dept. of Commerce - Census of Manufacturers			

Figure 5. Electric Power Production in California - 2010

302,565 Gigawatt-hours per year



Water Use for Industry

Industrial water is used in eight basic ways:

1. Cooling & boilers
2. Cogeneration and energy recovery
3. Process
4. In-plant conveyance
5. Cleaning
6. Environmental controls
7. Sanitation
8. Irrigation of landscape

To properly evaluate industrial water using operations, two terms must be defined: use and consumption.

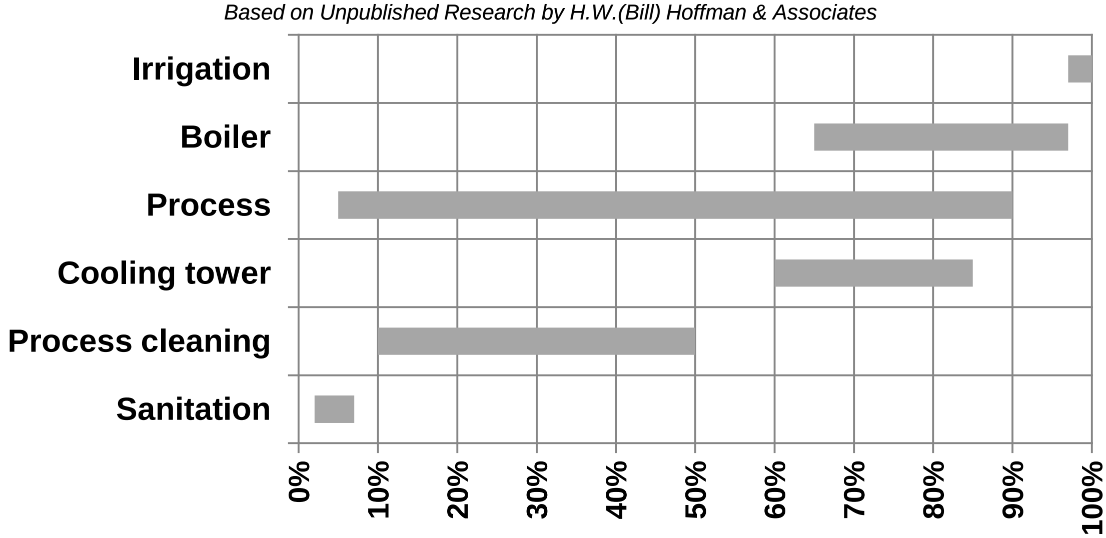
1. ***USE*** means the total water purchased or withdrawn from a fresh or saline body of water or from a well.

2. ***CONSUMPTION*** refers to water that is either included in the product, evaporated, or otherwise not returned as an effluent from the facility. Some food processors, especially fruit and vegetable processors and wineries use their effluent for irrigation of corps. In the final analysis, the water is consumed for crop production, but not in the facility.

The percent of water use that is consumed and not returned depends on the type of use, the industry, and the specific process. For example, in efficient carbonated beverage (soda) manufacturing, total water use per gallon of soda produced is about 1.7 gallons. This figure includes one gallon in the product and 0.7 gallons used in the plant. In petroleum refineries, over 75 percent of the water use is typically for cooling towers and boilers Figure 6. shows that the amount of water consumed in various types of industrial and commercial operations can vary considerably.

Figure 6. Percent of Water Used that isTypically Consumed in Industrial and Commercial Operations

Based on Unpublished Research by H.W.(Bill) Hoffman & Associates



One of the consequences of water consumption is that the remaining water contains the concentrated minerals and salts that were in the water source and the chemicals that were added.

When examining industrial use, the potential source of that water will also have an impact on overall water costs. Industry can often use water that is not suitable for other uses. Saline water from coastal areas is often used for cooling and recycled water and water from on-site sources can often be beneficially used.

To better understand the breadth of water use in industry, this section uses six industrial sectors as illustrations. They were selected because water use in each is very different. The six industrial sectors are:

1. Food processing and beverage industries, including fruit and vegetable processing, wine making, and poultry processing;
2. The aerospace industry, including making of engine components, metal finishing, and plastic extrusion and molding;
3. The petroleum refining and petrochemical industries;
4. Pharmaceuticals, including drug production and the emerging biotechnology industries;
5. Electric power generation;
6. The electronics (high-tech) industry, including microelectronics and circuit board manufacturing.

Technical Feasibility, Benefits and Cost

Industrial water efficiency efforts can result in significant water and monetary savings to the industrial water user. All of the Best Management Practices (BMPs) discussed in the industrial BMP sections are technically feasible and have been successfully employed elsewhere.

Determining the cost and benefits of each BMP depends on a number of factors. In most cases, the solutions must be engineered to the specific facility design and layout. For example, the cost of two-inch industrial piping within a facility depends on the type of pipe material that can be used, the length of the pipe needed, and the hurdles it must overcome to be installed along with the labyrinth of other piping in the plant. The cost per foot of pipe can be as low as $25 or more than $300. The same variations are true for even the same equipment. For example, a pigging system launcher and retriever (see section describing clean-in-place applications) can typically be purchased for $20,000 to $35,000 depending on the size and application. But this figure represents only a starting point. Again, piping, the power sources to operate it, and the way materials recovered from the pipes to be pigged must be engineered for that specific application.

Another example is the installation of a water recycle system to recover water from the processing of wafers in a microelectronics fabrication facility (fab). For a large fab, recycling could save half a million gallons of water a day or more, but costs could range from a few hundred thousand dollars to several million dollars depending on plant design.

The technical feasibility can also be limited by a number of parameters. Water quality, available space, regulatory and code requirements, and technical limitations specific to a given industry or process may limit applications of a BMP. These factors are different for each type of industry, even between similar facilities producing the same products.

The benefits of a given BMP also depend on a number of factors including:

- The cost of water and wastewater source for that plant
- Associated energy savings or costs
- The value of any products recovered or saved as a result of the BMP
- Potentially incurred labor, solid waste, air quality, or related costs.

Other important factors include:

- The degree to which a facility has already implemented water efficiency measures
- The specific type and model of process equipment used within the same industry
- The life expectancy of the plant, process, or equipment to be modified.

In this document, case studies will illustrate the feasibility and record potential costs and savings for specific examples. Where cost ranges for specific measures are available, they will be included in the text for each BMP section.

7B2: Industry-specific Information

7B2a: Aerospace and Metal Finishing Industries in California

Introduction

The term "aerospace industry" refers to a wide variety of industrial operations associated with the production and maintenance of aircraft, missiles, space vehicles, and the equipment and services that serve that sector. The industry encompasses both military and commercial aviation through original equipment manufacturing and reworking, which includes the maintenance, repair and modification of existing aircraft. All of the many tiers of the industry use water.

Metal finishing is the principal water using operation in the production of aircraft. Many of the operations common to this industry are found in industries that produce metals and plastics and that contain motors and controls. These products include appliances, boats, vehicles, and many types of commercial equipment. Best management practices that are applicable to the aerospace and metal finishing industry are equally applicable to these other industries.

The Aerospace Industry

The aerospace industry is part of the transportation sector according to the North American Industrial Classification System (NAICS) 336. Figure 1. shows the predominance of the aerospace industry in California over other transportation equipment sectors.

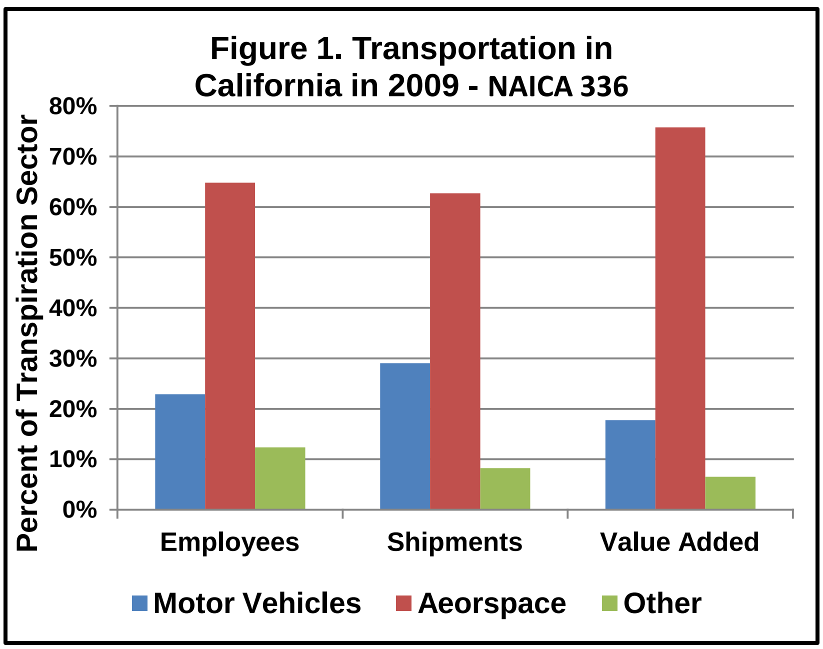
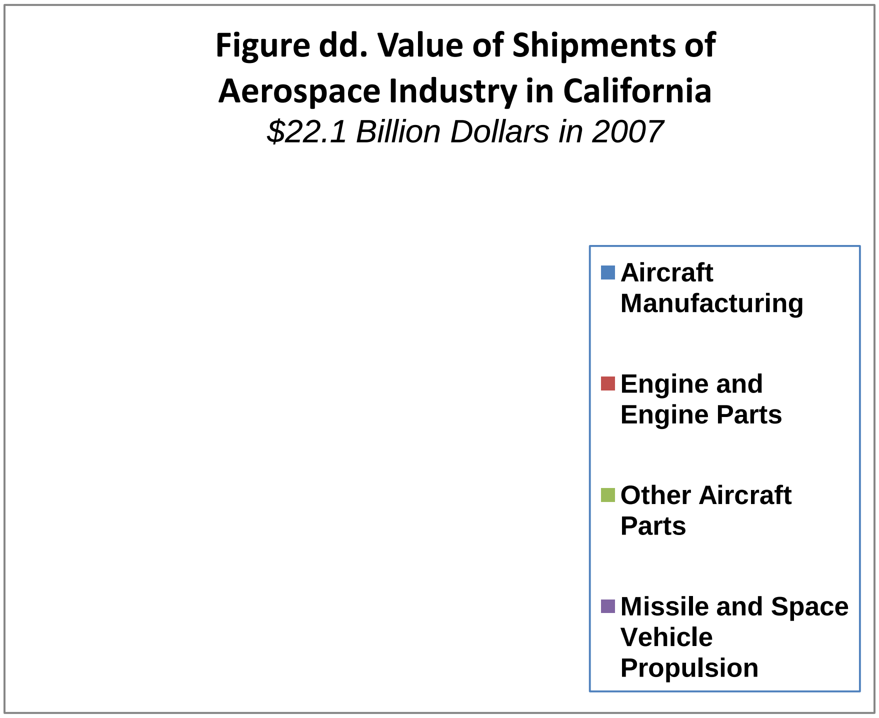


Figure 1. Transportation in California in 2009 - NAICA 336

Figure 2 shows the distribution of the value of shipments for the aerospace industry in California based on the 2007 US Census of Manufacturers.



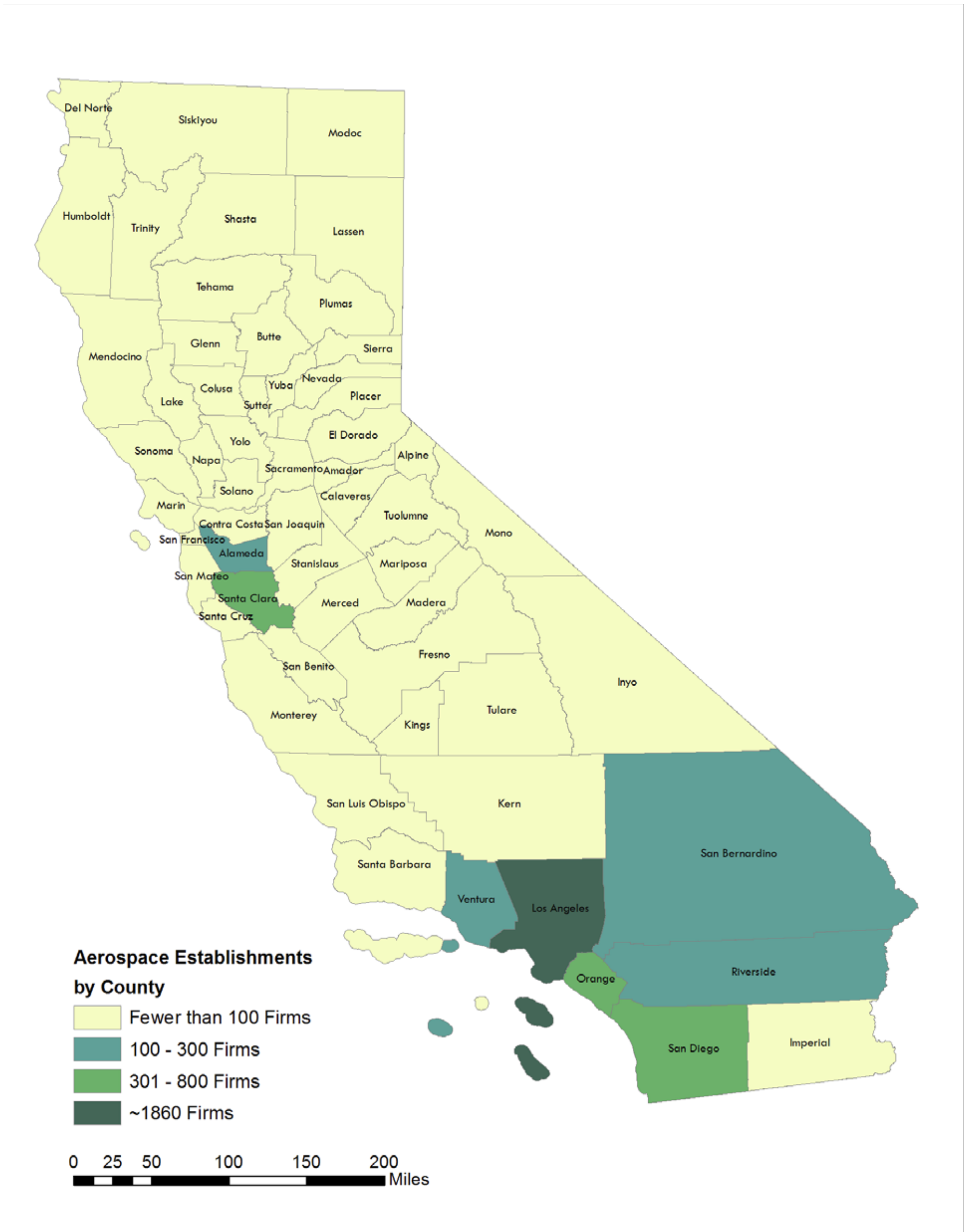
Based on U.S. Department of Commerce data, employment in this sector increased from 70,297 employees in 2007 to 79,098 employees in 2009. Likewise, the value of shipments rose from $22.1 billion in 2007 to $28.4 billion in 2009 in California. Table 1. summarizes employment and the value of shipments for 2007.

Table 1. California Aerospace Industry in 2007

NAICS	Description	Value Added (Billions of dollars)	Employment (Thousands)
336411	Aircraft Manufacturing	6.5	13.3
336412	Engine and Engine Parts	5.3	23.4
336413	Other Aircraft Parts	9.2	29.5
336414	Guided Missiles and Space Vehicles	0.1	0.1
336515	Missile and Space Vehicle Propulsion	1.1	4.1
	TOTAL	22.1	70.3

As figure 3. shows, most of California's aerospace industry is located in Southern California and the Silicon Valley - San Francisco Bay Area. Actual manufacturing has declined according to the publication, "Aerospace Manufacturing and Support Industries in California – 2010, but the research, design, repair, and refurbishment of electronics, and the warfare aspects of the industry and space research continue to be very active.

Figure 3. Aerospace Establishments in California



Source: Aerospace Manufacturing and Support Industries in California - 2010

The industry includes the following operations:

- Design
  - Design of all types
  - Administration
  - Academic research
- Testing and Research
  - Laboratory
  - Academic
- Manufacturing
  - Engines and propulsion systems
  - Air frames
  - Electronics
  - Structural parts
  - Life support and interior
  - Avionics
  - Metal working
  - Metal finishing
- Rework and refurbishing
  - Paint removal
  - Parts cleaning
  - Hydro blasting & plane washing
  - Processes like those in manufacturing

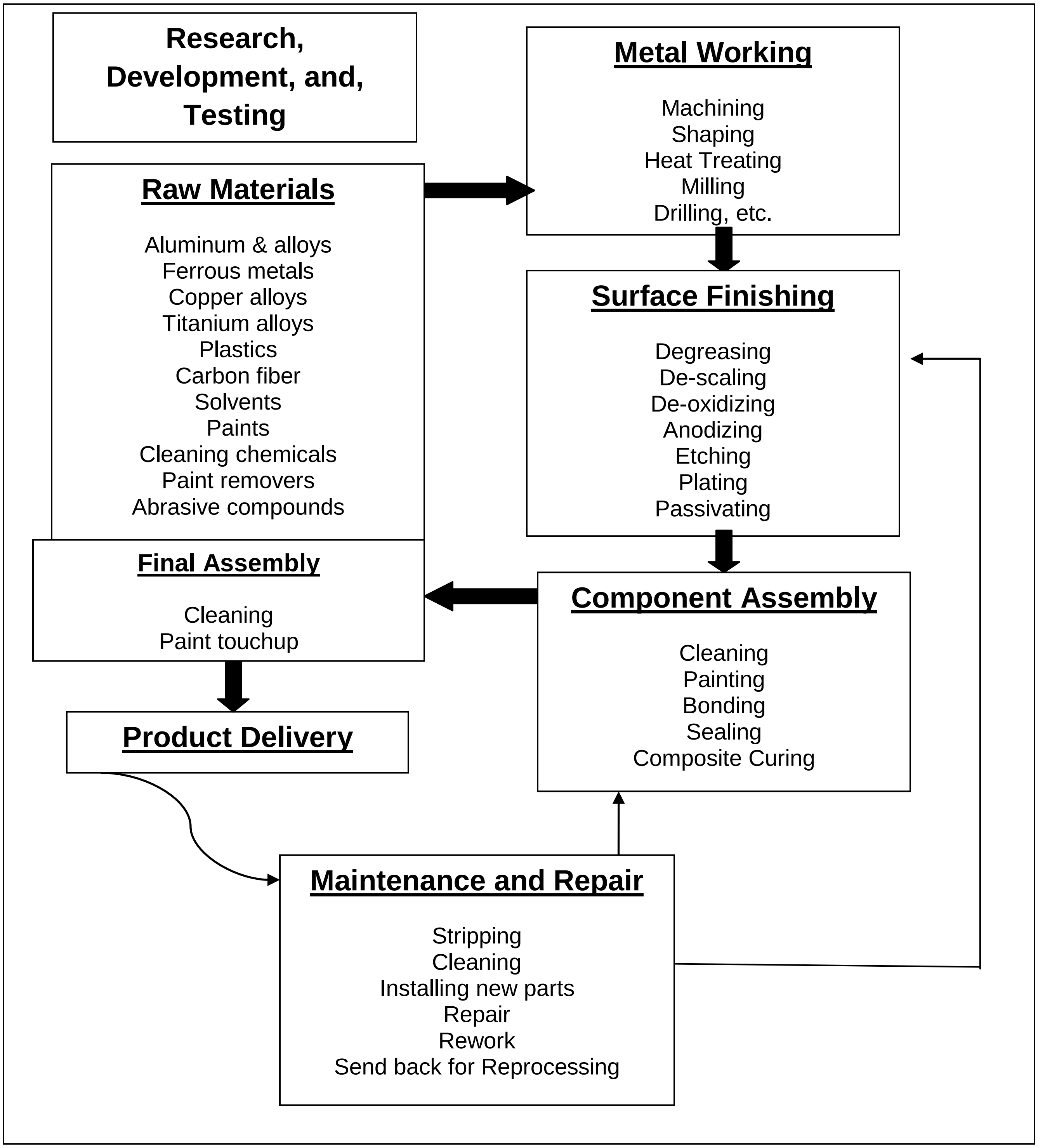
Many industries support the aircraft industry and use water in their operations. These Include:

- Hardware manufacturing - NAICS 332510,
- Machine shops - NAICS 332710,
- Precision turned product manufacturing - NAICS 332721,
- Bolt, nut, screw, rivet, and washer manufacturing - NAICS 332722, and
- Fluid power valve and hose fitting manufacturing - NAICS 332912

These industries are important in their own right and are recognized as major contributors to the Aerospace industry in California. They use water for casting, milling, machining, and related uses. Many have cooling towers and other process equipment. Water efficiency is important to these industries, but they are not included in the overall discussion of the aerospace industry.

Figure 4 shows the interaction between the different components of the aerospace industry.

Figure 4. Aerospace Manufacturing Process



Water Use

Because of the wide diversity of the industry, almost every conceivable type of water use occurs at some place in this sector. Normal uses range from landscape, cooling towers, boilers, sanitation, food service, and even laundry and swimming pool operations. Cleaning of all types is commonplace, including vehicle washing. Some operations even include medical and laboratory functions.

As Figure 4. shows, aircraft manufacturing employs many aspects of metal finishing. The section titled **Plating, Printed Circuit Board, and Metal Finishing** discusses water use and Best Management Practices for these operations.

Other water uses commonly found in aerospace and similar manufacturing industries include:

1. **Molding and casting** Many metal parts are made by either pouring or injecting a material into a mold or form. Water may be used both to make the mold material, such as a wet sand mold, or for cooling the molds after injection. Any material that can be melted – such as metals, plastics, and ceramic materials – can be molded or cast into a desirable shape. The investment or lost wax method of casting involves making a wax mold that is coated in a slurry of clay; the clay is dried, and the wax melted out to form the mold.

2. **Milling and cutting** are common practices in engine manufacturing, metalworking, and production of subassemblies with forged, stamped, or cast parts Water is principally used in three main technologies:

    a. *Electric Discharge Machining* **-** Micro electrical discharge milling of WC-Co using a deionized water spray and a bipolar pulse. This method of machining generally uses kerosene or deionized water as the working fluid.

    b. *Water Jet Cutting and Milling -* Water jet cutting uses a high speed jet of water containing abrasives to cut metals, ceramics and other hard substances.

    c. *Cutting and Milling Fluids -* Turning, mechanical milling and grinding, drilling, taping, and sawing of metals all use cooling and cutting oils. Most are water-soluble oil-water mixtures. Air, CO_2, nitrogen, oils, and gels may be used in place of oil-water mixtures, but all have cost considerations and limited applications.

3. **Welding** Resistance processes such as spot welding use water or a brine solution for tip cooling and for cooling when arc welding tungsten. Air or water may be used to cool tungsten arc welding torches and other arc welding devices.

4. **Quenching of metals** When quenching, there are four types of media: air, brine (salt water), oil, and water. Quenching is the final step in metal heat treating and annealing.

5. **Aircraft Parts stripping and cleaning** is a necessary step before hydraulic systems, engine parts, and other components may be refurbished and repaired.

6. **Air scrubbers** are used in many of the manufacturing and maintenance operations to remove fumes and particulates that would cause air pollution or cause health and safety hazards if not controlled. Water is used in most scrubber systems.

7. **Paint removal** is a routinely employed process to remove old paint from aircraft before repainting. Organic solvent strippers have been replaced with water-based caustic compounds as well as various particle, thermal, and high-pressure water systems. Caustic-based chemical stripping removes paint, but must use water to clean the stripped parts. Some systems use high-pressure water in conjunction with chemicals. The resulting wastewater - caustic mixtures are routinely filtered and recycled. Very high-pressure water systems that do not use chemicals or abrasives are also used, but they use large amounts of water.

   Dry paint removal methods use a wide range of materials, including walnut shells, plastic pellets, sodium bicarbonate, carbon dioxide pellets, intense light, and heat.

8. **Painting** with solvent-based paints has been all but eliminated in most industrial processes and replaced with water-based paints or with electrostatic dry paint systems and other dry coat processes. Water is used to clean equipment and as a solvent for the paint. Systems that filter and recycle cleaning water are available. Where water curtains are used to capture paint particles in spray booths, the water needs to be filtered and recirculated. Dry electrostatic paint methods should be used where applicable.

Metrics

Annual water use estimates for the aerospace and metal finishing industries are not available. The diversity of this industry and the decline in actual manufacturing of aircraft in California all indicate that this sector's water use is declining. Establishing metrics for such a diverse industry is not possible without, at the very least, an inventory of current water use.

Best Management Practices for the Aerospace and Metal Finishing Industry

The Best Management Practices described in this section are applicable to both manufacturing facilities and research laboratories/testing facilities for the aerospace and metal finishing industries. All of the BMPs are currently being successfully employed at various facilities. Their economic viability depends on specific facility design, cost of utilities, and a number of related factors. In other words, what works at one facility may not necessarily work or be economically practical at another similar facility.

The section entitled Plating, Printed Circuit Board, and Metal Finishing describes Best Management Practices (BMPs) for metal finishing and plating. BMP's for landscape, cooling towers, boilers, sanitation, food service, laundry and swimming pool operations, vehicle washing, medical and laboratory operations, and other similar uses are described in their respective sections.

The section on Water Use describes six common water using activities in the aerospace industry. BMP's for each of the six water using areas include:

1. **Molding and casting** - Water saving opportunities depend on the type of molding and casting process used. Sand molds are a "standby" of the industry. The sand can be held together either with water or resin. Where resins can be used, water use can be eliminated. Investment casting involves making a water slurry of clay. In all cases where water is used, alternative methods are available. Mold cooling should only be done with either air or a closed cooling loop system.

2. **Milling and cutting**

   a. *Electric Discharge Machining* **-** Use kerosene instead of water where feasible.

   b. *Water Jet Cutting and Milling -* Recycle water and abrasives.

   c. *Cutting and Milling Fluids -* Air, CO_2, nitrogen, oils, and gels can be used in place of oil-water mixtures, but all have cost considerations and limited applications.

3. **Welding** - Where possible, use welding techniques that do not require cooling water or brine. Spot welding and tungsten arc welding tips should be air cooled where feasible.

4. **Quenching of metals** When quenching, there are four types of media: air, brine (salt water), oil, and water. Where water or brine is used, water is lost directly through evaporation. Oil quench tanks are often cooled with water that circulates through coils of a heat exchanger. Once-through cooling water should be eliminated and replaced with a properly operated cooling tower or chilled water loop that recirculates the cooling water. Where feasible, air cooling should be used.

5. **Aircraft Parts stripping and cleaning** is a necessary step before hydraulic systems, engine parts, and other components can be refurbished and repaired.

6. **Air scrubbers** that use a water solution should be of the reticulating type and should be equipped with conductivity controllers or other devices to control the amount of makeup water. Scrubbers are excellent candidates for the use of alternate sources of water. Where feasible, a dry absorptive media should be used.

7. **Paint removal** **-** Dry paint removal methods, including the use of walnut shells, plastic pellets, sodium bicarbonate, and even carbon dioxide pellets, should be used where feasible. Intense light and heat sources are applicable for certain types of surfaces and offer water savings, but can use energy.

   Where caustic strippers or softening agents are used that require water to remove the residue, the resulting water should be filtered and recirculated. This recirculation reduces water and chemical use and concentrates waste materials for disposal. Very high pressure water systems should also be equipped with water filtration and recycle devices.

8. **Painting** - Dry paint systems should be used where feasible, but for large surfaces, spray painting is still the most commonly applied method. Systems that filter and recycle cleaning water are available. Where water curtains are used to capture paint particles in spray booths, the water should be filtered and recirculated.

Case Study: Spent Alkaline Cleaner Recycle at the Naval Aviation Depot - North Island, San Diego, California

Spent alkaline cleaner from the industrial cleaning operations at NADEP (Navel Aviation Depot – North Island) is contaminated with particulates, oil, and grease, which is then discharged to the Industrial Wastewater Treatment Plant (IWTP). NADEP hopes to eliminate that discharge through the use of an alkaline cleaner recycling system that uses cross flow filtration (CFF) technology originally designed to support oil and water separation, solid and liquid separation, and other applications in the petroleum industry.

The recycling system processes the spent alkaline cleaning solution in a batch mode. From a holding tank, the solution is pressurized and fed through a ceramic filter membrane. Oil and grease are removed by the membrane and separated into a collection bin. The treated alkaline cleaning solution is then reconditioned before reuse.

The CFF consists of ceramic membrane elements that have superior physical integrity, chemical resistance, and thermal stability. In addition, the ceramic membrane elements (either tubular or monolithic geometries) are packed separately in stainless steel housings. The stainless steel housings allow the membrane modules to operate at high temperatures (exceeding 80˚C in aqueous applications) and extreme chemical conditions.

In 1996, NADEP successfully pilot tested and evaluated the CFF system for recycling the alkaline cleaner. The study examined two commercially available non-ionic cleaner products and five lubricants commonly used by NADEP's industrial processes. Results of the pilot study showed that the CFF was effective in removing oil and grease from the alkaline solution. In addition, the pilot test showed that membrane fouling caused by hydrocarbon contaminants is negligible, and that the membrane permeability could be restored with simple cleaning techniques. The CFF process did not remove alkaline builder salts in the cleaner formulation, but the alkaline cleaner recycling system is a means to enhance the removal of fine abrasives, metals, and inorganic particles, as well as emulsified oil, from alkaline cleaning solutions. Therefore, it prolongs the life of the alkaline cleaning solution and reduces the volume of hazardous waste generated.

The alkaline cleaner recycling system yielded the following benefits:

- Resulted in a significant reduction of solution change-outs, thereby minimizing hazardous
  material purchase and hazardous waste generation.
- The pilot system reduced 97.5% of the spent cleaning solution requiring disposal during one change-out thus eliminating a corresponding amount of water use.

- Pilot-scale and laboratory data indicated a removal efficiency of greater than 99 percent for oil and grease.
- Assisted in achieving the P2 goals outlined in the NADEP Pollution Prevention Plan that was mandated by Executive Order 12856.

Implementation and Cost Information

The following implementation and cost factors were considered at NADEP:

- An initial capital investment of $50,000 is required for the alkaline cleaner recycling system. The calculated payback period for this investment is approximately 1.6 years. However, the payback period could be reduced by combining spent alkaline cleaning solutions from multiple sources at NADEP North Island.
- The proposal to design, install, and operate a full-scale CFF is expected to be fully supported by NFESC. Since the unit has not yet been installed, no installation cost data are currently available.
- Training requirements on the alkaline cleaner recycling system is minimal.
- The CFF process does not remove alkaline builder salts in the cleaner formulation, but does effectively remove oil and grease. The alkaline cleaner will require reconditioning before reuse.

Plating, Printed Circuit Board, and Metal Finishing

Cleaning metal, metal plating and surface finishing, coating plastic parts with metal, and the processing of circuit and wire boards all use similar techniques to clean and plate surfaces. Metal finishing includes all industrial operations that change the properties of metals to improve:

- Corrosion resistance
- Wear resistance
- Electrical conductivity
- Electrical resistance
- Reflectivity and appearance (e.g., brightness or color)
- Torque tolerance
- Solder-ability
- Tarnish resistance
- Chemical resistance
- Ability to bond to rubber (e.g., vulcanizing)
- Hardness

In these operations, the parts to be processed are either drawn through the tanks, as is the case with roles of metal to be cleaned and painted, or they are suspended on racks or placed in plastic barrels that are dipped in the tanks. All processes begin with the preparation of the parts by cleaning followed by the process. Water uses include:

- Process water
- Chemical solutions makeup
- Air scrubbers
- Water treatment
- Parts and plant cleaning
- Cooling towers
- Boilers
- Domestic use
- Irrigation

Processes include but are not limited to:

- Metal cleaning for painting
- Wire and circuit board processing
- Anodizing
- Electrolytic plating
- Electro less plating
- Galvanizing.

Process water: Water saving methods for equipment and plant cleaning, cooling towers, boilers, domestic use, and irrigation are discussed in their respective sections. The following section presents twelve ways to reduce water use in plating, PCB, and metal finishing operations.

1. *Dragout Control* - Dragout occurs when parts being processed are removed from one tank and transferred to another. Liquid adhering to the part contains the chemicals from that tank. Allowing this material to be carried to the next tank will contaminate that tank's contents and require that that rinse water or solution be dumped or reconstituted at some point. Minimizing this carry over is the objective of dragout control. Methods to accomplish this include:

    - Designing racks, barrels and processes, so that liquids captured in bends and curves of the pieces being processes are minimized, allowing time for parts to drain (dwell) over tank
    - Using sprays in place of dipping parts
    - Using air knifes, fogs or misting to remove solution
    - Vibrating or " bumping" parts to knock liquid off,
    - Ensuring parts are pointed down so that they drain most efficiently,
    - Using wetting agents,
    - Hanging bars above tanks to allow parts to drain,
    - Installing drip guards between tanks
    - Using drain boards.

2. *Chemical Concentration Control* – The use of conductivity meters, chemical analysis equipment, optical sensors and similar methods to control the timing of draining, rinse baths, or adding chemicals to ensure it is necessary.

Artistic Plating and Metal Finishing, Inc.
Reduces Water Use by 49%

Artistic Plating and Metal Finishing, Inc. of Anaheim, California plates brass, copper, nickel, and chrome of small parts. Rising water and sewer costs have led the company to explore cost reduction opportunities. In response, they have installed electrode-less conductivity controllers on nine tanks on the plating line, reducing water use by 49% and reducing chemical costs by 20%. With a total installed cost of $14,500 and annual savings of $13,800 per year, the improvement paid back in 13 months.

Source: Metal Finishing Association of Southern California

3. *Multiple Tank and Countercurrent Rinsing* - Countercurrent rinsing and the use of multiple tanks for rinsing allows the part to be placed in the most contaminated water first. The next rinse tank contains the cleaner water and so on. With countercurrent flow, the water from the cleanest tank is used to replace the more contaminated water in the next tank. Reactive rinsing, where the rinse water from the final tank is used for the pickle-rinse tank, can also be used in some applications. Dual purpose rinsing is an option where the same rinse tanks or spray rinses can be used for multiple purposes when water quality is not critical.

4. *Mechanical Mixing, Agitation and Air Blowing* - Agitation of plating liquids and rinsing solution maximizes contact of the liquid with the parts being processed, thus reducing time in each bath, extending the usefulness of plating liquids, allowing lower concentrations of the chemicals in a bath, and helping to improve uniformity of the product.

5. *Cleaning Method Selection-* Techniques for cleaning metals before painting have changed over the years. The classic zinc and iron phosphate cleaning processes require several rinses. New zirconium compounds and methods, such as the patented Piclex process, exemplify new strategies that eliminating one or more rinses.

6. *Pretreatment of Makeup Water* - The treatment of the water used to make up the solutions in the tanks can be important measures to achieve the maximum use of chemicals. Many plants soften their water and most major platers use reverse osmosis (RO) to produce high quality water for their makeup to plating solutions. By using RO water, unwanted constituents that would concentrate with evaporation are no longer present.

7. *Evaporation Control* - Many processes are operated at elevated temperatures or they actually produce heat during the plating process. Foams or floating balls specially designed to retard evaporation can cut evaporative losses by as much as 50 percent.

8. *Air Scrubbers* - Air pollution is a concern in many plating operations. Air scrubbers draw the contaminated air through a scrubbing system. The section on medical and laboratory facilities describes the scrubbing process in more detail. Installing recirculation systems with conductivity controllers, temperature probes, and fill and dump controls similar to conductivity blowdown controls on cooling towers helps reduce makeup water to the scrubbers. In plating operations, the reuse of spent rinse water and other sources of water is often an excellent alternate source of makeup water.

9. *Water Recovery and Recycle* - Rinse water can often be used as makeup water to the process tank containing the chemicals being rinsed. This practice recovers chemicals and reduces fresh water use. Some platers have used filtration and reverse osmosis to recover chemicals and produce a very clean stream of water for reuse. Zero liquid discharge (ZLD) is becoming a goal of many platers as levels of allowable chrome and other metals in effluent become more stringent.

Danco Metal Surfacing Reduces Water, Chemical and Wastewater Costs

Danco Metal Surfacing, Inc. of Ontario, California plates and dies small and medium size metal parts. It performs types 2 and 3 anodization, passivation of stainless steel, and chem-film dye colors. The facility implemented two major projects that resulted in savings of over $500 a month with a payback of less than two years and eliminated water use of over three gallons per minute. The modifications included installation of a two-tank counter flow rinse system and a reverse osmosis (RO) system to recover nickel in a black dye process.

Source: Metal Finishing Association of Southern California

10. *Platting Tank Cooling* - Input of electric energy into plating operations generates heat in the plating solutions. In the past, if the tank was air agitated or mixed, this heat was dissipated into the plating building. With the need to reduce air pollution and reduce evaporation, other cooling methods have been successfully employed. Recovery of this heat for use in other operation within the facility is the optimum method. This practice recovers waste energy, does not require cooling equipment, and does not consume water. Where cooling is needed, air cooling offers a real option where bath temperatures can operate at 140^{o}F or above. The use of a cooling tower or chilled water system represent other options, but they involve water and energy use. If cooling coils are used in the tank, some form of agitation will help ensure good heat exchange. Some

platers circulate tank fluids through heat exchangers with pumps, thus providng for good heat transfer and helping to agitate the tank fluids.

11. Rectifier Selection and Cooling - Rectifiers that convert alternating current (AC) to direct current (DC) for use in plating are found in all electroplating operations. Rectifiers may be either air cooled or water cooled. Air cooled rectifiers have to be placed where corrosive fumes from plating operations are not present, which usually means they are outside the plating line building. They also have to be sized so they do not overheat.

Many older facilities use once-through cooling to cool the rectifiers. The use of a cooling tower or chilled water loop will significantly reduce water use. The waste heat produced by the rectifiers should also be recovered where possible. In addition, many plating operations operate boilers, and the waste heat from rectifiers and tank cooling operations can be used to pre-heat boiler makeup water. Heating water for the reverse osmosis system also helps improve the productivity and efficiency of RO systems.

12. *Metering, Flow Control, and Data Acquisition* - The old adage of "if you don't measure it, you can't manage it" applies to plating and metal finishing operations. Metering of makeup water to the RO system, tank filling, cooling towers, and other major water using areas will help manage the system and reduce costs. Good metering will also alert managers to potential problems.

7B2b: Food Processing and Beverage Manufacturing

Background

The Food and Beverage Industry contributes $85 billion a year to California's economy and employs more than 180,000 people representing 15 percent of the State's manufacturing work force. Food processing and beverage manufacturing are often associated with California because of the volume and popularity of California products. California produces 89 percent of the United State's wine and is the leading producer of most of the nation's fruits and vegetables, accounting for about 21% of the fruits and vegetable products grown in the U.S. California is also a leader in dairy, beef, poultry and aquaculture production. Most of these products are processed to some degree in California before going to market.

Water is vital to the food processing and beverage manufacturing sector both to grow the crops that provide the input for the sector and to process its products. This chapter focuses on water used in the commercial and industrial processing of food and beverages. It does not address the water used in agricultural production or water used in the commercial food and beverage industries such as commercial food preparation and restaurants. Information on those industries appears in other sections of this report.

Food and beverage processing covers a wide range of products, which are not all covered in this section. Due to their size and scope, the industries that will be described as representative examples in this section include fruit and vegetable processing, chicken processing, and wine making. This section includes a description of the water uses in these industries, factors influencing the ability to conserve, best management practices, use of alternative supplies, and a summary of case studies.

Like all industries, food processing involves energy and water use. A 2004 study conducted by the California Energy Commission found that total food processing water use accounts for approximately 37 billion gallons of water a year (113,550 acre feet). This includes total water use by the major food processing sectors, but does not include the water used to grow the products. Due to the enormity of the fruit and vegetable processing sector in California, it accounts for a large percentage of water and energy use. California food processors produce over $13 billion of processed fruits and vegetables a year, accounting for 20% of the nation's total and $1 billion more than the next two states combined.

Table XX

Utility Use by Major Food Processing Industry in California Based on 2003-2004 Information

Food Processing sector	Water Use (million gal/Yr.)	Natural Gas (Million Therms/Yr.)	Electricity (Million kWh/yr.)
Fruits & Vegetables	30,000	300-400	600-800
Cheese	600	43	583
Milk powder/Butter	360	33	130

Beef	1200	5	88
Poultry	2000	40	360
Wine	2900	41	316
Source: **<u>California Food Processing Technology Road Map</u>,** California Energy Commission, 2004			

The amount of water used and the way it is used varies by the food product being processed (Table dd). Water uses that are common to multiple industry sectors are discussed in other sections of this report:

1. Domestic uses,
2. Thermodynamic processes (cooling towers, refrigeration and air conditioning, energy recovery, and cogeneration),
3. Laboratory uses,
4. Water treatment.

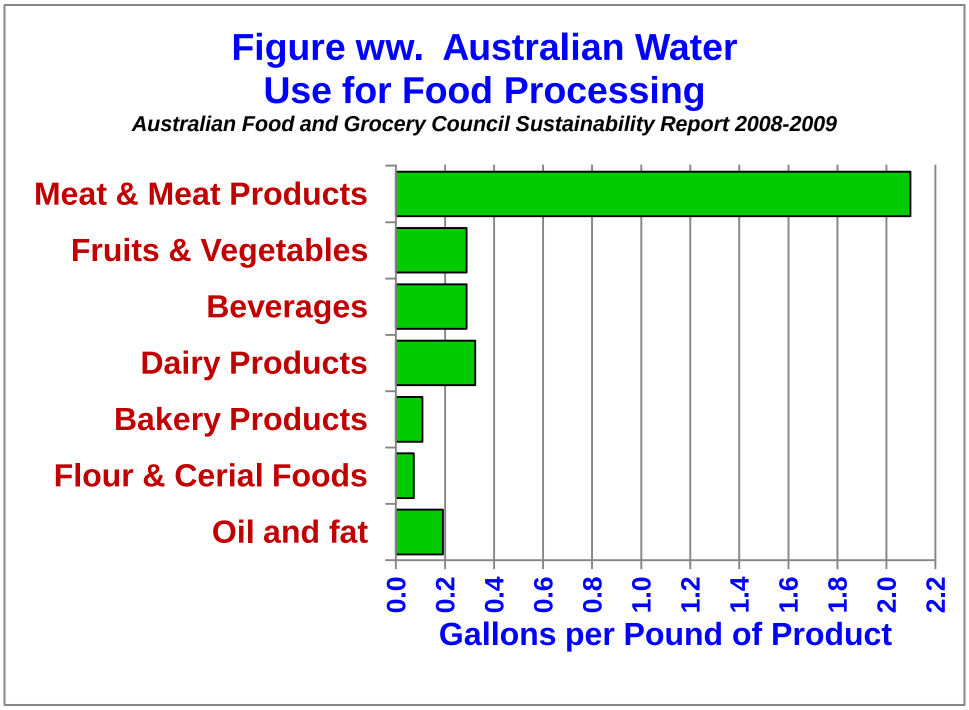
Table dd. Water Use in Food & Beverage Processing

Water Using Processes	**Food Processing Industry**									
	Animal Processing	**Animal Food**	**Bakeries & Tortillas**	**Beverages**	**Dairy Products**	**Fruits & Vegetables**	**Grains & Oil Seeds**	***Miscellaneous**	**Seafood**	**Sugars & Confectionaries**
1. Potential Water Reuse	x	x	x	x	x	x	x	x	x	X
2. Environmental Control	x	x	x	x	x	x	x	x	x	X
• Air Pollution	x	x	x	x	x	x	x	x	x	X
• Area Cleaning/Dust Cont.	x	x	x	x	x	x	x	x	x	X
• Wastewater Treatment/Reuse	x	x	x	x	x	x	x	x	x	X
3. Process Water Use	x	x	x	x	x	x	x	x	x	X
• Inclusion in product	x	x	x	x	x	x	x	x	x	X
• Fluming/transport	x	x				x		x	x	
• Product washing	x	x	x	x	x	x	x	x	x	X
• Cooking/Autoclaving	x	x	x	x	x	x	x	x	x	X
• Blanching/Pre-cook	x					x		x	x	
• Peeling & Prep.						x			x	
• Processing animal parts	x	x	x	x	x	x	x	x	x	
• Canning & bottling	x	x		x	x	x	x	x	x	
• Can/bottle cooling/warming	x	x		x	x	x	x	x	x	
• Conveyor lubrication	x	x	x	x	x	x	x	x	x	
• Pump seal water & other uses	x	x	x	x	x	x	x	x	x	X
4. Cleaning	x	x	x	x	x	x	x	x	x	X
• Clean in/out-or place systems	x	x	x	x	x	x	x	x	x	X

• Can/bottle/package cleaning	x	x	x	x	x	x	x	x	x	X
• Transport vehicle cleaning	x	x	x	x	x	x	x	x	x	X
• Crate & pallet washing	x	x	x	x	x	x	x	x	x	X
• Other cleaning	x	x	x	x	x	x	x	x	x	X
5. Domestic Uses	x	x	x	x	x	x	x	x	x	X
• Sanitation	x	x	x	x	x	x	x	x	x	X
• Irrigation	x	x	x	x	x	x	x	x	x	X
6. Thermodynamic Processes	x	x	x	x	x	x	x	x	x	X
• Cooling towers	x	x	x	x	x	x	x	x	x	X
• Boilers	x	x	x	x	x	x	x	x	x	X
• Refrigeration	x	x	x	x	x	x	x	x	x	X
• Cogeneration & thermal recovery	x	x	x	x	x	x	x	x	x	X
• Air Conditioning	x	x	x	x	x	x	x	x	x	X
• Humidification	x	x	x	x	x	x	x	x	x	X
7. Laboratory Operations	x	x	x	x	x	x	x	x	x	X
8. Water Treatment	x	x	x	x	x	x	x	x	x	X
* Miscellaneous - Snacks, Seasonings, Coffee, Dressings, etc.										

This chapter focuses on water uses specific to the food processing and beverage industry, specifically those uses involved in the product preparation, such as cleaning of equipment, boiler feed and cooling tower make-up, and inclusion in the product. The amount of water used per product varies depending on the product being produced.

Figure ww shows the result of the ***Australian Food and Grocery Council Sustainability Report 2008-2009***. With the exception of meat and meat products, water use for most food products produced in Australia falls within 0.07 and 0.32 gallons per pound of product produced. Meat and meat products use considerably more water than other food processing industries.



Fruit and Vegetable Processes Water Use and Efficiency (NAICS Code 311 and 312)

Description

Many fruits and vegetables are shipped directly to market from the field after an initial wash. Since they are perishable, however, many are processed to extend their life, as is the case with frozen products, juices, canned and packaged items, and pickled items.

Figures **, **and ** shown in Appendix ** show the steps required for processing raw fruits and vegetables, frozen fruits and vegetables, and canned tomatoes. Five major process areas that are common to all fruit and vegetable processing include:

- Cleaning and sanitation
- Product washing and sorting
- Preparation for processing (peeling, blanching, etc.)
- Food processing and cooking
- Final canning and packaging for shipment

Cleaning and sanitizing provide the most significant opportunities for water savings in many food and beverage processing facilities. Cleaning of vessels, pipes and equipment is covered in detail in the section entitled **Cleaning Industrial Vessels, Pipes and Equipment.**

Water use for cleaning is common to many industries, but clean–in-place and clean-out-of-place systems are unique to industries that must clean pipes and tanks from the inside for good sanitation, such as food and beverage processing.

Product washing and sorting uses a process called fluming to transport the product. It is often the first washing process as well. Health and safety regulations determine the degree to which this water can be treated and reused. Systems designed to meet all regulatory requirements have been used to reduce water use. Water used in washing and sorting of fruits and vegetables must be treated to remove solids, color, biochemical oxygen demand (BOD), and other wastes.

Preparation for processing involves blanching, peeling, coring, pitting, and washing of prepared items. The processes vary depending on the item being processed. In coring, pitting, and dicing operations, juices and waste are typically removed with water. Since peeling, blanching, dicing, and cutting release juices and sugars, the water used to wash produce after this operation may contain high BOD loads, thus limiting reuse options. Systems that do not use water to transport peels, cores, pits, etc. increase water reuse options.

Food processing and cooking extends the shelf life of the food product and produces a variety of desirable products. Produce can be preserved for market in a number of ways including:

1. Refrigeration and freezing
2. Canning
3. Irradiation
4. Dehydration
5. Freeze drying
6. Salting
7. Pickling
8. Pasteurizing
9. Fermenting
10. Chemical preservation

With the exception of irradiation and chemical preservation, these activities all involve thermodynamic processes. The section on thermodynamic processes for cooling towers, boilers, and similar equipment provides more information on how these thermodynamic processes work.

Many of the cooking, autoclaving, drying, and similar operations require steam. Thus, capturing and returning steam condensate represents a water saving measure.

In cases where food or juices are concentrated, a number of newer food processing technologies are now available to separate solids from liquids. Thermal methods have historically dominated the industry, but they consume large amounts of energy, largely for steam. More recently developed technologies include membrane treatment processes.

Pump seals in food processing can use significant amounts of water. In all pipe systems, pumps move the product to its destination. Food service pumps must be made of food grade materials and may not use lubricants or materials that could contaminate the food being processed. The seals on the pump must also keep out contaminants. As a result, water seals are commonly used. With water seals, if the seal leaks only clean potable water will enter the food. However, water seals on pumps continuously discharge water. With multiple pumps in a typical food processing plants, pump seal water use can be significant.

Canning and packing offers several opportunities for water conservation. First, cans must be cooled once they exit the retort or autoclave. Conversely, cold products such as bottled fruit juices, beer, and sodas must be warmed so the can or bottle does not collect condensation ("sweat"). Washing of bottles, jugs and containers after filling has historically taken place by immersion of large volume sprays that run as long as the process line operates. Electronic sensors on the line can actuate a spray system that only washes full cans and bottles when they are passing by.

Lubrication of conveyor belts that move cans and bottles through the process has commonly used water as the medium for lubrication. This water is softened and mixed with biocides and soaps before it is sprayed onto the conveyors. Dry lubrication systems are rapidly gaining acceptance in the industry.

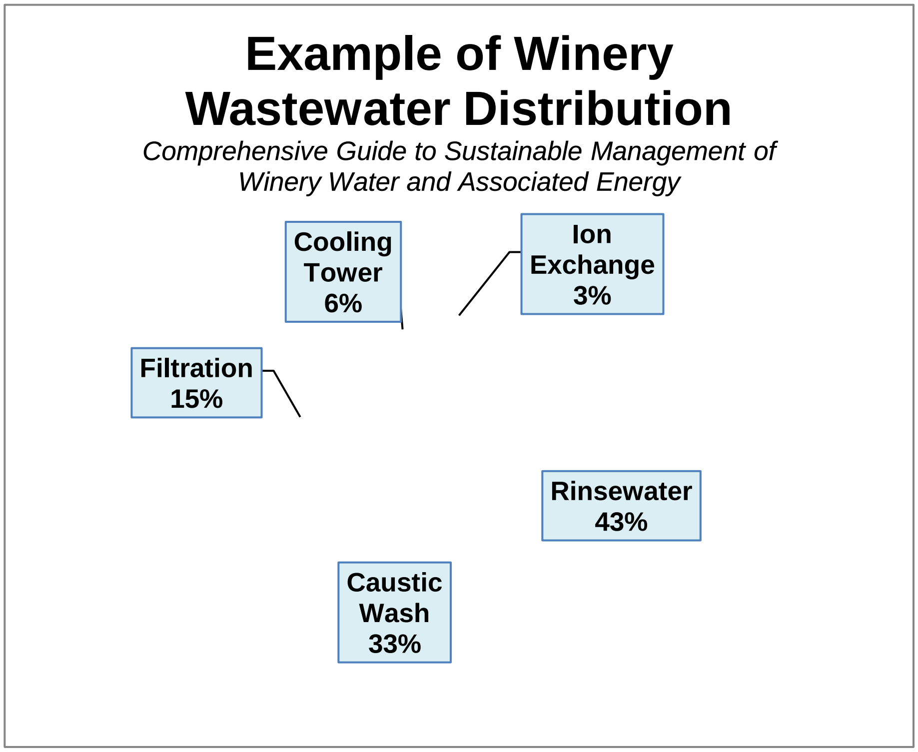
Beverage Manufacturing

Beverage manufacturing includes the production of bottled and packaged fluids such as distilled spirits, beer and wine, soft drinks, bottled water, and related products. With a few exceptions, all of these beverage products have the same basic water uses and opportunities for water savings. They all use water for cleaning, bottling, and the common uses of boilers, cooling towers, domestic use, irrigation, and related uses.

In light of these similarities, this document focuses on wine making as a common example.

Making wine is one of the oldest food processing activities on earth. While modern wineries use many of the same techniques as ancient wine makers, they also use automation, newer materials, and more advanced sanitation techniques. California produces between 85 and 90 percent of the wine made in the U.S. It is a nearly $20 billion dollar industry and a major employer.

The wine making process is water intensive since water is needed at every step of the process. Uses include the normal domestic and landscape uses found in all workplaces, as well as cooling towers and steam boilers in some facilities. With respect to cooling, the California winemaking industry consumes over 400 gigawatt-hours of electricity annually, making it the second largest electricity-consuming food industry in California after fruit and vegetable processing (California Energy Commission, 2004). A large portion of this electricity is used to operate refrigeration equipment that requires cooling towers, a water intensive operation. The 2010 publication, ***Comprehensive Guide to Sustainable Management of Winery Water and Associated Energy***, provides an overview of the sources of wastewater in the wine making industry. This information provides a reasonable approximation of how water is used within this sector (Figure ##).



Understanding the potential for water efficiency in the wine making process requires an examination of the steps in winemaking. This section examines water conservation methods and internal reuse methods unique to wine making. Subjects such as ion exchange, clean-in-place systems, cooling towers, boilers, and water used for employee sanitation are covered in their respective chapters.

The single largest use of water in wine making is for cleaning vessels and equipment, but there are many other uses, including:

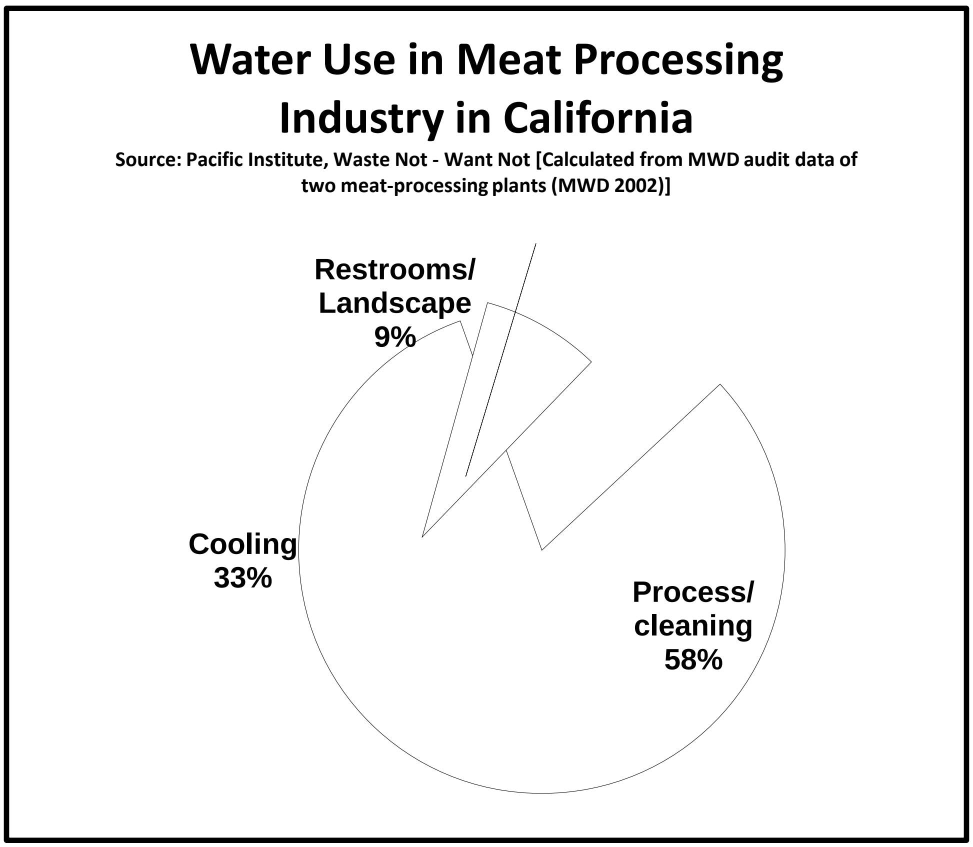
- Crush operations
- Press operations
- Tank cleaning
- Transfer line cleaning
- Barrel cleaning and soaking
- Cellar operations
- Distillation
- Ion exchange
- Bottling
- Water softening
- Boiler feed
- Cooling

Figure dd in appendix ** shows a diagram of the wine making process for both white and red wines.

The Meat and Poultry Industry

The meat, pork, poultry and seafood industries are undergoing a historical change driven in part by consolidation in the retail food market industry and the need for increased efficiencies due to rising energy and utility costs. This change is similar to trends seen in other food processing areas, such as fruit and vegetable processing. As of 2007, the industry employed nearly 25,000 Californians and produced $8.7 billion in the value of shipments.

While each of these sectors has differences, they all involve bringing animals to a central location, processing them to remove skin, hair, scales or feathers, removing internal organs, taking the animals apart, processing the parts, and packing them for shipment. Water use for the cleaning and processing of the carcasses, cleaning and sanitizing equipment, boiler operations and cooling and refrigeration are the major water uses in these industries. Figure ee shows the breakdown of water used on meat processing in California.(Pacific Institute, Waste Not - Want Not). This document used the Poultry industry as a representative example of meat-related water use.

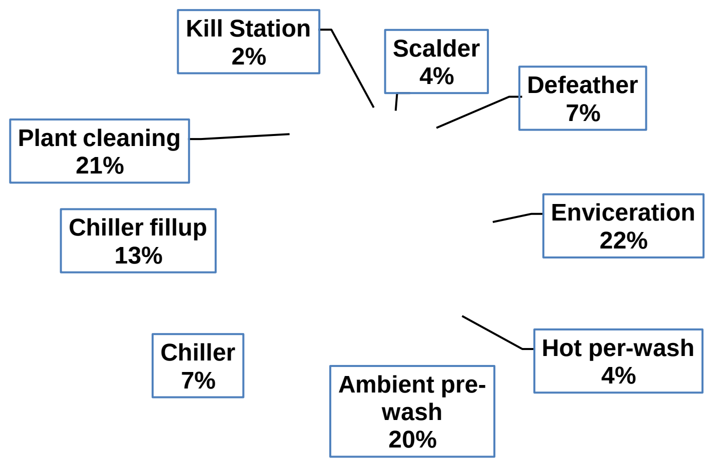


Poultry Processing

Poultry processing is a major component of the animal slaughter industry in California. According to the California Poultry Federation, 250 million chickens and almost 16 million turkeys are processed each year in the State.

Figure tt shows typical water uses in poultry processing. There may be additional water uses if the poultry is cooked or breaded.

Figure tt. Typical Water Use in Chicken Processing



Equipment found in poultry processing is unique to that industry. Table II in appendix ** shows some of the types of equipment normally found in poultry processing facilities require cleaning. The major difference between the meat processing industry and other food processing industries is that most of the cleaning is done on the outside surfaces of equipment rather than in pipes and the inside of vessels, tanks, casks, etc.

Regulatory Factors Effecting Water Use Efficiency

Regulations governing the food processing are an integral part of the operation of food processing facilities. Food processors must follow a number of State, Federal, and local regulations that control every aspect of their industry to ensure protection of public health and the environment. These regulations cover food safety, water quality, and waste disposal regulations. These regulations affect food processors’ ability to use water more efficiently by limiting the use of recycled and reused water.

Water that comes in contact with food products must generally be potable water or higher quality in order to protect public health. Although, there are many regulations related to non-water using aspects of food and beverage processing, this document summarizes only the ones related to water use. A summary of the main regulations covering these areas that relate to food and beverage processors may be found in Appendix ***.

The Hazard Analysis and Critical Control Point (HACCP) of 1997 is a regulation that establishes stringent controls on sanitation food processing, especially meat processing, juice and raw fruit, and the vegetable industries. After its implementation, water use per chicken increased by 26 percent.

At the Federal level, four agencies – The US Department of Agriculture, the Food and Drug Administration, and the US Environmental Protection Agency – are the main Federal agencies governing food safety and processing.

- **US Food and Drug Administration** Title 21 provisions cover both processing and labeling regulations. The Current Good Manufacturing Practices guide (21 CFR Part 110) covers sanitary practices.
- **US Department of Agriculture** Food Safety and Inspection Service is responsible for inspection of most types of meat and poultry.
- **US Environmental Protection Agency** regulates water supply, wastewater treatment, and disposal and related factors.

Water quality represents another major concern for food processors. The State and Regional Water Quality Control Boards enforce strict water quality objectives for effluent whether it is land applied for irrigation or sent to publicly-owned treatment facilities. There are limits on the number of times water can be reused in a facility as constituent concentrations increase with every reuse. In some cases, dilution may be necessary to meet water quality objectives.

Best Management Practices for Food Processing and Beverage Manufacturing

The best management practices identified below were included based on input and expertise from representatives within the industry, experts working in the area of water conservation, and recognized studies and documents on water conservation. These BMPs are generally used and proven in industry, but they may not be applicable to every site. A specific site assessment would be needed to determine whether a particular BMP is applicable and appropriate.

General BMPs that apply commonly to the food industry can also be found in the sections entitled ***Cleaning Industrial Vessels, Pipes and Equipment*, *and Thermodynamic Processes*.** Therefore, these are not described as BMPs in this section. BMPs specific to Food Industries are presented below:

Fruit and Vegetable Processing

1. In washing operations:

    a. Use vibration and air to help clear fruit and vegetables of debris and dirt before fluming or washing.
    b. Use brushes to clean produce

c. Spray wash instead of submerging fruits and vegetables to wash them
d. Use countercurrent washing
e. Reduce overflow
f. Use can cooling water for first flush water

2. In fluming for transport of raw, peeled, or blanched products :

   a. Where the fruit or vegetable will not be damaged by mechanical handling , use conveyors belts, use pneumatic systems and totes to move product instead of water
   b. Use flumes with a minimum cross section to reduce water volume
   c. Recirculate flume water where allowed by code
   d. Use flumes with parabolic cross-sections rather than flat-bottom troughs
   e. Eliminate fluming water and use dry removal of dirt.
   f. Sorting, culling and grading should occur before fluming or washing. This will also reduce wastewater and save energy

3. When preparing for processing, use:

   a. Dry peeling and blanching
   b. Mechanical peeling
   c. Chemical peeling
   d. Steam blanching

4. When coring, pitting and dicing use dry transport and conveyor belts as an alternative to transporting product by water.

5. When concentrating food and juices, use filtration and membrane processes as an alternative to thermal/steam operations The following summarizes some of these membrane applications.

   a. micro-filtration for:
      - cold sterilization of beverages
      - clarification of fruit juices, beers and wines
      - continuous fermentation
      - separation of oil- water emulsions
      - wastewater treatment

   b. Ultra-filtration for:
      - concentration of milk
      - recovery of whey proteins
      - recovery of potato starch and proteins
      - concentration of egg
      - clarification of fruit juices and alcoholic beverages.

   c. Nano-filtration for:
      - removal of micro-pollutants

- water softening
- wastewater treatment.

d. Reverse osmosis for:
   - desalination
   - concentration of food juice and sugars
   - concentration of milk.[111]

6. Reuse pump seal waste water for washing crates and pallets

7. For rinsing and cleaning cans and beverage bottles (including wine bottles)
   a. Use self closing valves and/or automatic shutoff's or sensors that only allow timed sprays run to rinse bottles and cans when they are passing the spray nozzle.
   b. Clean bottles with air,
   c. For cleaning sweep and use squeegees to remove solid waste, in place of using a hose,

8. For clean in places processes. the list below articulates methods for reducing water use:
   a. Dry recovery of refuse
   b. Eliminate wet transport of wastes where possible
   c. Installing drip and catch equipment to keep floor clean
   d. Use squeegees to remove bulk waste from floor before cleaning
   e. Use floor scrubbing and vacuum systems
   f. Hand clean larger parts from equipment.
   g. place level indicators on tanks and overflow alarms on vessels

9. For conveyor belt operations, investigate use of dry lubrication systems Early attempts at dry lubrication systems were not always successful, but dry lubrication is now becoming commonplace.

Poultry Operations

1. The principal opportunities for reducing water use in poultry processing by moving from wet to dry cleaining include:

   a. Dry recovery of manure, drippings, intestines, etc.
   b. Eliminate wet transport of wastes where possible
   c. Install drip and catch equipment to keep floor clean

[111] Nóra Pap*, Eva Pongrácz, Liisa Myllykoski, Riitta Keiski , Waste minimization and utilization in the food industry: Processing of arctic berries, and extraction of valuable compounds from juice- processing by- products, Proceedings of the Waste Minimization and Resources Use Optimization Conference. June 10, 2004, University of Oulu, Finland.

d. Use squeegees to remove bulk waste from floor before cleaning
e. Use floor scrubbing and vacuum systems
f. Hand clean larger parts from equipment

2. If the poultry is breaded or cooked, the following water efficiency measures can be employed:

   a. Use drip pans and splash guards to catch breading or parts
   b. Practice manual cleaning procedures before washing
   c. Only wash equipment once dry waste has been removed.

Use Alternate Sources of Water and recycled water

Use of alternative sources and recycled water is a best management practice for all industries. Issues and uses specific to Food Processing and Beverage Manufacturing are discussed in this section. These BMPs may include:

- Recycling water within the plant
- Use of alternate sources for non-food processing areas
- Reuse of plant effluent for irrigation

One of the most important considerations is that most food processing wastewaters can be used for irrigation. Nutrients in the wastewater can help fertilize the crops, and irrigation removes pollution from receiving streams or wastewater treatment plants. In examining food processing water use, this reuse is often left out of the analysis.

Where water is to be used for crop irrigation, water quality – salts, especially sodium salts – becomes a major concern. Organic loading, irrigation rates, nutrient levels and other factors are important to consider. Many companies are using potassium salts for recharging softeners and pH adjustment, isolating waste streams with very high concentration of salts, and providing "end-of-the-pipe" treatment technologies to make their effluent usable for irrigation. (See the **Manual of Good Practice for Land Application of Food Processing/Rinse Water**.)

Examples of water reuse practices may be found the canning, dairy, beer and winemaking, and frozen foods industries, just to mention a few. Many canneries follow this practice as long as sodium levels and total salinity remains within bounds. Regulations specific to land application of wastewater from food processors include:

1. Porter Cologne Act -Reuse cannot impact beneficial uses of groundwater;
2. Basin plans - Defines the beneficial use of water for each region; and
3. Anti-degradation policy:
   a. Protects groundwater
   b. Requires the use of Best Practicable Treatment and Control

The US Federal Food and Drug Administration and the US Department of Agriculture's strict guidelines for food safety often means that much of the water used in meat and poultry processing, as well as other food processing operations, may only be used once. The use of ozone and membrane treatment of wastewaters are being experimented with in the poultry industry, and the use of recovered water for non-contact uses such as cage cleaning, dust control, etc. are now common.

Summary of Case Studies

To be added at a later date (one paragraph per case study…details in appendix)

California Food and Beverage Information from the U.S. Department of Commerce for 2009

Meaning of NAICS-based code	NAICS-based code	Year	Number of paid employees for pay period including March 12	Annual payroll ($1,000)	Total cost of materials ($1,000)	Total value of shipments ($1,000)	Value added ($1,000)
Animal food mfg	3111	2009	4,393	211,809	2,199,835	3,510,288	1,308,768
Grain & oilseed milling	3112	2009	3,394	198,634	3,072,253	4,683,906	1,612,932
Sugar & confectionery product mfg	3113	2009	6,742	337,798	1,321,768	2,549,318	1,242,968
Fruit & vegetable preserving & specialty food mfg	3114	2009	32,143	1,231,723	6,885,212	12,834,029	6,120,784
Dairy product mfg	3115	2009	17,022	871,511	8,021,191	11,847,995	3,833,542
Animal slaughtering & processing	3116	2009	20,868	696,639	4,291,901	7,339,875	3,028,075
Seafood product preparation & packaging	3117	2009	2,239	67,701	666,274	937,203	271,348
Bakeries & tortilla mfg	3118	2009	33,744	1,145,688	2,742,711	6,707,244	3,961,891
Other food mfg	3119	2009	29,539	1,135,650	6,487,987	13,081,103	6,655,519
Beverage mfg	3121	2009	D	D	D	D	D

7B2c: The High-tech Industry in California

Industry Overview

Starting in the 1950s, high technology companies in California began a rise that has lasted through today. Silicon Valley saw the development of the silicon-based integrated circuit, the microprocessor, the microcomputer, and other key technologies. Products produced by high-tech include microprocessors, personal computers and peripherals, video games, and with rising demand over the past 10 years, a wide array of mobile devices such as cell phones, smart phones and tablets, and a resulting increase in networking systems and cloud computing infrastructure like datacenters.

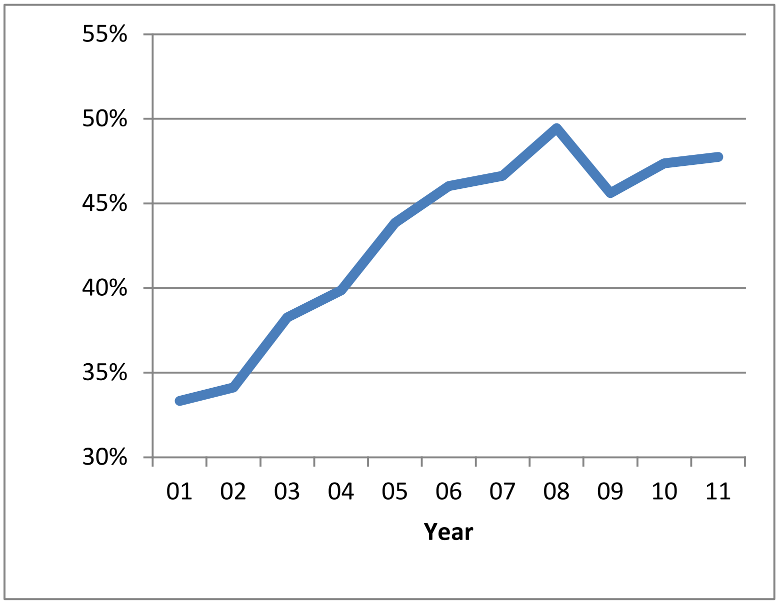
In the 1980s and 1990s, California led the nation in the number of facilities built to fabricate semiconductors and other microelectronic components. Towards the end of the 1990s the trend began to reverse. High tech companies began building new facilities elsewhere, and the state's older facilities began to shut down. Some of the reasons for this shift include the high cost of doing business in the state, an increasingly skilled global workforce, and large incentives offered by other states and countries. As a result, a significant fraction of semiconductor manufacturing has moved out of the United States to East Asian countries, especially Japan, China, and Taiwan. By 2009, the United States semiconductor production capacity had slipped to just 17% of global capacity, down from 25% only two years earlier.[112] This net migration of high-tech microelectronic manufacturing has been pronounced in California, and it is true not just with semiconductors, but also with networking equipment, servers, computers, peripherals, and mobile devices.

As a result, employment in the high-tech industry – especially in manufacturing – began to decline, only to be further exacerbated during the dot-com crash of the late 1990s. According to US Department of Commerce information, overall employment in the high-tech industry in California has declined by 100,000, from 298,000 employees in 2002 to 198,000 in 2009. This trend is further explored in a recent Milken Institute report, which states that California is losing a larger share of manufacturing employment overall, and in high-tech in particular, at a faster rate than that of other states.[113]

Within high-tech, California has seen a growth in services, in contrast to product manufacturing. The recent Milken Institute Report shows this transition in terms of the numbers of jobs generated by high-tech services and high-tech manufacturing in the State (Figure 1).[114] It is manufacturing that is the most water intensive.

Figure 1. Percent Increase in High-tech Service versus Manufacturing Jobs in California, 2001-2011

[112] http://www.manuacturingnews.com/news/10/0212/semiconductors.html
[113] Manufacturing 2.0, A More Prosperous California, Milken Institute Report. www.milkeninstitute.org/pdf/CAManufacturing.pdf
[114] The Milken Institute, 2011, "State of the State Conference: Blueprint for California", http://www.milkeninstitute.org/pdf/SOS2011BriefingBook.pdf



Source: Moody's Analytics, Milken Institute

Most data on the composition and size of industry draws from the North American Industry Classification Systems (NAICS), but these numbers are misleading due to the fact that the NAICS code does not reflect true manufacturing numbers. Intel Corporation provides a good example. The global leader in semiconductor chip making, Intel is headquartered in California where it concentrates a large amount of its research activity. All the corporation's manufacturing sites are located in other states, including Arizona, New Mexico, Oregon, and Massachusetts, and other countries, including China, Ireland, and Israel. Intel is listed with a NAICS code of 334413 - "Semiconductor Manufacturer," but while the company has a considerable number of employees in California working in design, validation, finance, legal, etc., virtually none work in semiconductor manufacturing. Similarly, Global Foundries, the world's third largest independent semiconductor foundry is headquartered in Milpitas, California but has its fabrication plants in Singapore and Germany, with one new plant within the United States being built in New York.

Clearly the high-tech sector in California is going through a period of adjustment and evolution, shifting from the manufacture of products to f the delivery of services such as software, databases, and cloud computing. Therefore, when considering its water footprint, it is important to consider the industry as it stands in California today. For the purposes of this report, this discussion of water conservation best management practices focuses on the smaller scale semiconductor and other electronic component manufacturing remaining in the state, and the research and development laboratories that support these industries.[115] In addition, we focus on solar energy, which is a sector that is closely related to high-tech where manufacturing is growing thanks to abundant natural resources, strong state mandates like the 33% renewable portfolio standard, and incentives like Senate Bill 71, the clean-tech manufacturing equipment tax credit.

Figure 2 Water use in High-Tech

[115] It should be noted that the R&D and design work that goes into electronics manufacturing is also moving elsewhere.

Life-cycle stages	Design	Raw Materials	Fabrication	Assembly	Packaging	Shipping	Operational Life	End of Life Retirement
Activities	Prototypes R&D	Silicon, gold, aluminum, lithium	Chips, board processors, drives, casing, etc.	Contract manufacturing	Cardboard? Electrostatic? Shrink wrap? Wood? Foam?	Multi-modal	Data centers/lab climate control (i.e. HVAC, CRAH)	Disassembly, smelting
In California?	Yes	No	No	No	Yes	Yes	Yes	Yes
Level of Water Use	*Low*	High	High	*Medium*	*Medium*	*Low*	*Medium*	*Low*

The Growth of Solar Energy Systems

The industry has seen an almost 7 percent growth nationwide since 2010, and solar job growth over the next 12 months is expected to be about 24 percent for the U.S.[116] Figure 3 provides a value-chain breakdown for solar employment in California. Aggregate data on water used for solar power generation is not available at this nascent stage for the industry at this time.

Source: The Solar Foundation: National Solar Jobs Census 2011

Water Use in the High Tech Sector

Much of the water use in high-tech is for human use and for cooling, neither of which falls into the focus of this sector analysis. For high-tech the most water-intensive activities are: (i) fabrication processes in semiconductor manufacturing, and (ii) the cooling of enterprise-scale data centers that provide access to the free flow of large amounts of data. Estimates suggest that a typical fabrication plant uses between 1,500 and 15,000 cubic meters of water per day, using around 16 gallons per chip fabricated. Much of the water is ultrapure water (UPW),

[116] The Solar Foundation, Oct. 2011, **National Solar Jobs Census 2011**, http://thesolarfoundation.org/sites/thesolarfoundation.org/files/TSF_JobsCensus2011_Final_Compressed.pdf

produced from local feed water. From 1.25 -2 gallons of city water is needed to produce 1 gallon of UPW.[117] On the other hand, a 15-megawatt data center may use up to 360,000 gallons of water per day.[118] However, as with semiconductor and other high-tech manufacturing, data centers, which are growing with the move to cloud computing, are also leaving the state due to a number of factors similar to those noted above. Further, while data centers require large amounts of water, this water is used for cooling and is therefore covered in the ??? section of the report that describes cooling towers.[119]

Ultra pure water (UPW) is used widely in the high-tech sector. Water from a utility is not nearly pure enough for high-tech uses.[120] Very strict requirements for microchip fabrication and for use in the manufacturing of many stages of printed circuit boards (PCB) require that the water contain less than 27.7 parts per billion of total dissolves solids (salts and minerals), less than 10 ppb of total organic carbon, and that the water be sterile. To achieve this level of purity, water is passed through particle filtration, activated carbon, softening, micron size filtration, reverse osmosis, strong cation and anion ion exchange, and post micro filtration and disinfection with ultraviolet light. Special materials, such as **Polyvinylidene Fluoride (PVDF), are used for pipes and storage tanks that carry UPW. The production of UPW and the reuse of RO reject water offer many opportunities for water conservation in the semiconductor and printed circuit board computer chip insertion processes.**

Semiconductor processing **consists of a number of water-using steps including:**
- Wet cleans
- Photolithography removal
- Dry etching
- Wet etching
- Chemical-mechanical planarization (CMP)
- Wafer backgrinding (to reduce the thickness of the wafer so the resulting chip can be put into a thin device like a smartcard or PCMCIA card.)

Printed circuit boards, also called wire boards, are non-conducting materials such as a base made from a dielectric core impregnated with resin. A completed board with electronic components such as microchips inserted and soldered in is called a printed circuit board assembly.
To make a printed circuit board, the copper coated board is manipulated through a number of steps to add layers, etch away layers, and drill and plate holes to form the needed circuits on the board. The processes involved include:
- Patterning (etching)
- Chemical etching
- Lamination
- Drilling
- Exposed conductor plating and coating
- Solder resist
- Screen printing
- Testing
- Printed circuit assembly and packaging

[117] Based on information from Intel's annual sustainability reporting on water use (pg 43 – 46), http://www.intel.com/content/www/us/en/corporate-responsibility/eco-responsible-operations.html
[118] http://www.datacenterknowledge.com/archives/2010/04/07/water-usage-the-next-disclosure-challenge/
[119] For IT and data center best practices, contact the Green Grid, http://www.thegreengrid.org/
[120] Even the wastewater produced by the high-tech sector is significantly cleaner than drinking water for most constituents.

Manufacturing printed circuit boards is somewhat similar to metal plating and finishing. A typical circuit board process involves both electrolytic and non-electrolytic plating, acid etching, silk screening to add material or "masking," and similar processes. Between each step, multiple rinses are needed. Although water is used in the actual processing such as etching, and plating, rinsing requires the most water.

Populating circuit boards with microchips, resistors, and other electrical components is the last step before the product is shipped. In this process, semiconductors and other electronic components such as resistors and capacitors are inserted into the PCBs. The connections are soldered to make good electrical connections, usually by passing the back of the board over a molten solder bath. The boards are then washed for a final time to remove residue

Research and Development occurs at both the academic and corporate level. Virtually all of the nanotechnology processes and equipment used by manufacturers to create semiconductor circuitry are developed and tested by these research facilities. Relatively few of these processes involve water use; instead, they use gasses to create the structures. Water is used in chemical mechanical planarization and wafer cleaning, but because of the smaller scale of these facilities, BMPs for fabricators and foundries are generally not cost effective and would not result in any significant water savings. Nonetheless, elimination of once-through cooling by using chilled water circuits and using RO reject water for other purposes such as vacuum pump seal water or makeup for scrubbers all still apply. See the case study for examples of practices implemented.

Metrics

It is hard to normalize for different sections of the high-tech sector due to the diversity of product types and thus uses of water, which means normalization is impossible. However some possible metrics are gallons per dollar in revenue and gallons per chip manufactured.

Please also refer to the section XX, the metrics section for overall industrial sector metrics.

Best Management Practices for High-tech

The Best Management Practices described in this section are applicable to both manufacturing facilities and research laboratories for the high tech industry. All are currently being successfully employed at various facilities. Their economic viability depends on specific facility design, cost of utilities, and a number of related factors. In other words, what works at one facility may not necessarily work or be economically practical at another similar facility.

Promoting Water Conservation: The Role of Information and Communication Technologies (ICT)

Technology – including unified communications and the integration of telecommunications (telephone lines and wireless signals), computers, middleware as well as necessary software, storage- and audio-visual systems – enables users to create, access, store, transmit, and manipulate information. The fast development of ICT solutions is allowing us to move from a scarcity of data to a data rich world that is providing real-time information about the natural and built environment.

ICT products, systems, and networks are the essential drivers of productivity improvements and innovation for the 21st century. ICT can bring enormous benefits to water authorities in mapping and monitoring water resources, as well as in forecasting river flows and giving advance warning of water-related emergencies such as flooding. ICT will also enable solutions in urban life: buildings, energy production and use, mobility, water and sewage, open spaces, education, and public health and safety.

In particular, smart metering technologies will play an important role in measuring water consumption in real time, identifying leaks at the consumer level and making consumers more conscious about their water usage. There are a number of benefits to adopting smart meters:

- Enabling early leak detection
- Supplying customers with tools to monitor/reduce water use
- Providing more accurate water rates
- Curbing overall water demand
- Improving the ability to conduct preventative maintenance.

Apart from employing smart meters and other ICT technologies, high tech industries can reduce water use in a number of other ways. The following information presents some of the most common methods that have been employed by this industry to successfully accomplish reductions in water use.

1. *Reduction of Water Use for Wafer Processing* - Over the years, a number of water reduction practices have been implemented to reduce water use.
   - Using programmable tool features
   - Installing control equipment to only use the exact amount of water needed throughout the specific operation
   - Using spray rinsing in place of emersion rinsing
   - Using process timers instead of dump rinser cycles
   - Countercurrent rinsing
   - Optimizing ion-exchange regeneration cycles

2. *Ultra Pure Water (UPW) Production* - In a typical reverse osmosis operation of the magnitude found in semiconductor operations, the RO unit recovers 75 percent of the water fed to it. Many plants have employed treatment systems such as nanofiltration to recover the water from the reject stream. Because it is expensive to create UPW, there is a natural economic incentive to reduce water use for wafer processing. Savings are possible by recovering part of the fresh water processed through the ultrapure water system.
   - Using RO reject water for cooling tower water

3. *Reuse of Water for Non-UPW Purposes* - Much of the water used at high tech facilities does not have to be treated to UPW quality. As a result, water from the UPW waste streams, reject water from the RO unit, and other alternate on-site sources can be used in places that do not require UPW. Some of these uses include:
   - Cooling tower makeup, though it is often necessary to supplement with water with dissolved solids content
   - Scrubber water, though it is often necessary to supplement with water with dissolved solids content
   - Toilet and urinal flushing
   - Ornamental fountains and features

   Sources of non-potable water for these used can range from RO reject water and selected UPW waste streams to stormwater runoff, air conditioning condensate, foundation drain water, rainwater, and others. Section ?? describes the use of these alternate sources in more detail.

4. *Heat and Energy Recovery to Reduce Water Use* - If process and air conditioning waste heat can be recovered, it can be used to pre-heat incoming water making RO units operate more efficiently. This use also reduces heat load on the cooling tower thus saving water in this operation while reducing energy bills.

5. *Substitution of Non-Water Using Processes* - As the size of the geometry and complexity of semiconductors shrinks, even ultra pure water begins to present problems. For this reason, the industry has investigated a number of closed-loop and "dry cleaning" methods. Some of these include:
   - Pinpoint cleaning
   - Supercritical fluid cleaning
   - Cryogenic aerosol cleaning
   - HF vapor cleaning
   - Closed-loop
   - Dry manufacturing

   The most important part of this discussion is that in the future, water use may decrease for technical reasons other than water efficiency. Promotion of these technologies would help promote reduced water use.

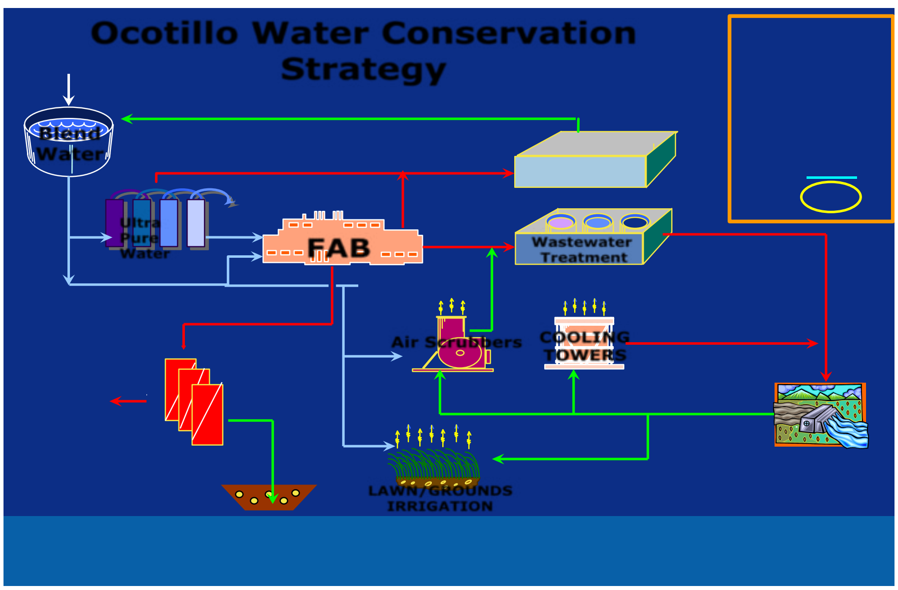
Example: Intel's Water Conservations Efforts

Intel purchases potable water from the City of Chandler, AZ. Most of this water goes to production of ultra pure water for manufacturing processes. Cleaning silicon wafers during fabrication is one of the largest uses of water in Intel factories. Once used, the water's quality is still suitable for a number of on-site and off-site reuse and recycling programs. Intel and Chandler's strong partnership has made it possible to implement a progressive water management system over the past decade that maximizes water conservation and reduces use of potable water by a factor of millions of gallons each day.

Chandler Reverse Osmosis Water Treatment Facility – Aquifer Recharge
This Arizona site has a unique partnership with the City of Chandler, which operates an Intel-funded treatment process. Using reverse osmosis (RO) technologies, the wastewater from Fab 12, 22, and 32 is treated to drinking water standards and re-charged to the underground aquifer to replenish the groundwater supply in Chandler. Since 1996, this water conservation strategy alone has resulted in over 4.5 billion gallons of water put back into the aquifer by Intel.

This water conservation strategy supports a key City of Chandler effort to store water in the underground aquifer to assure the city has enough water to meet the future needs of all citizens and businesses for many more years even if the drought continues.

Reuse of wastewater – Reclaim
Intel also uses treated wastewater from Chandler's Ocotillo Water Reclamation Facility, avoiding the use of the potable water supply. Every day of the year, the Arizona site takes back millions of gallons of processed wastewater from the City of Chandler sewage treatment plant to supply water to cooling towers, operate air abatement equipment, support the site landscaping, and irrigate the farm fields around the Ocotillo site.


Ocotillo Water Conservation Strategy
Blend Water
Ultra Pure Water
FAB
Wastewater Treatment
Air Scrubbers
COOLING TOWERS
LAWN/GROUNDS IRRIGATION

Opportunities for reducing water use in the plating areas area discussed in the section entitled: Plating, Printed Circuit Board, and Metal Finishing.

Solar

Although water is required to wash solar panels, the intensity of use is lower. Water is used in the production of Photovoltaic (PV) cells and associated manufacturing for all wet processing steps such as removing chemical residues from equipment and rinsing of substrate wafers and panels. In the PV manufacturing process, both standard industrial water and purified deionized water are required to manufacture wafers and cells. Up until recently, no industry standards on water quality for Photovoltaic manufacturing existed. In March 2010, Semiconductor Equipment and Materials International (SEMI) released a PV standard called SEMI PV3-0310, Guide for High Purity Water Used in Photovoltaic Cell Processing.[121]

At the simplest level, there are four steps in making a crystalline solar panel.[122] Step one involves using molten polysilicon to grow crystals or cast blocks of polycrystalline silicon. Step two involves cutting and polishing the material into thin, smooth wafers. Step three involves chemically treating the wafer and adding electrical contacts to turn it into a solar cell. The final step involves connecting many solar cells together, covering them with glass, enclosing them in an aluminium frame and adding an electrical junction box.

There are a number of ways that the solar industry can reduce water use, as noted in this discussion of methods that have been employed by the PV industry to accomplish reductions in water use. Adding to the effectiveness of these strategies is an understanding of the importance of the critical relationships between facility, process technology, and manufacturing equipment requirements related to water reuse strategies. Finally, characterization of water quality requirements for every step in the manufacturing process helps in identifying ways to minimize water usage.

Best management practices for water conservation in solar energy system manufacturing

1. *Use filters to produce pure water* – Optimize pre-treatment upstream for RO, including employing activated carbon filtration to produce high-quality deionized water, increasing water recovery and therefore decreasing consumption as reject water is minimized.

2. *Employ more efficient manufacturing systems* – By using faster cutting systems, solar manufacturers can use less water for lubrication as process time is decreased.

3. *Segregate and treat to facilitate water recovery* – It is difficult to reclaim and recycle water if everything is run down one drain. However, if wastewater is segregated up front thus avoiding co-mingling, it is possible to divert the waste streams that are more desirable for recycling to a treatment system.

4. *Employ re-use paths for process chemicals and water* – Utilize re-use paths for chemical wet baths and rinse water. Employing chemical spiking or dosing can minimize bath dump, which includes water. Whenever possible, manufacturers should eliminate

[121] For more information on the standard, visit: SEMI PV3-0310 - Guide for High Purity Water Used in Photovoltaic Cell Processing
[122] Of course, different manufacturers have their own methods of producing solar modules and thin-film PV manufacturing is different. This is merely a high-level illustrative explanation.

single-pass rinse steps as this means using the water and chemicals contained in the wet baths only one time.

5. *Employ water reduction strategies for wet scrubbers and chemical abatement systems*. For point of use abatement systems utilize an "on demand" water flow, meaning that the system is scrubbing when process gas is being abated rather than maintaining a constant flow of water through the system. This mode of operation needs to be verified on an individual basis taking into account other potential issues related to safety, environmental emission considerations (i.e. ensure this does not decrease the efficiency of the abatement system), biological growth, fouling, etc. Utilize potable city supply water for POU abatement systems rather than RO/DI, minimizing the use of RO and associated generation and disposal of the reject stream.

   For packed bed wet scrubbers, use alternate methods to regulate the delivery of makeup water, such as conductivity or pH, rather than using a constant makeup flow. This needs to be verified investigated on an individual basis taking into account other potential issues related to safety, environmental emission considerations (i.e. ensure this does not decrease the efficiency of the scrubber), concentration of prohibited materials (i.e. metals/fluorides) that could cause violation of discharge limits, biological growth, fouling, etc. Utilize potable city water supply for scrubber systems rather than RO/DI, reducing the need for RO operation and reject stream volumes.

Example: Solaria's Water Conservations Efforts

Based in Fremont, California, Solaria designs, develops, and manufactures silicon photovoltaic products. At its Fremont facility, the company manufactures solar modules. The company employs a number of methods to reduce water consumption during manufacturing.

In-line recycler Water is used as a processing lubricant. Non-toxic particulate is combined with the water after processing. A recycler consisting of a cascade of filters is used to purify the water back to its original state, thereby reducing the consumption of new water by as much as 80-90%. The recycler consists of a stand-alone system hooked up to processing machines. A pump is deployed to ensure water pressure is sufficient while injecting recycled water back into the processing.

Water management Water systems for machines are typically for cooling and processing. Re-piping/plumbing of the cooling water system enable for minimized recycling needs. Depending on the machine design, this re-piping can decrease water consumption by 30-60%. The cooling water will absorb heat after passing through the machine sub-modules that needs heat management, but contains no solid waste, so it is ideal to just loop this back into a chiller and re-use it through the machine. Note: This improvement has not been deployed yet; it will be deployed next year.

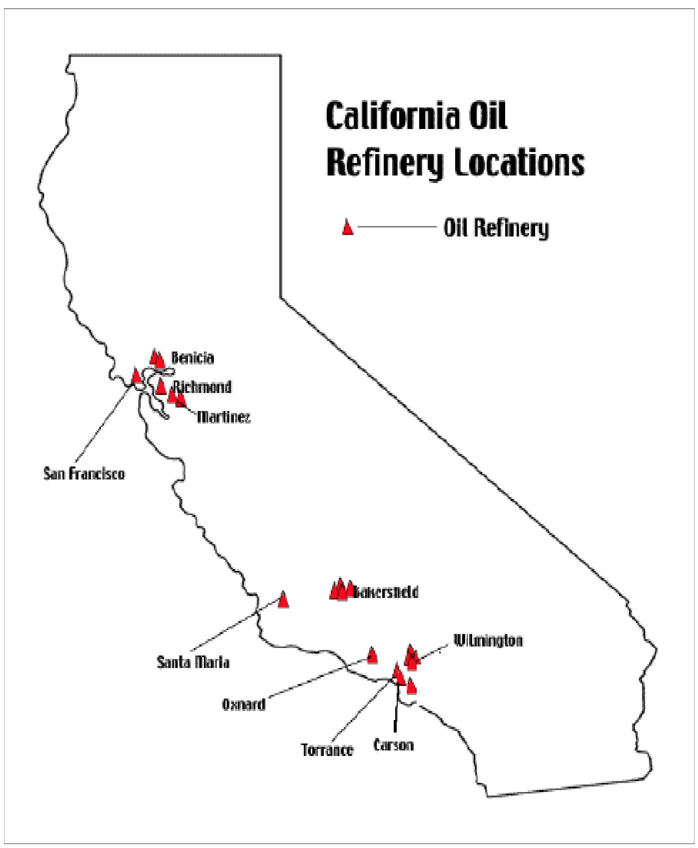
Advanced water-free system The next step involves utilizing lasers instead of mechanical technology to form the ideal shape for the cells. Lasers present multiple advantages over current methods, but the high cost has stood in the way of implementation. Recent technological advances have enabled more precision and speed, thus allowing for a lower total cost of operation. As a bonus, employing laser technology also virtually eliminates the need to use water. Note: This has not been deployed yet; it will be deployed next year.

7B2d: The Petroleum Refining and Chemical Industries in California

This section explores the potential for water efficiency in the petroleum refining and chemical industries in California. Both industries have much in common, though the chemical industry is more diverse. While the US Department of Commerce includes the pharmaceutical industry in the chemical sector, for the purposes of this report, the pharmaceutical industry is discussed in its own chapter.

Petroleum Refining Industry: California has approximately 11.3 percent of the refining capacity in the United States, currently refining 2.1 million barrels of crude oil a day. It ranks third behind Texas and Louisiana in refining capacity. According to the US Department of Commerce, in 2009 the petroleum refining sector employed 12,426 Californians, had a Value Added of $11.9 billion, and total shipments valued at $65.9 billion.

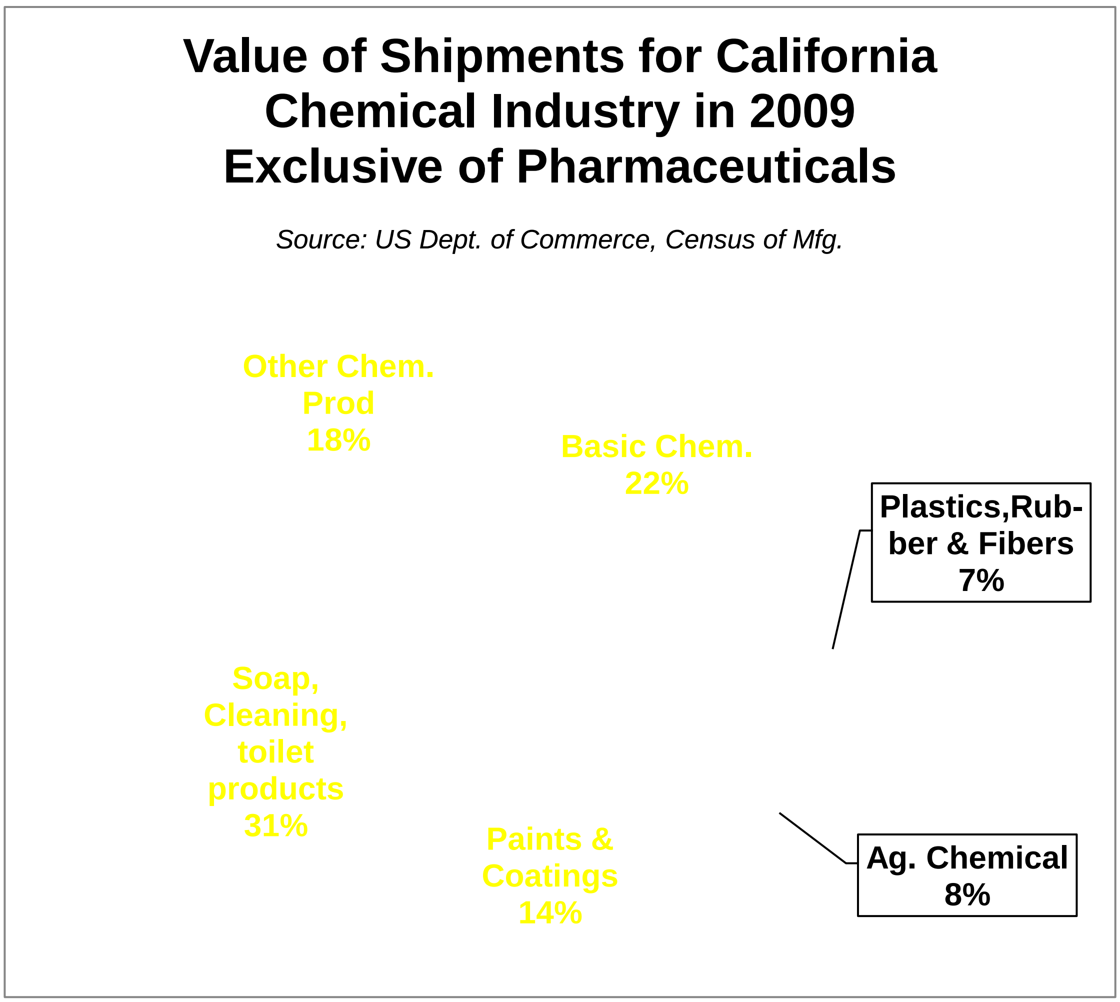
Figure ww shows that oil refineries in California are primarily located in three areas, the San Francisco Bay area, the Los Angeles area, and the Bakersfield area.



The petroleum refining industry separates crude oil, a mixture of many organic molecules, into useful products, or it rearranges molecules into useful products. Figure pp in Appendix xxx shows the basic processes involved in refining oil. Water is used within the refinery to cool and condense oil fractions, provide steam to heat fluids, for use in reactions such as hydrogen synthesis and catalytic cracker operations, for air pollution control, washing of crude to remove salts, for fire and safety, and for equipment testing and maintenance.

Chemical Industry: The California chemical industry sells and consumes significant amounts of chemicals in the State, but actual production of these chemicals often occurs elsewhere. According to the definitions of the North American Industrial Classification System (NAICS) basic chemicals include petrochemicals, synthetic dyes, inorganic chemicals, industrial gases, and other organic compounds that often serve as the building blocks for other products. Most basic petrochemicals, such as ethylene, are produced in other states.

Figure bb shows that only 22 percent of the value of shipments in California is for basic chemicals. The rest are "downstream" products that use the basic chemicals. In addition, California produces many inorganic minerals and chemicals.



These chemicals are often used in industries such as aerospace, textiles, computers, and retail products. In fact, the largest non-pharmaceutical segment of the industry is the production of soaps, cleaners, polishes, and toiletries.

Employment in the chemical sector (excluding pharmaceuticals) has followed the national declining trend. In 2000, California had 32,312 workers in the chemical sector (excluding pharmaceuticals). By 2009, this number had declined to 28,396 according to the US Department of Commerce. Table CC summarizes the non-pharmaceutical chemical industry in California in 2009. As the table shows, only 15 percent of employment in the sector is in basic chemicals while the largest sector of employment is for the soaps - toilet preparations areas and "other chemical products and preparations." The largest dollar and employment sectors are primarily using chemicals produced elsewhere to make consumer products sold in bottles, tubes, vials, and jars in retail and commercial establishments.

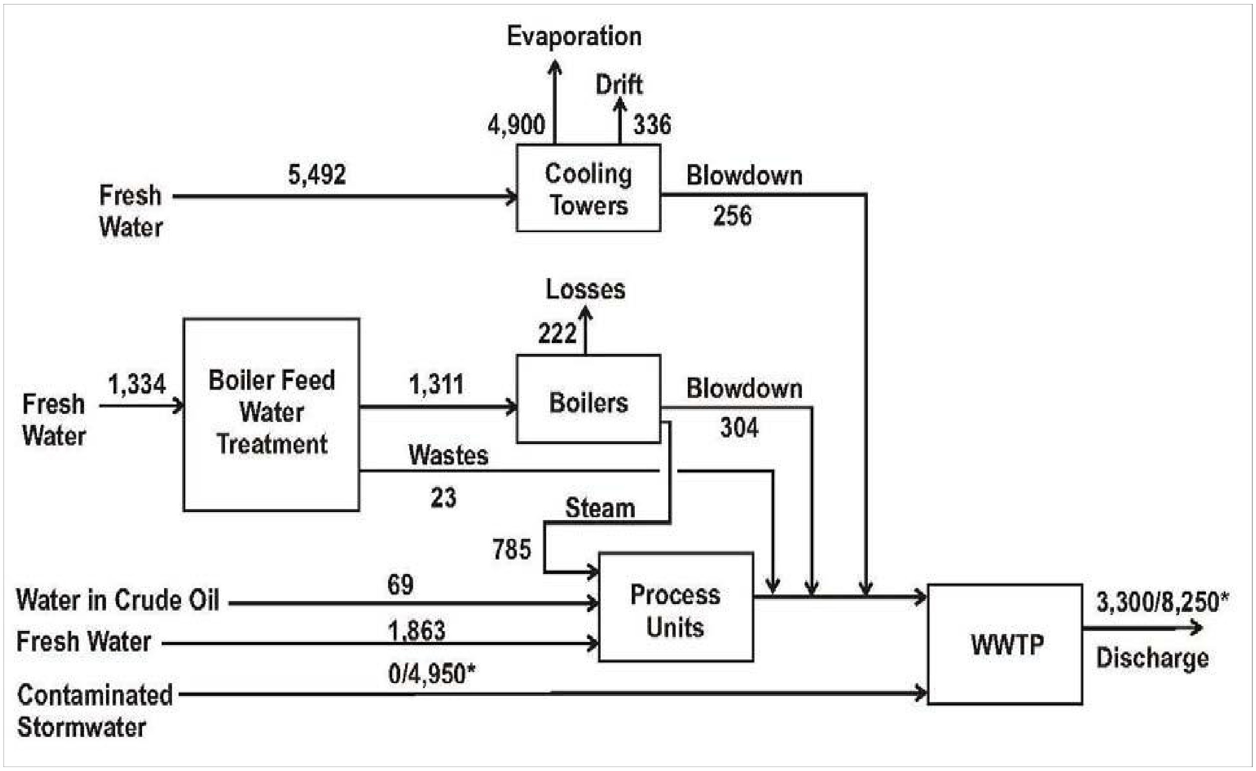
Table CC. California Chemical Industry Statistics in 2009*Excluding the Pharmaceutical Sector
Source: US Department of Commerce - Census of Manufacturers

NAICS Code	Category of Chemicals	Number of Paid Employees	Total value of shipments ($1,000)	Value added ($1,000)
3251	Basic chemicals	4,149	$2,831,095	$1,332,074
3252	Resin, synthetic & artificial rubber, fibers & filaments	3,542	$943,571	$463,760
3253	Pesticide, fertilizer, & other agricultural chemicals	1,699	$1,023,483	$479,630
3255	Paint, coating, & adhesives	3,712	$1,726,426	$854,818
3256	Soap, cleaning compound, & toilet preparation	9,111	$3,893,498	$2,346,906
3259	Other chemical product & preparation	6,183	$2,266,708	$1,030,322
	TOTAL FOR CALIFORNIA	28,396	$12,684,781	$6,507,510

* *Pharmaceuticals is part of the NAICS Chemical Sector, but will be covered in its own chapter*.

Water Use in the Petroleum Refining: Water use in the petroleum refining industry is dominated by cooling and boiler feed water requirements. In fact, according to information from the American Petroleum Institute, some 75 percent to 90 percent of all water used in a refinery is for these two purposes. Figure rr illustrates water use in a typical refinery.

Figure rr. Typical Water Balance for a 160,000 Barrel a Day Refinery
Flow rates in gallons per minute



Source: Council of Great Lakes Industries - Water Footprinting - www.cgli.org/waterfootprint/.../SlideDeck5-**Petroleum**Refining1.pdf

According to the Pacific Institute study entitled *"Waste-not, Want-not,"* 57 percent of the water use in petroleum and coal processing is for cooling, 34 percent is boiler feed, 6 percent is process use, and 3 percent goes toward other uses. It is obvious from this information, that energy conservation and reusing water for cooling tower and boiler makeup are major ways to reduce water use. Cooling towers, boilers, and cogeneration are covered in the section titled "Thermodynamic Processes," which covers the best management practices for the operation of these processes. However, it is important to recognize that energy efficiency and the choice of energy efficient processes will minimize water requirements for cooling towers, boilers and energy systems. Table ll summarizes energy efficiency measures for refineries.

Table II, Technologies for Energy Efficiency in Refineries in California

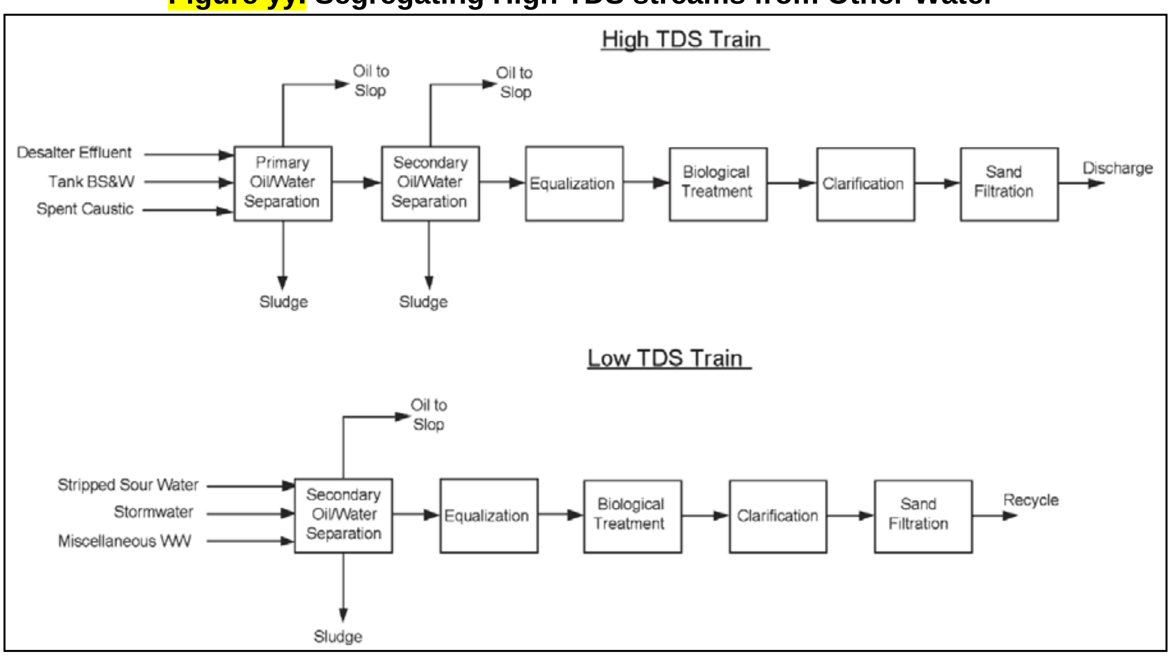
Technology Area	Technology Examples
Process Control	Neural networks, knowledge based systems
Process Optimization and Integration	Analytical tools, site integration
Energy Recovery	Hydrogen recovery and integration, flare gas recovery
Catalysts	Higher selectivity, increased lifetime
Reactor Design	Process intensification, membranes, reactive distillation, dividing-wall column
Biotechnology	Biodesulfurization, bio-feedstocks
Combustion Technology	Low NOx burners, high-efficiency burners
Utilities	Membranes, low-maintenance pumps
Power Generation	Advanced cogeneration, Gasification (IGCC), power recovery

Source: Profile of Petroleum Refining Industry in California, Lawrence Berkley National Laboratories, LBNL 55450

Best Management Practices for Water Conservation in Petroleum Refining

Segregate and reuse water within the refinery. Segregating wastewater streams by total dissolved solids content is one way to make sure that salty streams are not mixed with fresher water that can be reclaimed (Figure YY).

Figure yy. Segregating High TDS streams from Other Water



Source: IPIECA, Petroleum Refining Water/Wastewater Use and Management, 2010, www.ipieca.org

Table qq provides a summary of the major water reusing opportunities within the refinery its self.

Table qq. Water Reuse Options for Oil Refineries

Water category	Contaminant specification	Potential source of re-use water
Desalter makeup	• Sulphide: < 10 mg/l • Ammonia: < 50 mg/l • Total dissolved solids (TDS): < 200 mg/l	• Stripped sour water • Vacuum tower overhead • Crude tower overhead
Coker quench water	• Total suspended solids: < 100 mg/l • Biological solids: none • H_2S and other odorous compounds: none	• Stripped sour water
Coke cutting water	• Total suspended solids: < 100 mg/l • Biological solids: none • H_2S and other odorous compounds: none	• Stripped sour water
Boiler feedwater makeup (quality required is highly dependent on the pressure of steam being produced)	• Conductivity: < 1 µS/cm • Hardness: < 0.3 mg/l • Chlorides: < 0.05 mg/l • Sulphates: < 0.05 mg/l • Total silica: < 0.01 mg/l • Sodium: < 0.05 mg/l • Dissolved oxygen: < 0.007 mg/l	• Treated and upgraded refinery wastewater
Cooling tower makeup	• Conductivity: < 6,000 µS/cm • Alkalinity: < 3,000 mg/l • Chlorides: < 1,500 mg/l • Suspended solids: < 150 mg/l	• Treated and upgraded refinery wastewater

Source: IPIECA, Petroleum Refining Water/Wastewater Use and Management, 2010, www.ipieca.org

Stormwater and other on-site sources: Refineries on the East and Gulf Coasts have successfully used storm water and other on-site sources for a number of uses including fire protection, water for boilers and utilities after proper treatment, pump seals, and cooling tower makeup. In areas with low rainfall, like much of California, the feasibility of capturing, treating and reusing storm water is not likely to be practical and will need to be examined for cost effectiveness. Condensate from refrigeration and air conditioning processes, treated wastewater from restrooms and showers, and similar sources may provide inexpensive but small quantities of water for the refinery operation.

The use of municipal recycled water is another way to reduce use of freshwater supplies that could be used for potable purposes. Recycled water can be used for cooling tower makeup, boiler feed, and all other uses except potable use. However, it may need additional treatment and its availability may be limited due to lack of public infrastructure to produce and deliver the recycle water to industrial users. Use of recycled water has significant potential to reduce potable use and is already being successfully used by a number of California refineries and being considered by other refineries and recycled wastewater providers. Recycled water is a freshwater source and like all freshwater sources should be use efficiently. The section in this report concerning recycled water has additional information.

Other areas of potential water conservation include:

- Meter, sub meter, and install automated data recording systems to follow water use at all major use points;
- Converting pumps to mechanical seals;
- Where packing glands are required, using alternate sources of water for seal water;
- Using dry vacuum pumps;
- Where liquid ring pumps are required, either installing a water recirculation system or use wastewater for the seal;
- Installing automatic cutoffs and solenoids on all water using equipment to ensure that water flow is stopped when the equipment is not working;
- Instituting training programs for employees;
- Installing water efficient plumbing fixtures and appliances; and
- Following vessel washing and pipe cleaning procedures. (See **Cleaning Industrial Vessels, Pipes and Equipment.)**

Potential Metrics for Evaluating Water Conservation in Petroleum Refining

Unfortunately, simple generic metrics, such as gallons of water used per some unit of production, are not particularly suitable for petroleum refineries, especially if the intent of those metrics is to compare one refinery to another. Although most refineries may produce gasoline, diesel or jet fuel, they do it in different manners, using different processes that may be tailored to achieve a certain product array, for a certain product specification, and volume from different input crudes. As the IPIECA Operations Best Practice Series 2010 for Petroleum Refining Water/Wastewater Use and Management states "Petroleum refineries are complex systems of multiple operations that depend on the type of crude refined and the products desired. For these reasons, no two refineries are alike. Depending on the size, crude, products and complexity of operations, a petroleum refinery can be a large consumer of water, relative to other industries and users in a given region. Within the refinery, the water network is as unique to the refinery as its process." Hence, a simple generic metric designed as a benchmark for all refineries is neither practical nor appropriate.

However, it may be appropriate for an individual refinery to measure and monitor its own water use for the different processes and operations so as to evaluate trends, to develop and evaluate BMPs, and to achieve cost-effective water use management within the context of operational, equipment, and production needs. The IPIECA Operations Best Practice Series 2010 for Petroleum Refining Water/Wastewater Use and Management is a good starting point for refineries to evaluate potential options to measure and evaluate water use. At this time however, the CII Task Force cannot recommend simple, generic metrics for the refining sector.

Collection of Process Condensate and Refrigeration Condensate

Refineries and chemical plants produce various types of condensate in their operations. Clean steam condensate from sources such as steam heaters and reboilers can be recycled back to the boiler feedwater treatment plant deaerator to reduce the need for fresh water makeup. Recovering hot condensate also provides a side benefit of energy savings at the deaerator.

Other forms of steam condensate are also formed through chemical reaction and by heating of fluids containing water. The condensate produced in these processes can also be evaluated for reuse within the process. Refrigeration processes also produce very clean condensate. Both of these condensates should be evaluated for reuse.

Water Use in the Chemical Industry: Water use in the chemical sector varies by type of product produced. For basic petrochemicals, cooling water and boiler feed uses dominate, but for end-use products such as cosmetics, cleaning of vessels and equipment, inclusion in the product, and sanitary water use by employees can represent large uses in a facility along with cooling water and boiler feed. In addition,

1. <u>Stormwater and other on-site sources</u> have been successfully used by facilities on the East and Gulf Coasts. Uses include fire water, boiler and utility water after proper treatment, pump seal, and cooling tower makeup. However, in areas of lower rainfall, such as California, the feasibility of capturing, treating and reusing storm water is unlikely to be practical and will need to be examined for cost effectiveness. Condensate from refrigeration and air conditioning processes, treated wastewater from restrooms and showers, and similar sources may provide inexpensive but small quantities of water for the facility's operation.

2. The use of <u>municipal recycled</u> water is another way to reduce the use of freshwater supplies that could be used for potable purposes. Recycled water can be used for cooling tower makeup, boiler feed, and all other uses except potable use. However, it may need additional treatment. Use of recycled water has the highest potential to reduce potable use. It is already being successfully used by a number of California plants and is being considered by other plants and recycled wastewater providers. Recycled water is a freshwater source and like all freshwater sources should be use efficiently. The section in this report **Recycled Water** contains additional information.

Other areas of potential water conservation include:

3. Metering, sub-metering, and installing automated data recording systems to follow water use at all major US points;
4. Converting pumps to mechanical seals;
5. Where packing glands are required, using alternate sources of water for seal water;
6. Using dry vacuum pumps;

7. Where liquid ring pumps are required, either installing a water recirculation system or using wastewater for the seal;
8. Installing automatic cutoffs and solenoids on all water using equipment to ensure that water flow is stopped when the equipment is not working;
9. Instituting training programs for employees; and
10. Installing water efficient plumbing fixtures and appliances.

For many of the industries in this sector, such as pesticides, cosmetics, soaps, and toiletries, cleaning of vessels, pipes and equipment is a major water user. The chapter entitled **Cleaning Industrial Vessels, Pipes and Equipment** covers cleaning in detail, but cleaning methods specific to the chemical industry are covered in Table aa. (This information was gathered from publications of the British Government for use in its industries.)

Table aa. Vessel-Washing Equipment

for Chemical Manufacturing

- Communication - Make sure your staff understands the most effective washing methods.
- Batch formulation - Processing the same types of chemical in batches can reduce the frequency of vessel washing.
- Mixing outside the vessel - This practice may reduce the need for vessel washing.
- Dedicated equipment - Using specific vessels for specific products can reduce cleaning requirements.
- Production scheduling - Batching compatible products together will minimize the washing needed between them.
- High-pressure cleaning - Systems that direct dense sprays and jets of wash liquor can help reduce the amount of water used, while improving wash efficiency by 90 percent.
- Automated vessel washing - You can use this process to control water use more precisely and reduce emissions, especially in enclosed vessels.
- Optimizing cleaning levels - Ensure that you use only the required level of cleaning for particular products. You may not need to wash at all, or you might be able to reuse wash liquor.
- Optimizing cleaning agents and solvents - Using different cleaning agents and solvents may reduce washing.
- Using wash liquor in product - Look into using wash liquor to dilute subsequent product batches where required.
- Material recovery – In areas where you cannot reuse wash liquors, look at ways of recovering materials from the effluent.

Source: British Government Web Site - Business Link
http://www.businesslink.gov.uk/bdotg/action/detail?itemId=1083098743&r.i=1083098500&r.l1=1079068363&r.l2=1082900032&r.l3=1083098121&r.t=RESOURCES&type=RESOURCES

Water Savings and Cost Effectiveness

The two case studies below show the potential for water and cost savings from implementation of water conservation BMPs in the Refining and Petrochemical Sector.

Water-conservation technology at Dow plant saves one billion gallons of water

Water conservation programs have enabled Dow to become more energy- efficient and decrease its global footprint. In alignment with Dow's commitment to water, the Company partnered with Nalco to implement water-reduction and cost-saving technology at Dow's largest manufacturing site globally in Freeport, Texas. The power plant has been designed to use seawater instead of freshwater for cooling. The 3D TRASAR Cooling Water Technology has been recognized with a United States Presidential Green Chemistry Challenge Award. The use of seawater saves $600,000 per year in avoided treatment, energy, and water costs.

Dow's long-term commitment to water conservation programs has resulted in reducing the amount of water used per pound of product by more than 35 percent since 1995. Dow is harnessing its expertise in science and innovation toward becoming a global leader in water efficiency, conservation, and treatment – striving to incorporate a zero liquid discharge design philosophy into new design and construction of plants, minimizing water impacts, and continuously improving the efficient use of water resources.

*Source: Dow Chemical, www.**dow**.com/sustainability/stories/operations/**water**.htm*

RECLAIMED WATER FOR CHEVRON IN CALIFORNIA

- Operating Responsibly Building Capacity Designing sustainable water systems
- Active membership of stakeholder groups
- Developing more efficient production

Chevron has a number of refineries in areas of the US where conflicting demands on water resources are acute. Chevron has responded to these pressures by seeking new ways to both manage and conserve water. In El Segundo, California, for instance, a severe drought in the 1980s saw the local Water District transform from a fresh water wholesaler to an authority that also supplied specially produced reclaimed water.

Chevron's El Segundo refinery now takes eight million gallons a day of this reclaimed water – with four million gallons going to cooling tower makeup water, and four million gallons a day to boiler feed water. Reclaimed water now accounts for some 80% of the refinery's overall water consumption.

Further north in California, the drought also prompted the East Bay Water District to find ways of supplying more reclaimed water to relieve the pressure on fresh water demand. Chevron's Richmond refinery currently uses three million gallons a day of reclaimed water in its cooling towers. The refinery is also exploring the possibility of using another three million gallons a day as boiler feed water – which would see its overall consumption of reclaimed water account for more than 50% of daily usage.

Source: Water Resource Management in the Petroleum Industry, IPIECA, 2005

7B2e: The Pharmaceutical and Biotech Industries

The Pharmaceutical/Biotech industry produces a wide variety of products. It is one of the largest industries in California, and California's Pharmaceutical/Biotech industry is the largest in the nation. The industry includes research, diagnostic chemical, Pharmaceutical/Biotech substances produced by the conversion of organic and natural substances, products produced by fermentation or synthesis, and the formulation and production of final products. In great part, the biotechnology revolution was birthed in California, and many people see it as the next "big thing" to revive the California economy after the "high tech" bust. *A 2005 report by Junfu Zhang and Nikesh Patel, titled "The Dynamics of California's Biotechnology Industry," points out that although the biotechnology industry is still small compared to the rest of the Pharmaceutical/Biotech industry, it is the fastest growing sector in the industry.*

Based on 2009 data from the US Department of Commerce, the pharmaceutical/biotech sector employs 40,989 Californians, and it has a total value of shipments of $30,840,359 and a value added of $25,335,967. The last year the US Department of Commerce published information at the six digit NAICS level for California is 2007; Table 1 presents this information. Approximately 75 percent of value of shipments and 61 percent of employees in the California Pharmaceutical/Biotech industry work in the area of the preparation and manufacturing of products for the industry. Overall, California represents 11 percent of the United States industry. Historically, this sector has spent fifteen to twenty percent of its revenues on research according to Congressional Budget Office estimates.

Table 1. US Census of Manufacturers Information for Pharmaceutical/Biotech Industry in California in 2007

Pharmaceutical/ Biotech Product	NAICS Code	Number of Establishments in California	Value of Shipments in California ($1,000's)	Number of Employees in California	Number of Establishments in USA	Value of Shipments in USA ($1,000's)	Number of Employees in USA
Medicinal and botanical manufacturing	**325411**	**64**	**$945,161**	**3,346**	**410**	**$11,316,752**	**24,626**
Pharmaceutical/Biotech preparation manufacturing	**325412**	**170**	**$20,082,378**	**26,762**	**991**	**$142,876,257**	**158,531**
In-vitro diagnostic substance manufacturing	**325413**	**71**	**$3,131,798**	**8,960**	**259**	**$12,407,704**	**29,080**
Biological product (except	**325414**	**50**	**$2,740,830**	**4,767**	**350**	**$21,798,314**	**36,163**

diagnostic) manufacturing								
	TOTAL	**355**	**$26,900,167**	**43,835**	**2010**	**$188,399,027**	**248,400**	

The three basic tools of the Pharmaceutical/Biotech/biotech industry are chemical synthesis, natural product extraction, fermentation, and Pharmaceutical/Biotech.

- Chemical synthesis, including reaction, separation, purification, and drying, is used to produce many of the pills and other products found on pharmacy shelves;

- Extraction of natural products from organisms ranges from plants and roots to fungus and animal parts as well as blood fractionation;

Fermentation is a fundamental process for many of today's medical products.

- Formulation processes convert bulk chemicals into refined products that include: tablets, capsules, liquids, patches and ointments. Typical formulation operations include mixing, blending, granulating, drying, coating, polishing, tablet pressing, capsule filling, sorting, and packaging.

Major water uses in the pharmaceutical/biotech/biotech industry are:

- cooling
- boilers
- clean steam boilers (fed with ultrapure water)
- ultrapure water treatment systems
- inclusion in product
- fermenters
- cleaning of equipment and containers
- autoclaves and sterilizers
- air pollution - scrubbers
- vacuum pump seal water
- pump seal water
- humidification
- used in reaction
- sanitation
- irrigation

All aspects of production are covered under the Federal Food, Drug, and Cosmetic Act (FD&C Act), Food and Drug Administration Amendments Act (FDAAA) of 2007, and other legislation, rules and regulations. Water used or pharmaceutical/biotech production must meet Food and Drug Administration (FDA) standards. The FDA has established eight categories of water, ranging from non-potable water for outdoor uses, potable water, and six USP (United States Pharmacopeia) categories of purified water.

US Federal Food and Drug Administration Classification of Water for use in the Pharmaceutical/Biotech Industry

2. Potable (drinkable) water
3. USP purified water
4. USP water for injection (WFI)
5. USP sterile water for injection
6. USP sterile water for inhalation
7. USP bacteriostatic water for injection
8. USP sterile water for irrigation

Source:http://www.fda.gov/ICECI/Inspections/InspectionGuides/InspectionTechnicalGuides/ucm072925.htm

The non-potable water can be used for irrigation of landscapes, cooling tower makeup, and similar uses. Potable water can be used for much of the in-plant general cleaning, but USP must be used in the production of medicines and for much of the cleaning of equipment.

The production of ultra-pure water offers some unique opportunities for water efficiency in the pharmaceutical/biotech, nanotechnology, and microelectronics industries. In this process, potable water is passed through a series of water treatment operations to produce water that is almost completely pure, purer, in fact, than distilled water. Depending on the quality of water needed, water is passed through a sediment filter and activated carbon, softened, filtered with a micro filter, disinfected with ultraviolet light, and then passed through a reverse osmosis (RO) system. In some cases these processes still do not produce pure enough water. In those cases, the water is then passed through strong acid - strong base ion exchange resins that remove all but about 20 parts per billion of total dissolved solids. The wastewater produced by the use of this water for washing and similar operations is often "cleaner" than the tap water supplying the plant and can be reused in other areas.

The operation of the RO system offers many opportunities for both water use reduction and reuse. Modern RO units recover more than 75 percent of the water fed to the system. The remaining 25 percent, called reject water, is soft, particle free, and of good enough quality to use in cooling towers and similar applications. In some facilities, the reject water is again passed through either a saltwater RO membrane or a nanofiltration system, and that product water is recycled to the front of the RO system.

If ion exchange is used, the facility can choose to regenerate the resins on- or off- site, which will shift water use from one site to another, but water will still be used.

Most new biotechnology industries use biological fermentation bioreactors to produce antibiotics and similar products. Figure rr in appendix xx shows a diagram of such a reactor.

Cross contamination is a major concern of the industry. To prevent it, cleaning involves thorough washing, rinsing, and sterilizing. In addition, steam and strong oxidizing agents are often used in the sterilizing phase of the clean-in-place system. Much of the cleaning operation used in the Pharmaceutical/Biotech industry is similar to the processes used food processing and chemical manufacturing cleaning.

For years, the general trend in the industry was toward larger reactors, but for some specialty biotechnology companies, the use of smaller reactors with disposable plastic liners has gained some acceptance. These smaller reactors lessen the need for the thorough cleaning now practiced and significantly reduce the potential for cross contamination. They reduce water use while producing a recyclable plastic waste.

Cooling tower makeup, boiler feed water, and water used for processing product are the main uses of water in a Pharmaceutical/Biotech manufacturing operation. Figure kk in the appendix shows an actual water balance for such a facility.

For water uses common to many CII facilities such as employee sanitation, cooling towers, and irrigation, the reader is referred to those sections elsewhere in this document.

Best Management Practices for Water Conservation

1. Reusing RO reject water in production cycles, cooling tower makeup water, boiler feed water, and irrigation.
2. Metering, sub-metering, and installing automated data recording systems to follow water use at all major use points;
3. Converting pumps to mechanical seals;
4. Where packing glands are required, using alternate sources of water for seal water;
5. Using dry vacuum pumps;
6. Where liquid ring pumps are required, either installing a water recirculation system or using wastewater for the seal;
7. Following vessel washing and pipe cleaning procedures (see **Cleaning Industrial Vessels, Pipes and Equipment;**
8. Installing automatic cutoffs and solenoids on all water using equipment to ensure that water flow is stopped when the equipment is not working;
9. Instituting training programs for employees; and
10. Installing water efficient plumbing fixtures and appliances.
11. Stormwater and other on-site sources have been successfully used for firewater, and for boiler and utility water after proper treatment. Pump seal water is another possibility, as is cooling tower makeup. In areas of lower rainfall, such as California, the feasibility of capturing, treating and reusing storm water will need to be examined to determine cost effectiveness. Condensate from refrigeration and air conditioning processes, treated wastewater from restrooms and showers, and similar sources may provide inexpensive but small quantities of water for the refinery operation.
12. The use of municipal recycled water is another way to reduce the use of freshwater supplies that could be used for potable purposes. Recycled water can be used for cooling tower makeup, boiler feed, and all other uses except potable use. However, it may need additional treatment. The section in this report concerning recycled water has additional information.
13. Seawater can be used for cooling purposes for plants located along the coast, entirely eliminating the use of fresh water for cooling. However, power plants using seawater for cooling are now being required to eliminate once-through or pass-through cooling, which

will further require them to install recirculating systems to reduce the volumes of water they withdraw.

<u>Summary of Water Conservation Audits off Pharmaceutical/Biotech Manufacturing and Research Facilities</u>

During 2009 and 2010, four biotechnology companies, including a research facility, and three manufacturers in the San Diego, California area, received water efficiency audits. All four entities used half or more of their water for a combination of cooling tower makeup, landscape irrigation, and boiler makeup. Since the audits were targeted at process water uses, they did not address domestic plumbing fixtures and irrigation system efficiencies. The single largest non-irrigation use by far for all four facilities was for cooling tower makeup. The auditors examined all process water uses listed and identified five areas where the most water could be saved.

1. Installing water tempering devices on autoclaves.
2. Increasing cycles of concentration in cooling towers.
3. Using recycled water for cooling.
4. Recovering and reusing high quality rinse water from cleaning of vessels and water from still reject and clean steam discharge for boiler makeup.
5. Eliminating once-through cooling.

7B2f: Preliminary Working Draft - Power Plants

Background

This section has not yet been reviewed by the Task Force.

Electric Power subsector (NAICS 2211) comprises power generation (22111), transmission and distribution (22112). Most of water use is concentrated on the power generation subsector which will be the focus of discussion in this section.

Electric Power generation is further divided into four subsectors in NAICS as Hydroelectric power generation (221111), Fossil fuel electric power generation (221112), nuclear electric power generation (221113), and other electric power generation (221119). Most of renewable energy plants should be included in the last subsection, such as solar, wind, biomass, and geothermal energy plants. Table 1 shows some basic statistics in Electric Power Generation Subsector quoted from U.S. Census Bureau, 2007 Economic Census which is the latest data available to the public. Not all the survey data are reported by the U.S. Census Bureau that suppresses data to protect the identity of any business or individuals.

Table 1. Background of Power Plant Sector

NAICS Code	Subsector	Employers (191)	Revenues ($)	Payrolls ($1,000)	Employees
221111	Hydroelectric Power Generation	32	NA	NA	NA
221112	Fossil Fuel Electric Power Generation	87	NA	209,738	2,187
221113	Nuclear Electric Power Generation	3	NA	NA	NA
221119	Other Electric Power Generation	69	NA	NA	NA

Data sources: U.S. Census Bureau, 2007 Economic Census.

Hydroelectric power generation (NAICS 221111) converts the hydrostatic (gravitational) or kinetic flow energy to electric energy. It deals with water directly but it usually does not consume a lot of water or the water consumption involved in the process is hard to be evaluated. In the renewable energy subsector, wind turbines do not use water; geothermal power plants and solar energy facilities may use some water. Biomass energy production may involve a lot of water consumption from the point of view of Life Cycle Assessment (LCA) because the plant growth and energy generation both need a lot of water. However, the current energy generation from the biomass processing still accounts for a very small percentage. The most water use and water consumption is concentrated in the fossil fuel power generation and nuclear electric power generation.

Water Use in Power Plants

Fossil fuel power electricity and nuclear power electricity are usually generated through thermoelectric process in which the heat energy or radioactive energy released through either fission or fusion process is converted to the electric energy. Water is extensively used in thermoelectric power plants to produce steam, and water is also widely used in many other power generation industries to cool equipment. In a report, *Estimated Use of Water in the United States in 2005*, the United States Geological Survey (USGS) reported that 49% of the water withdrawal (both fresh and saline water which included; Public supply, Domestic fresh, Irrigation fresh, Livestock fresh, Aquaculture fresh, Industrial fresh and saline, Mining fresh and saline and Thermoelectric Power fresh and saline supplies) was used in thermoelectric power sector nationwide. In California the thermoelectric power sector used 12,650 million gallons per day (MGD) which consisted of 12,600 MGD of saline water and 50 MGD of fresh water. As the total water withdrawal statewide in the year 2005 was 45,770 MGD (32,900 MGD of fresh water and 12,900 MGD saline water), the thermoelectric power sector in California took nearly 28% of the statewide total, a percentage less than the nationwide average. One of the reasons for this lower percentage is because California annually has imported about 35% of its electricity from other states. Also note that the California thermoelectric power plants used more than 99.6% of saline water and less than 0.4% of fresh water.

Water is used in power plants mainly for two purposes – heating water to produce steam or using water for cooling. The cooling system uses far more water than the heating system in the whole power generation industry. In general, water is used in two types of cooling process – once-through cooling (or open cycle wet) or recirculation cooling (or closed cycle wet). The once-through cooling uses a lot of water but most of the water used is discharged back to the water system. On the other hand, recirculation cooling needs less water supply but it consumes more water in the cooling process. There are several other cooling systems which use less or almost use no water at all, such as wet surface air cooler (WSAC), hybrid wet/dry system, and dry cooling tower (Electric Power Research Institute, 2007).

SWRCB Policy Proposal (2008)

On May 4 of 2010 the California State Water Resources Control Board (SWRCB) adopted Resolution No. 2010-0020 – "*Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling*" – and associated certified regulatory program environmental analysis. The Resolution has stated that there are 19 electrical power plants (including two nuclear-fueled plants) located in the state that use marine or estuarine waters as a source of cooling water in a single-pass system, known as once-through cooling system (OTC). These power plants combined have the capacity to withdraw over 15 billion gallons of water per day. The withdrawal of marine and estuarine water for the purpose of OTC results in the impingement and entrainment of marine life to the detriment of the marine environment. The Resolution establishes uniform requirements for the implementation of Clean Water Act (CWA) Section 316(b),using best professional judgment in determining best technology available (BTA) for cooling water intake structures at existing coastal and estuarine power plants that must be implemented in National Pollutant Discharge Elimination System (NPDES) permits. Resolution No. 2010-0020 intends to ensure that the beneficial use of the state's coastal and estuarine waters are protected while the electrical power needs essential for the welfare of the citizens of the states are also met. To conserve the state's scarce water resources, the State Water Board encourages the use of recycled water for cooling water in lieu of marine, estuarine or fresh water.

BMPs in water use in power plants

USEPA and other federal and California state agencies recommended many water saving methods or the best management practices (BMP) of water use in industries general and in electricity power generation in particular. Those methods include use of reclaimed water or treated municipal wastewater for power plant cooling; adaptation of innovative water use and water recovery, water reuse and water recycling measures; implementation of advanced cooling technologies; take water survey and water audit, etc. Electricity generation from the renewable energy sources, such as solar, wind, and geothermal energies, generally use far less water than from traditional thermoelectric power plants. (Electricity generation from biomass may consume more water than from the traditional method.)

Electric Power Research Institute (2007) summarized the following strategies to increase fresh water use efficiency in the electricity power generation.

1. Increase electricity generation efficiency
2. Use dry/hybrid cooling
3. Recycle water within plant
   – Increase closed cooling cycles
   – Use blowdown
   – Capture vapor produced in wet cooling tower
4. Use degraded/impaired waters
   – Waste water treatment plant discharge
   – Water produced in oil/gas extraction
   – Storm water flow
   – Mine drainage
   – Agricultural runoff
   – Saline aquifers
   – Coastal waters

(Refer to Section 7 for the BMPs in the Thermodynamic Process Section)

Case Studies

Electric Power Research Institute (2007) reported at the First Western Forum on Energy & Water Sustainability March 22 – 23 2007, some water saving examples in electricity power generation. One is the Bighorn 530 MW combined-cycle which is air-cooled. Another example is the 1,800 MW Southwest Coal-fired steam plant which adopted internal plant water reuse. The table below shows the water-into-plant, water-out-of-plant, and make-up allocation of water (Table 2).

Internal Plant Water Reuse:
1,800 MW Southwest Coal-fired Steam Plant

Water Stream	Flow[1] gpm	Flow[1] %
Water into plant	13,270	100%
make-up application		
cooling tower	12,120	91.3%
Scrubber	90	7.0%
Ash handling	960	7.2%
Plant service water	100	0.8%
Water out plant		
Cooling tower (evap/drift)	11,355	85.6%
FGD cake	100	0.8%
Scrubber evap.	1,430	10.8%
Ash system	90	0.7%
Steam loss	180	1.4%
Evap. pond	115	0.9%

gpm - gallons/minute; evap. - Evaporation; FGD – Flue Gas Desulfurization;
Flow[1] - @ capacity factor of 76.2% for 22,000 acre-feet/year.

7C: Common Devices, Processes, and Practices Applicable to the CII Sectors

7C1: Alternate On-Site Sources of Non-Potable Water

Introduction

One of the most rapidly developing areas of increased water use efficiency is the use of alternate sources of water collected on-site for non-potable use. In the past, the use of alternate on-site sources has been hindered by an absence of a regulatory framework and a lack of readily available technologies to help facilitate their use. These obstacles are rapidly disappearing as a result of a number of changes: the two major plumbing code bodies (International Association of Plumbing and Mechanical Officials and the International Code Council) are developing "green codes," the National Sanitation Federation is developing water quality criteria for gray water reuse, organizations are forming to promote the use of alternate sources, and California is moving to begin the development of state level guidance and regulations.

Underlying Concepts

1. The use of an alternate on-site source of water is a best management practice (BMP) in and of its self.
2. Alternate on-site sources of non-potable water are freshwater resources, and they should be used efficiently.
3. Any water source can be treated to meet the needs and conditions of a desired end use. Economics and volume of water available are the major limiting factors.
4. These sources of water are perfect candidates to use in conjunction with potable water, recycled water, and self-supplied fresh water.
5. The potential of this resource is only limited by the limits of the amount available and the ingenuity of the user.

Codes, Standards, Regulations, Organizations, and Rating Systems

Many factors have converged to encourage the use of the alternate on-site non-potable sources of water. The most important among these are summarized below:

Codes provide officials with building standards to follow. In the past, without written national codes, each jurisdiction had to approve projects on a case–by-case basis, thus having to invent code each time a project arose. Two national codes now or will soon allow builders to build many types of on-site systems to code. Currently both codes are supplements that must be adopted locally.

The current code of the International Association of Plumbing and Mechanical Officials (IAPMO) only addresses untreated graywater defined as water from the bathtub and shower, clothes washer, and hand washing lavatories. IAPMO's new Green Plumbing and Mechanical Code

Supplement was adopted in 2010 and is now being revised for a 2012 edition. It is the first such code. California follows the current IAPMO plumbing codes. The new supplement is designed to be incorporated directly into existing IAPMO codes. This code recognizes four types of non-potable, alternate on-site sources of water. They are:

1. Recycled (Reclaimed) water - water from municipal wastewater treatment facilities;
2. Graywater - Untreated water from showers, bathtubs, clothes washers, and hand washing sinks that is used for subsurface irrigation;
3. Rainwater that is water collected from roofs and elevated surfaces;
4. On-site Treated Non-Potable Water - all other on-site sources that are treated to the level required for their intended use.

The International Code Council (ICC) is currently developing the International Green Construction Code, which will have similar provisions

Standards set criteria that must be followed. The National Sanitation Federation (NSF) has established NSF Standards 350 and 350-1 for graywater reuse. They provide water quality parameters for graywater for use above ground for irrigation and toilet flushing (350) and for subsurface irrigation (350-1).

Regulations by the State of California for commercial graywater use are under development and will be incorporated into code for commercial and institutional water users. Currently under Chapter 16A of the Department of Housing and Community Development, ***residential*** graywater use is allowed, but this allowance does not yet extend to commercial users. The new IAPMO Green Plumbing Code has been coordinated with current California Chapter 16A regulations for untreated graywater.

Regional water control boards and local jurisdictions are also considering local ordinances and regulations such as the guidelines available from Los Angeles, but they remain "works in progress."

Organizations such as the American Rainwater Catchment Systems Association, American Water Works Association, and others are working to promote the use of alternate sources of water. All environmental organizations such as the Sierra Club also promote alternate sources use.

Rating Systems such as the US Green Building Council's LEED (leadership in energy and environmental design) and the Green Globes' Green Build Initiative (GBI) provide points toward certification for use of alternate on-site, non-potable sources of water.

The Potential Sources of Alternate On-Site Sources of Non-Potable Water

Many diverse sources of water are produced on every type of property. Most of the time, this water is discharged to sanitary sewers or it becomes part of the stormwater system. The capture and use of these resources is growing as conventional potable freshwater rise in cost. These on-site sources offer real opportunities to stretch limited resources and have positive impacts on the environment. The following section provides a brief description of some of the most commonly used sources:

__Rainwater harvesting__ is the catching of water from roofs and other elevated structures and stored in cisterns for future use. (By contrast, stormwater is collected off of more contaminated surfaces such as parking lots and lawns. Stormwater is covered below.)

Rainwater harvesting is one of the oldest forms of alternate on-site sources of water. Although rainwater has been use for drinking purposes in some homes in the past, this document only discusses the non-potable uses in commercial, institutional, and industrial settings.

Approximately 0.62 gallons of water can be collected per square foot of collection surface per inch of rainfall. In practice, however, most installers assume an efficiency of 80 percent. Some rainwater is lost to first flush, evaporation from the roof surface, or splash-out from the gutters. Rough collection surfaces are less efficient at conveying water, and water captured in pore spaces is lost to evaporation.

The inability of the system to capture all water during heavy storms also affects practicable efficiency. For instance, spillage may occur if the flow-through capacity of a filter-type roof washer is exceeded, and overflow rainwater will be lost after storage tanks are full. The use of rainwater collection systems, also referred to as cisterns, is most practical in regions with periodic precipitation throughout a plant’s growing season. For example, in California, since most regions don’t receive precipitation during the summer, early fall, or late spring, cisterns are far less practical than in other parts of the country, because very large storage capacities are needed to capture enough water to use at any length into the irrigation season. Stated another way, the more frequent the precipitation, the smaller the needed storage facility and the less the capital costs.

__Stormwater harvesting__ is catching runoff water from parking lots, roofs, landscape, etc. This water can either be captured in storage structures such as holding ponds or storage tanks for future use after proper treatment, or it can use the soil profile of the landscape as a storage medium. If storage structures are used, economics and design considerations are similar to that for rainwater, except that stormwater generally contains higher levels of contaminates than rainwater.

The recent symbiotic development of stormwater management and the collection and storage of water in the soil profile harkens back to the oldest form of rainwater harvesting for agricultural practices by native American tribes in the Southwest. Storing water in the soil profile is almost always the least expensive form of storage. It also allows for water to percolate into local aquifers and helps support local wildlife. An example of this practice may be found in the County of San Diego's handbook on stormwater management. An excerpt from this document is presented below to illustrate this point.

County of San Diego
Low Impact Development Handbook

Stormwater Management Strategies

Integrated Management Practices (IMPs) help developers mimic the site's natural hydrological function. IMPs may include directing runoff to natural and landscaped areas, man-made filtration devices such as small vegetated swales, rain gardens, and permeable pavements and pavers. Other basic principals include dividing and sectioning impervious surfaces (no large continuously paved areas), eliminating runoff pathways and re-dispersing runoff (no downspouts connected to storm drains), and, where feasible, harvesting of rain water in rain barrels or cisterns and using runoff as an irrigation source. These LID techniques can be applied to areas of residential, commercial, industrial, and municipal development.

The capture and use of stormwater in the landscape by simply using the landscape is a significant opportunity, but the site must be designed to take advantage of this resource.

Air conditioner condensate is the water formed on inside air conditioning coils from dehumidification of air being cooled. Since the source of this water is the atmosphere, it does not contain minerals and salts, but it does collect bacterial and particulates from the air that is being cooled.

Estimating the amount of condensate produced requires a psychrometric evaluation of makeup air, climatic data, and operation of the air conditioning systems. This evaluation will determine the amount of condensate that may be available. The best time to incorporate condensate collection systems is in the design phase of a facility.

Swimming pool filter backwash water from the backwash of sand filters can be used for landscape irrigation and other uses if properly treated. Backwash water can contain high levels of suspended solids and bacteria. Sedimentation, filtration, and disinfection may be needed before use. Swimming pool water also may contain fairly high dissolved solids levels. Chlorine may be a factor if it is too high for the plants being irrigated. Algaecides can also damage plants, but in most cases, it can be used for irrigation after minimal treatment.

Cooling tower blowdown is the water discharged to keep minerals from building up in cooling towers. It is usually high in total dissolved solids, but it can be used toirrigate salt tolerant plants. Blowdown can also be used for other purposes such as toilet flushing, but special attention would need to be given to total dissolved solids levels and the type of treatment needed to bring it to the level needed for those uses.

Reverse osmosis (RO) and Nanofiltration (NF) Reject Water is purge water rejected from this type of treatment equipment. This water has typically been treated and disinfected. In the case of RO reject water, the water has almost always been softened. One constituent of concern with RO or NF reject water is total dissolved solids. Where nanofiltration is used for softening, the reject water can also be very hard.

Graywater is water from laundries, bathing, and hand washing fixtures. See the NSF 350 and NSF 350-1 standards for this type of water. If the IAPMO Green Plumbing and Mechanical

Code is followed, gray water refers to ***untreated*** water from graywater sources that is only used for subsurface irrigation.

On-site treated wastewater systems are sewage treatment plants located on the premise where the wastewater is generated. When treated properly, this effluent can be as viable source of fresh water from municipal facilities.

Foundation drain water is water pumped from under foundations, French drain systems, basement sumps, and from under slabs to prevent flooding of basements or buildings below the land surface. This water can vary significantly depending on the type of soil and ground it comes in contact with. This water should have a major cation and anion analysis performed on it prior to use to determine its makeup. Normally, this type of water is an excellent candidate for landscape irrigation and often for cooling tower makeup.

Boiler blowdown - The quality of blowdown from boilers varies considerably depending on the quality of steam needed. Most commercial low -ressure boilers produce a blowdown that is high in total dissolved solids, but high pressure boiler blowdown is often low in total dissolved solids and can be used for non-potable purposes.

There are many potential sources not covered in this document. Each site should look at all of its possible alternate sources to determine if there is an opportunity to capture and use it.

Potential Uses of Alternate On-Site Sources for Non-Potable Purposes

Many potential uses exist for these alternate non-potable sources. The most important concept to use in the evaluation of these possible uses is ***what is the minimum water quality needed*** by the intended use.

Some of the potential uses include:

- irrigation
- green roofs
- cooling tower makeup water
- toilet and urinal flushing
- makeup for an ornamental pond/fountain
- swimming pools
- laundry
- industrial process use
- any other use not requiring potable water.

These sources can even be used for aquifer recharge and meeting environmental needs for in-stream flow and wetlands maintenance.

Making these sources usable often requires; however, these sources do not need to be treated to more than that required for the intended use. Table 1 illustrates some of the water quality considerations that must be taken into account when using alternate sources.

Table 1. - Water Quality Consideration for Alternate On-site Sources of Water						
Possible Sources	**Water Quality Considerations**					
	Sediment	**(TDS)**	**Hardness**	**Organic (BOD)**	**Pathogens**	**Other considerations**
Rainwater	**1-2**	**1**	**1**	**1**	**1**	*None*
Storm water	**3**	**?**	**1**	**2**	**2**	*Pesticides & fertilizers*
Air conditioner condensate	**1**	**1**	**1**	**1**	**2**	*May contain copper when coil cleaned*
Pool filter backwash	**3**	**2**	**2**	**1**	**2**	*Pool treatment chemicals*
Cooling tower blowdown	**2**	**3+**	**3**	**2**	**2**	*Cooling tower treatment chemicals*
RO & NF reject water	**1**	**3+**	**3**	**1**	**1**	*High salt content*
Untreated Gray water	**For subsurface application only. May need lint screening**					***Detergents and bleach***
On-site wastewater treatment	**3**	**2**	**2**	**3+**	**3+**	*Human waste*
Foundation Drain Water	**1**	**?**	**?**	**2**	**2**	*Similar to stormwater*
Other Sources	**?**	**?**	**?**	**?**	**?**	*Depends on source*
The use of pass-through (once-through) cooling water is also a possible source of on-site water, but it should be discouraged because of its huge potential to waste water. While it does provide a very clean source of wate, it is not included in this list.						
1. Low level of concern 2. Medium level and may need additional treatment depending on end use 3. High concentrations are possible and additional treatment likely ? Dependent on local conditions						

The type of treatment that may be needed will depend on the ultimate use of the alternate water source. For example, if the water is to be sprayed into the air for irrigation in areas where human contact is possible, disinfection is needed if the water contains pathogens. However, if the water is to be used for subsurface irrigation or cooling tower makeup where there is biological control already, disinfection may not be needed. Each situation must be evaluated separately. The National Sanitation Federation (NSF) recently released its Standard 350 that addresses end use quality for graywater for aboveground irrigation and toilet and urinal flushing and 350-1 for subsurface irrigation. These standards may be used as a guide of end-use water quality from any on-site source. Table 2 summarizes the more stringent above ground use parameters and Table 3 summarizes parameters for subsurface irrigation. Again, these are treatment levels for the use of water for irrigation and toilet and urinal flushing. Treatment levels for cooling tower use, boiler feed, etc. should be determined on a case-by-case basis.

Table 2. NSF Standard 350 Effluent Criteria for Commercial Reuse Above Ground

Parameter	Overall Test Average	Single Sample Maximum*	Description
$CBOD_5$ (mg/l)	10	25	Carbonaceous biochemical oxygen demand
TSS (mg/l)	10	30	Total suspended solids
Turbidity (NTU)	2	5	***Nephelometric turbidity units***
E. Coli[2] (MPN/100 ml)	2.2	200	Most probable number of colonies
pH (SU)	6-9	NA	7.0 in neutral: >7 - basic, < 7 - acetic
Storage Vessel Chlorine Concentration (mg/l of Cl)	>0.5 & <2.5	NA	Other disinfectants can be used
Color	MR	NA	Measured and reported
Odor	Non-O	NA	Non-offensive
Oily film and foam	ND	ND	None detectable
Energy Consumption	MR	NA	Measured and reported
* NA - Not applicable			

Table 3. NSF Standard 350-1 Effluent Criteria for Commercial Reuse for Subsurface Irrigation

Parameter	Standard	Description
$CBOD_5$ (mg/l)	25	Carbonaceous biochemical oxygen demand
TSS (mg/l)	30	Total suspended solids
pH (SU)	6-9	7.0 in neutral: >7 - basic, < 7 - acetic
Color	Non-O	Measured and reported
Odor	ND	Non-offensive
Oily film and foam	MR	None detectable
Energy Consumption	Non-O	Measured and reported

Treatment technologies described in Section ? (Water Treatment) can be used to treat any on-site source to the quality specified in the tables above. Table 4 illustrates possible treatment technologies that may be needed to treat various sources to meet the NSF Standard 350 criteria for above ground irrigation. These treatment levels are only to be used as guides since the end use will determine the treatment needed. Explanation of treatment methods can be found in the section on Water Treatment.

Table 4. - Types of Treatment That May Be Employed Depending on Intended End Use Quality Needs

Source	Filtration	Sedimentation	Disinfection	Biological Treatment	Softening & Other	Other Considerations
Rainwater	?		?			Depends on end use
Storm water	X	?	X	?	?	Oils and heavy metals
Air conditioner condensate	?		X		?	Copper and bacteria
Pool filter backwash	X	?	X		?	Sediment, bacteria, & pool chemicals, salts
Cooling tower blowdown	X		X		X	High dissolved solids, bacteria, sediment
RO & NF reject water			?		?	High dissolved solids
Gray water	X	X	X	?		Bacteria, BOD, sediment
On-site wastewater treatment	X	X	X	X	?	Bacteria, BOD, sediment
Foundation Drain Water	X		X		?	Hardness, bacteria, sediment

Multiple Sources

Plumbing of rainwater, gray water, drain water, and blowdown from various sources to common end uses, like landscape irrigation, or non-potable indoor uses, such as toilet flushing, is not common, but it is recommended. The cost effectiveness of such “hybrid” systems is improved by diversifying the sources of water and improving the consistency of water availability, since rainfall episodes, often the largest and most significant single source of water, are sometimes separated by long dry periods.

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7C2: Building Meters, Submeters, and Management Systems

Overview

An important axiom in building and property water management is that you cannot manage what you don't measure. The absence of water meters is one of the biggest obstacles to measurement faced by facility managers. While most properties contain one or more main source meters that are provided and serviced by the water utility, additional meters (submeters) for tracking water use *within* the property and at specialized end-uses do not exist. Yet, such meters are generally easy to install, easy to monitor, and easy to maintain.

Tracking total property water use as well as specific uses with the building(s) is a key component of facility management efforts and essential to managing water costs and maintaining systems and processes on the property.

In addition, meters are used extensively in industrial and other process operations within the facility to track and manage water consumption and act as an alarm bell when processes fail.

Technical Feasibility

All of the practices, products, and technologies described within this report section have been in existence for an extended period of time and found to be technically feasible. In each case, however, economic feasibility must be evaluated within the context of the physical condition and demands of the specific process, property, or building being considered for metering and management.

Locating submeters

Where submeters should be installed is unique to each application, yet there are some locations that are typically recommended for most CII properties and operations. In some cases, the selection of these locations will be based entirely upon those building elements with high water use, while other submetered operations may be selected because of their vulnerability to failure, leakage, or other maintenance issues.

For example, submeters are commonly employed to measure usage for specific activities such as cooling towers, processes of all types, and landscape irrigation, where the water consumption at these activities is sufficient to warrant a meter. In the case of the latter two, a failure in these systems could quickly lead to substantial water waste. As such, measuring water use in real time can help facility managers identify water consumption anomalies that demand immediate attention by maintenance staff. Measuring also helps to identify areas for targeted reductions, track progress achieved with water-efficiency upgrades, and manage water and sewer costs.

Centralized building management systems

Meters and submeters can be integrated into a centralized building management system, making it easy to track usage and implement a full water management plan. These management systems are capable of electronically storing data from meters and submeters, reporting hourly, daily, monthly, and annual water use. They also trigger alerts upon detecting leaks or other operational anomalies. Real time monitoring and management systems are essential where there are multiple water using activities that consume large amounts of water, such as in certain industrial processes and large campus operations with diverse activities and building types.

Meter selection

Installing the correct meter and ensuring it continues to function properly are critical to accurate water measurement. There are many types and sizes of meters intended for different uses, so it is important to choose correctly. Improper sizing or type can cause problems for the system. For example, an undersized water meter can cause excessive pressure loss, reduced flow, and noise, among other problems. Oversized meters are not economical and do not accurately measure minimal flow rates.[123] Regarding the quality of products, all source meters provided by the water utility for domestic water service are considered utility grade water meters, and they must comply with American Water Works Association (AWWA) standards. However, submeters used for the purposes described above and not used for revenue purposes are not subject to such standards.

Best Practices

Consider the following best practices for metering water use:

Determine What to Meter and Submeter

The following recommendations are based on the U.S. Green Building Council's proposed 2012 Leadership in Energy and Environmental Design (LEED) rating system:

Source meters

- Meter all water conveyed to the facility, regardless of source. For example, even if a building's water is solely supplied by an alternative source (e.g., municipally supplied reclaimed water), a source meter should be installed.[124]

[123] Smith, Timothy A. 2003. *Plumbing Systems and Design*. Water-Meter Selection and Sizing. <www.ctaspe.com/docs/techarticles/Water%20meter%20selection%20and%20sizing.pdf>.

[124] U.S. Green Building Council. 2010. Leadership in Energy and Environmental Design—November 2010 Draft Rating System for Building Design & Construction <www.usgbc.org/ShowFile.aspx?DocumentID=8182>.

- If multiple sources of water are provided to a facility, each source should be metered and tracked separately.

Submeters

- Consider installing separate submeters to measure the following uses if they are permanently plumbed:[125]
    - Freestanding building with projected annual water use of 100,000 gallons or more.
    - Tenant space with projected annual water use of 100,000 gallons or more.
    - Cooling tower with projected annual make-up water use of 100,000 gallons or more. Make-up water added to the system and blowdown water discarded from the system should be separately metered. A single make-up meter and a single blowdown meter may record flows for multiple cooling towers if they are controlled with the same system. Separately controlled cooling towers, should have separate make-up and blowdown water meters.
    - Heating, ventilating, and air conditioning (HVAC) systems with aggregate annual water use of 100,000 gallons or more. If the facility has 50,000 square feet or more of conditioned space, the following systems should be submetered individually or collectively: (1) evaporative coolers, humidifiers, and mist cooling devices; and (2) recirculating water systems with a fill water connection, such as chilled water, hot water, and dual temperature systems.
    - Any boiler with aggregate projected annual water use of 100,000 gallons or more, or a boiler of more than 500,000 British thermal units per hour (BtuH). A single make-up meter may record flows for multiple boilers.
    - Landscape irrigation that is automated and permanent.
    - Water use from alternative water sources such as rainwater, air handler or boiler condensate, or other sources.
    - Make-up water used to supplement rainwater, graywater, and other onsite water collection and treatment systems plumbed to receive supplemental water (reclaimed, raw, or potable) from municipal supply, on-site treatment systems, or a groundwater well.
    - Manmade ornamental and recreational bodies of water including pools, spas, and ornamental water features. Make-up water provided to such water bodies with a combined surface area of 500 square feet or more should be metered, regardless of the projected amount of water use. Do not meter individual features of less than 50 square feet that cannot be reasonably metered collectively.
    - Any other process with a projected annual water use of 100,000 gallons or more.

In addition, also recommended for consideration are the following[126]:

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[125] ibid

[126] Huff, Winston, American Society of Plumbing Engineers (ASPE), 2009. *Water Meters: A Facility's Cash Register,* Plumbing Systems & Design Magazine, December.

- Other nonpotable water uses (process water) from sterilizers, air compressors, water filtration systems, laundry, and vehicle wash systems.
- Commercial food service water heaters, with another meter for all food service water.

<u>Meter Selection</u>

- First, determine the meter's use and select the appropriate meter from the meter types listed below.[127]
    - *Positive displacement meters* are best suited for small commercial or institutional applications because they have high accuracy at low flows and can precisely measure peak flows. Costs range from under $50 to over $1,000 depending on size, not including installation cost, meter box and piping, and related costs.
    - *Compound meters* are good for large commercial or institutional facilities because they accurately measure low flows and high flows with their multiple-measuring chamber design.
    - *Turbine and propeller meters* are most appropriate for continuous, high flow applications and are inaccurate at low flows. These types of meters are not usually recommended for commercial, institutional, or residential buildings because water flows are in constant fluctuation, with very low minimum flow rates. Their costs are similar to positive displacement meters.
    - Electromagnetic flow meters have no moving parts and do not obstruct flow. They have electronic outputs that are easy to connect to automated systems and data management systems. Meters between 2" and 10" cost from $1,000 to $2,500 depending on size.
    - Ultrasonic and time-flight meters can be attached to the outside of the pipe and are excellent for temporary flow measurement such as a water conservation audit. These meters cost from $3,000 to $7,000 depending on the system.
- Next, select the appropriate size of the meter. It is important to understand the building's size, function, fixture types, usage occupancy, and peak population in order to select the appropriately sized meter. These statistics determine the minimum and maximum flow rates and should result in the selection of a properly sized water meter.[128] AWWA Standard M22, *Sizing Water Service Lines and Meters,* provides additional guidelines for selecting and sizing utility-owned and installed water meters.[129]

<u>Meter Installation and Maintenance</u>

- When installing a meter, follow the manufacturer's instructions. Improper installation can lead to metering inaccuracies.

[127] Smith, Timothy A. 2003. *Plumbing Systems and Design*. Water-Meter Selection and Sizing. <www.ctaspe.com/docs/techarticles/Water%20meter%20selection%20and%20sizing.pdf>.
[128] ibid
[129] American Water Works Association. 2004. Sizing Water Service Lines and Meters (AWWA Manual, M22).

- Meters should be installed in an accessible location to allow for repair and calibration. In addition, the meter location should be protected from potential damage by surrounding equipment.
- To ensure uniform flow entering the meter, do not install the meter near pipe bends. In general, place the meter with at least 10 inch pipe diameters downstream and 5 inch pipe diameters upstream of straight pipe.[130]
- Create a map indicating the location of all source meters and submeters.
- Include a strainer on all meters and submeters. It is possible that debris and sediment will enter a meter with the flow of water and can have an adverse effect on accurate measurement. An in-line strainer on the meter's inlet will collect debris and sediment and prevent them from entering the meter body.[131]
- Meters deteriorate with age and should be tested for accuracy and calibrated on a regular basis. Sub-meters, however, may be subjected to more frequent inspection and calibration, depending upon the type and size of the meter and its application.

Water Use Tracking and Integration Into a Water Management Plan

Meters, in themselves, do not yield efficiencies. Instead, meters are a tool used to provide the data that can be monitored to aid in the efficient operation of a facility. This value includes discovering and correcting water use anomalies, and helping the organization allocate the cost of water to the appropriate tasks or processes. In addition to staffing the facility with motivated, aware, and trained monitoring personnel, best practices to be considered are:

- Consider installing a 'real time' centralized building management system with remote communication capabilities to the meters and submeters.
- If not integrating metering data into a centralized system, consider the following:[132]
    - Assign responsibility to track water use on a monthly or more frequent basis.
    - Train staff on meter reading and data recording.
    - Plot total water use and submetered data monthly and examine data for unexplained fluctuations.
    - Evaluate trends and investigate and resolve any unexpected deviations in water use.

Additional Resources

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7C3: Thermodynamic Processes

Introduction

The use of energy in commercial, institutional, and industrial (CII) processes is a key element to our modern civilization. Thermodynamics is the term physicist use to describe the dynamics of energy, in this case the use of energy to perform work and transfer energy from one place or substance to another. Single pass (once-through) cooling, cooling towers, evaporative coolers, and boilers are examples of water dependent thermodynamic processes technologies found throughout the CII sectors. Water is the key substance used by these two technologies to affect heat and energy transfer and transformation. This section covers both heating and cooling systems that use water. The Heating, Ventilation, Air Conditioning and Heating (HVAC) industry is directly involved in providing heating, hot water, and cooling to the commercial and institutional sectors. The North American Industrial Classification System (NAICS) code for that industry is 238220. For industrial operations, cooling tower construction and installation can be classified under NAICS 333415 or 332313, while boilers can be classified under NAICS 238290 or 332400.

Cooling Systems Terms and Definitions

Cooling systems remove "unwanted" energy in the form of heat. They dissipate that heat to the environment. Examples of cooling systems include air conditioning, process cooling, dehumidification, and refrigeration. Cooling is either achieved by evaporating water, by the direct use of water, or by the use of a mechanical refrigeration system. To begin this discussion two terms need to be defined.

1. **<u>Heat Pump</u>** - A heat pump is a machine or device that "moves" thermal energy from one location to another. In the case of refrigeration or air conditioning, heat is moved from the "source," which is at a lower temperature, to location of higher heat, called the "heat sink." Mechanical air conditioners and refrigeration systems are heat pumps. In the air conditioning or refrigeration mode, heat pumps are used to cool a space. If reversed, the heat pump moves heat from the outside to the inside to warm a space.

2. **<u>Heat Sink</u>** - A heat sink in this context is the environment – air, water or earth – that holds the unwanted heat.

   <u>Air as a heat sink</u> - An example of air as a heat sink is the typical home air conditioner. The outside unit contains the compressor, cooling coils, and fan. The compressor pump compresses the working fluid, such as Freon gas, which becomes very hot from the energy put into it though the compression. A fan then cools the gas by drawing in outside air and forcing it over the coils, thus returning the working fluid to a liquid phase. The heat from the motor and the heat from liquefying the Freon is rejected to the atmosphere. The liquid then flows back inside air conditioning coils where it expands as it passes through a small valve. As it turns back into a gas, it becomes very cold, able to absorb the heat from the room being cooled as the inside air handler (fan) blows over the coils. The gas returns

to the compressor, and the process repeats over and over again. The heat in the room is therefore pumped to the outside environment and discharged to the outside air (heat sink).

Air coolers for removing process heat provide another example. They work like car radiators. A fan draws outside air over coils as the warm fluid is pumped through the coils. The air acts as the "heat sink" to remove heat from (cool) the liquid in the tubes.

Earth as a heat sink - Some air conditioning units use the ground as a heat sink. These "geothermal" units run coils into the earth and the earth absorbs the heat rejected by the unit.

Water as a heat sink - Water is passed over the coils or through a "heat exchanger" where the working fluid or material being cooled transfers that heat to the water. The water can also be used in direct contact with the air to cool it through evaporation, such is the case with an evaporative cooler, which is sometimes called a swamp cooler.

A variation of this system is the chilled water loop. Water is cooled mechanically and circulated through a building to cool air (air conditioning) or equipment and then returned to the chiller unit.

Cooling towers represent a combined case where water is used to remove heat from a compressor or from a manufacturing process. The warmed water is then sent to a cooling tower where the waste heat is "rejected" to the atmosphere by evaporating that water.

There are five basic types of cooling systems that rely on water.

1. Single -pass cooling
2. Once-through cooling on natural bodies of water
3. Cooling reservoirs
4. Evaporative cooling
5. Cooling towers

COOLING SYSTEMS

Single - Pass - Cooling

Single-pass cooling uses water to remove heat, thus cooling equipment components. The water passes through a coil within or casing around a piece of equipment and then discharged to the sewer.

For the purposes of this report, single - pass cooling refers to the use of water to cool non-industrial type equipment. Types of equipment that often use single-pass cooling include:

- Chillers or other refrigeration systems
- Condensers
- Air compressors
- Hydraulic equipment
- CAT scanners

- Degreasers
- Welding machines
- Vacuum pumps
- X-ray equipment
- Ice machines
- Wok stoves

Vacuum pumps, X-ray equipment, ice machines, and wok stoves use water for processes in addition to the water used for single-pass cooling. Such equipment and its associated water use, apart from single-pass cooling, are discussed in BMPs within this Guidebook.

Large industrial operations, including manufacturing facilities and power plants, sometimes use "once-through" cooling with water from a natural body of water. This type of cooling is discussed in the next two sections.

The flow rate needed to cool the equipment depends on the amount of heat rejected by the equipment. Manufacturer specifications generally provide a flow rate. If not, the measured energy rejected by the equipment can be used to calculate flow rates.

Example1.:

A piece of equipment has a recommended flow rate of 2.5 gallons per minute. How much water does it use in a day?

Equation 1.

Water use = flow rate (gpm) X 1,440 = 2.5 X 1,440 = **3,600 gallons per day.**

Once-through Cooling on Natural Bodies of Water and Cooling Reservoirs

Once-through cooling on natural bodies of water refers to the use of a river, natural lake, or saltwater body as a source of cooling water. Water is directly returned to the natural body of water from which it was withdrawn. Since enormous volumes of water are typically involved, these withdrawals can impact aquatic wildlife by both entrapping them in the flow of water and by creating thermal barriers with the warm water that is discharged. To put this into perspective, one 750-megawatt power plant can withdraw as much as 1.5 billion gallons of water per day. For these reasons, the State of California no longer allows power plants to employ once-through cooling using sea water and freshwater sources that are not sufficient to support this type of flow rate. Smaller industrial facilities and some air conditioning systems can use this type of cooling, but permitting requires careful consideration. Because of its limitations, no further consideration is given in this document. Once-through cooling is not recommended as a best management practice.

Cooling reservoirs, sometimes called cooling ponds, are manmade reservoirs used by industries and power plants for process cooling. Water is pumped through heat exchangers and recirculated through the reservoir where it cools through natural processes. If water is pumped from a natural body of water such as a river, lake, or saltwater body, it is a form of once through cooling.

The amount of water evaporated from a cooling reservoir is a combination of natural evaporation and evaporation from the added heat from the cooling process ("forced evaporation"). These systems do not find wide use in California and are not discussed further.

Evaporative Cooling

One of the oldest technologies used to cool an occupied space is an evaporative cooling system, sometimes called a swamp cooler. These coolers simply pump water over wet pads that have air drawn through them. The evaporation of the water cools the air passing through it. This air is then blown into the space to be cooled (Figure 1.). These systems are inexpensive and use less energy than a refrigerated air system common to most residential and light commercial applications. However, they can consume significant volumes of water if not controlled properly.

Figure 1. Evaporative "Swamp" Cooler
www.ose.state.nm.us/water.../conservation/evap-coolers-brochure.pdf

Another technology uses a heat exchanger arrangement. Part of the air is humidified and thus cools. This cool air is passed through a metal "heat exchanger." This device passes the humid cool air on one side of metal sheets and discharges the cooler, more humid air back to the atmosphere. On the other side, air from the occupied space is circulated where it contacts the cooler metal surfaces, where it absorbs heat from circulating air. The cooled air is returned to the living space and the humid, cooler air is exhausted to the outside. This system is called indirect evaporative cooling.

In recent years, a new form of evaporative cooler has entered the market. It works by "pre-cooling" air that is being used to cool conventional air-cooled air conditioning coils. These systems are also used to pre-cool air for gas turbines and other industrial operations. These pre-cool systems use the same evaporative technology and have the same considerations as conventional "swamp coolers." The cool, humid air is then drawn through conventional air coils of an air conditioning system.

The effectiveness of this type of cooling depends on the relative humidity of the outside air and the outside temperature. They only work well in relatively dry climates. Under perfect conditions, the amount of water that must be evaporated to provide one ton of air conditioning is 1.48 gallons based on the latent heat of water of 970 BTUs per pound or water evaporated. Water is also needed to flush out dissolved solids in the supply water so these salts do not build up and precipitate out on the pads and in the cooler basin. Current models can use from 3 to 15 gallons of water per ton-hour according to the Alliance for Water Efficiency.

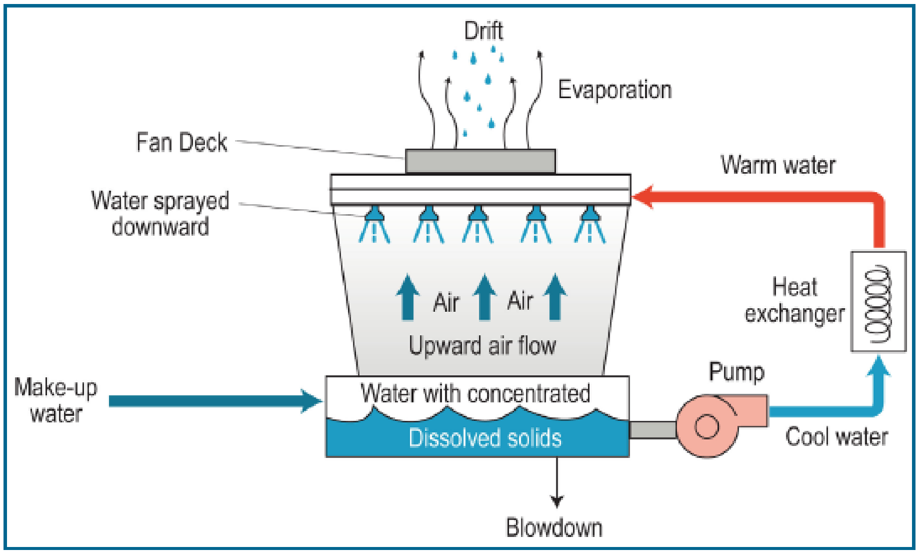
These evaporative ("swamp") coolers can either be of the once through type in which water, usually from a potable water supply, is continuously run over the pads and allowed to drain either to the yard or to a storm or sanitary drain. These systems are very wasteful. Most modern evaporative ("swamp") coolers have recirculating pumps that continuously pump water from a basin over the pads when the system is on. They use a float valve similar to that in a toilet tank to maintain the level in the basin. Water is "bled-off" to flush salts from the system either by a valve left partially open or with the use of a conductivity probe and solenoid valve system, as is the case in larger more sophisticated systems.

Cooling Towers

Cooling towers reject heat (unwanted energy). Their most common applications in the CII sectors are to remove heat generated by a manufacturing process and for air conditioning and refrigeration equipment. Warm water from process or cooling equipment is introduced at the top of a cooling tower and allowed to trickle over a packing material, such as plastic corrugated fill. The water breaks up into a film or droplets to maximize surface area, which maximizes evaporation. The water collected in the basin at the bottom of the tower is recirculated to the process or cooling compressor unit. The recirculating water undergoes a temperature change of about 5^0F to 15^0F through this process. The water is usually cooled to within 10^0F of the wet-bulb temperature. The total amount of water circulating in the cooling tower loop is called the mass flow, and it can vary from 100 to 200 gallons per ton hour depending on the change in temperature. At a 10^0F change in temperature as the water is pumped through the heat exchanger, the flow is just under 150 gallons per ton hour.

There are two basic tower configurations. Counter-flow towers draw air from the bottom, while water is sprayed onto the top of fill material in the tower. With cross-flow towers, air is drawn in from the sides and across the fill, while water is sprayed in from the top in a manner identical to counter-flow configurations. Fans can be located at either the outside or the bottom of the towers (forced-draft) or on top of the tower to draw the air out the top (induced-draft). Figure 2. shows the general operation diagram for cooling towers and Figure ww shows an actual cooling tower in operation.

Figure 2. General Water Flow Diagram for a Cooling Tower



Source: US. Department of Energy, Federal Energy Management Program
Cooling Towers: Understanding Key Components of Cooling Towers and How to Improve Water E
http://www1.eere.energy.gov/femp/program/waterefficiency_bmp10.html

Figure 3. Marley Counter-flow Towers

The amount of water used by a cooling tower (makeup water) depends on the amount of heat dissipated by evaporation, the amount that must be discharged to prevent the buildup of dissolved minerals and salts (blowdown), and the amounts lost through drift, leaks, overflows, and other losses. This can be expressed in a simple equation (Equation 4).

<u>Equation 4.</u>

$$M = E + B + D + L$$

Where

M = Make-up

E = Evaporation

B = Blowdown

D = Drift and wind loss

L = Leaks, overflows, and other losses

Evaporation and Blowdown

When warm water from a process or an air conditioning compressor is returned to a cooling tower, its energy is dissipated to the atmosphere primarily by evaporation. The amount of heat removed by evaporating one pound of water is approximately 973 BTUs and is known at the latent heat of evaporation. One gallon of water weighs 8.34 pounds so the evaporation of one gallon removes 8,114.8 BTUs. One ton-hour of cooling is equal to 12,000 BTU's by definition. Therefore, 1.48 gallons of water is evaporated for every ton-hour rejected to the cooling tower.

As the water evaporates, the dissolved minerals and salts in the make-up water remain behind. Additional water must be added (make-up) and some of the water in the basin periodically discharged (blowdown) to keep these minerals from building up and causing scaling and corrosion.

Drift and Wind Losses

Another type of water loss derives from drift and wind. It is caused by the entrainment of small droplets of water in the air stream as the fans force air through the tower or from wind blowing through the tower. If no drift eliminators are used, drift loss could be as high as 0.3% of circulation

Modern towers are equipped with very effective drift eliminators. Many manufacturers report that drift losses can be reduced to under 0.003 percent of the mass flow of the tower. For a typical cooling tower, mass flow is in the range of 150 gallons per hour per ton-hour of cooling. This would mean that with a modern drift elimination system, drift loss would be in the order of only 0.004 gallons per ton hour or under 0.3 percent of evaporation. This makes drift loss almost ***negligible.*** Drift eliminators also significantly reduce aerosols containing bacteria such as legionella, as well as particulate deposition and salt deposits. ***The implication of this is that drift term (D) in equation 4. [M= E + B + D + L] can be dropped as part of the calculation***

Leaks and Other Losses

Leaks and other losses are primarily a maintenance issue. Well-maintained systems have little or no leak loss. One common source of loss is an improperly set water level in the basin of the cooling tower.

Figure 4. Cooling Tower Float Valve and Overflow Pipe

An alternative to a float valve is an ultrasonic level detector such as the one shown in Figure 5.

Figure 5. Ultrasonic Cooling Tower Level Control Valve

Regardless of the type of level controller used, one of the most common types of water loss is an improperly adjusted float, or level controller. Leaks can also be a problem. Properly maintaining the float or level controller, eliminating leaks, and installing modern drift eliminators, simplifies Equation 4 to Equation 5:

Equation 5.

$$M = E + B$$

Cycles of Concentration

The concentration of the minerals (salinity) in the blowdown divided by the concentration of the minerals in the make-up water is called the cycle of concentration. This concentration of minerals is often called "total dissolved solids (TDS)" and is reported in milligrams per liter (mg/l) or parts per million (ppm).

Since the electrical conductivity of the water is related to the TDS, conductivity can be used to estimate TDS. The units of measure used for these conductivity reading are microSiemens. For example, if the conductivity of the make-up water is 100 microSiemens and the conductivity of the blowdown is 500 microSiemens, the tower would be operating at five cycles of concentration (CC). {500/100 = 5}

Equations 6 and 7 show the calculation of cycles of concentrations.

<u>Equation 6.</u>

Cycles of Concentration (CC) = Total Dissolved Solids (TDS) in Blowdown ÷ by TDS in Makeup Water

CC=TDS (*blowdown water* ÷ TDS (*makeup water)*

Where conductivity is used in place of TDS, as it is for all cooling tower controllers, the following equivalent equation should provide the same results.

Equation 7.

Conductivity can be used as an approximate substitute

CC=µS (*blowdown water)* ÷ µS (*makeup water)*

If leaks, overflows, and drift are truly negligible, Equation 5 can be rearranged to provide an estimate of cycles of concentration:

Equation 8.

$$CC = M/B$$

and therefore:

Equation 9.

$$B = M \div CC$$

Equation 10.

$$M = E + (M \div CC)$$

Equation 8 provides an important check to determine how well the tower is operating. If the results of Equation 8 vary from the results of either Equations 6 or 7 by more than 5 percent, something is wrong. Either the conductivity probe or meter are not calibrated correctly, or there is a leak or failed drift eliminator. As cycles of concentration increase, the amount of makeup needed and thus the amount of water used by a cooling tower decreases, but only to a point.

Cooling Tower Water Use

The amount of water a cooling tower uses depends on two factors:

- The amount of heat discharged to the tower
- The cycles of concentration

Heat is the driving force for evaporation. Table 1. summarizes the amount of evaporation that will occur per ton-hour of heat rejected. For most situations, the actual amount of heat rejected to the tower is known. In those cases, the process row in Table ww should be used. It shows that one ton-hour of rejected heat energy results in 1.48 gallons of evaporation.

Air conditioning chillers – chilled water systems – present an interesting challenge. The more efficient the chiller system is as a whole, the lower the total heat load to the tower will be and thus the lower the evaporation per ***ton-hour of actual heat removed in the refrigeration process.*** When a chilled-water cooling system – chiller – works, it pumps heat from the building out to the cooling tower. The energy used by all the equipment involved in the system also counts towards the amount of heat rejected to the tower. It takes energy to pump the water in both the chilled water and cooling tower loops, to operate the air handling units in the buildings, and of course, to operate the compressor. A compressor may be rated at 0.5 kilowatt-hours per ton-hour, but when all of the other pump and air handling unit energy is added, an additional 0.1 to 0.15 kWh of energy is typically needed per ton-hour. Table ww shows the impact of this "additional" energy on the amount of water evaporated per ton-hour of actual cooling achieved for comfort inside a building. The point is that the higher the energy efficiency of the system, the less water it needs. Compressor efficiency has improved significantly over the last few decades. Compressors with an efficiency rating of 0.5 kWh/ton-hour or less are available, but even with these very efficient systems, total loads per ton-hour of actual cooling will be in the 0.6 to 0.7 kWh/ton-hour range. Most total system energy efficiencies are currently under 1.0 kWh per ton hour even for less efficiency systems. Nonetheless, the amount of water evaporated per ton-hour of actual cooling in a building can range from 1.67 gallons per ton hour to 1.86 gallons per ton hour of ***TOTAL CHILLER SYSTEM OPERATION***.

Table 1. Impact of Air Conditioning System Efficiency on Water Evaporation

System Efficiency *(kWh / ton-hr.)**	**Energy Efficiency Ratio (EER)** *BTU's/ Watt-hr*	**Coefficient of Performance (COP)** *BTU's Removed/ BTU's Input*	**BTU's Rejected to Tower per / ton-hr**	**Gallons Evaporated per Ton Hour**
1.50	8	2.3	16,608	2.05
1.00	12	3.5	15,072	1.86
0.75	16	4.7	14,304	1.76
0.50	24	7.0	13,536	1.67
Process	N/A	N/A	12,000	1.48

One ton-hour = 12,000 BTU's per hour = 12.66 Million Joules per hour = 3.52 kWh of heat energy to the tower.

* kWh / Ton-hr. is often abbreviated to kW/Ton

The gallons evaporated per ton-hour of cooling times the hours of operation will equal the actual amount of water that will be evaporated. This will provide the "E" in Equation 10.

$$M = E + (M \div CC)$$

The next step in estimating water use for a cooling tower is to take the cycles of concentration. Figure aa shows the impact of increasing the cycles of concentration on the total makeup water needed per ton-hour of actual heat removal based on system efficiency. Figure 6. makes two major points. First, energy efficiency saves water. Second, after achieving six to ten cycles of concentration, additional water savings are minimal. Figure 7. shows this decreasing impact more dramatically. Going from 10 to 20 cycles of concentration only saves 0.10 gallons, while going two to five cycles of concentration saves 1.3 gallons of makeup water.

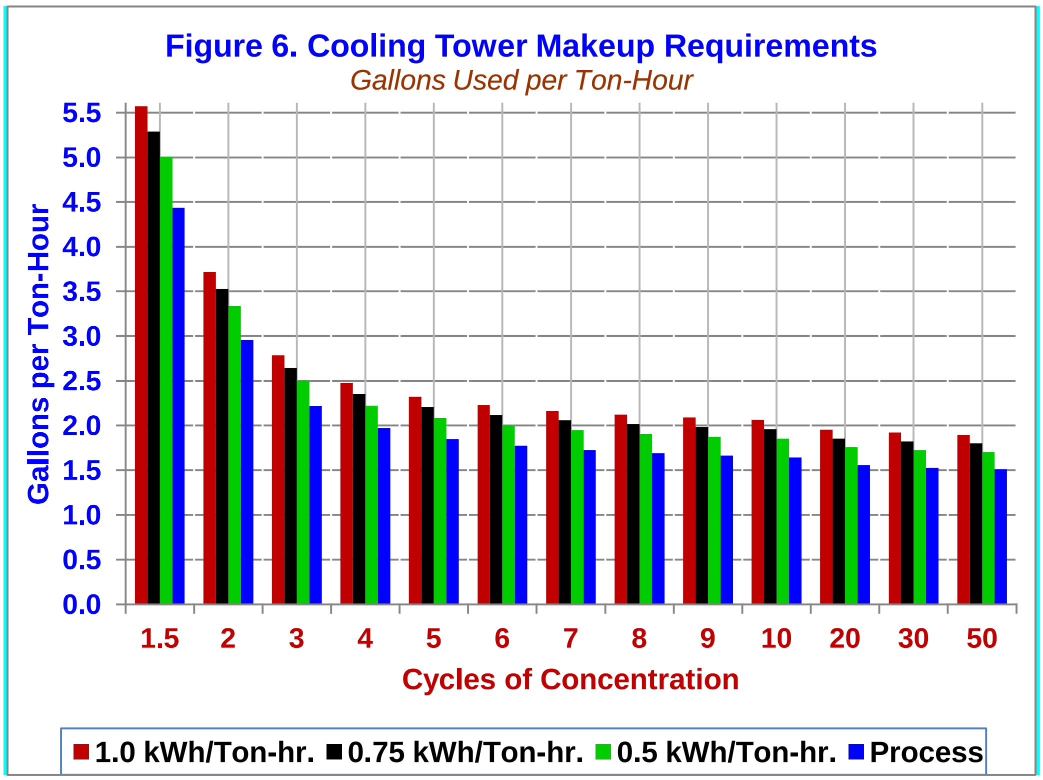


Figure 6. Cooling Tower Makeup Requirements

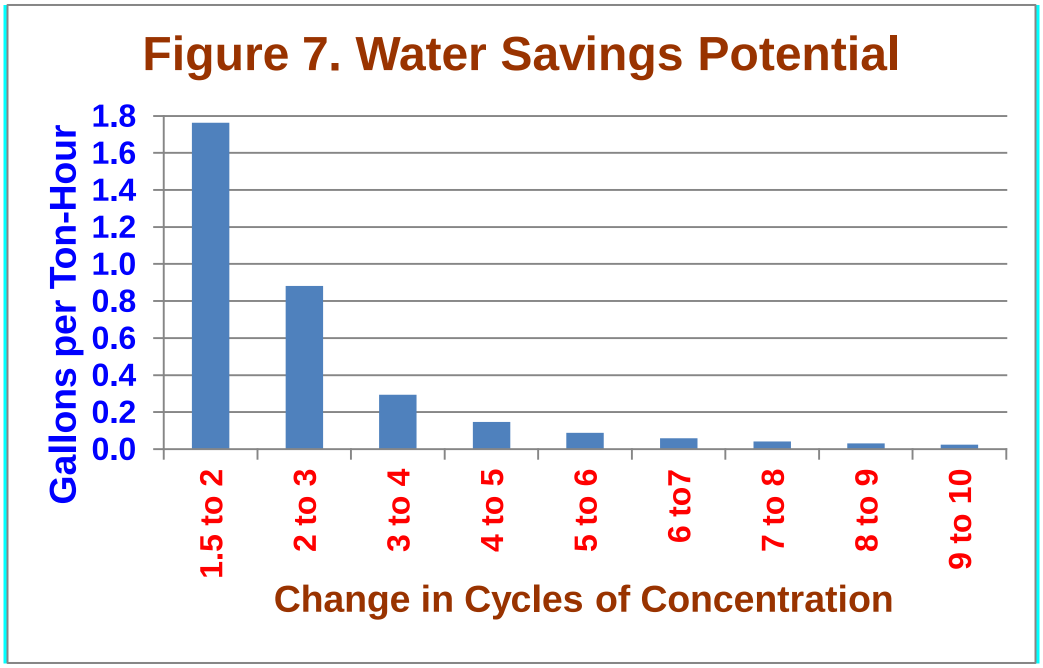


Figure 7. Water Savings Potential

Water Quality Considerations

Water quality considerations for the water circulating in the cooling tower are critical. Biological growth can foul the heat exchanger tubes and tower fill material; scaling compounds such as hardness or silica can precipitate out; and under the right conditions, the water can become corrosive to all metals in the tower. The materials that the tower and heat exchanger equipment are made from, the quality of the makeup water, and the type of treatment provided determine the tower's safe cycles of concentration. Calcium carbonate will begin to precipitate out above 750 to 850 mg/l, and silica can form a very hard scale on hot surfaces at concentrations as low as 120 mg/l. Towers also act as huge air scrubbers as they operate, capturing dirt in the air, insects, and other blown debris.

As the conductivity increases (salt concentrations increase), metals become more susceptible to corrosion. The type of material that the tower and exchanger are made of determine this susceptibility. Based on the author's many years of experience, most commercial operations operate towers at 3,500 microSiemens or less. The standards for pretreatment established by various authorities represent other considerations. These include total dissolved solids limits and limits for metals, such as cooper and zinc in the blowdown from the tower.

Over the years, many treatment methods have been developed to control these factors including:

1. Scaling - the buildup of calcium, magnesium, or silica deposits on tower surfaces and more importantly, the heat exchanger surfaces. These deposits restrict flowand significantly reduce thermal efficiency.
2. Corrosion - the oxidation of metals due to rusting and other forms of corrosion causes pitting, rusting, and determination of metal surfaces.
3. Biological fouling - the growth of algae and bacteria causes fouling of heat exchanger surfaces and of cooling tower fill and basin material. It also promotes corrosion and deterioration of tower surfaces.

Managing the water chemistry of cooling tower water is not simple. Corrosion and scaling can easily damage both the cooling tower and the condenser equipment if not properly controlled. The balance between water chemistry that corrodes metal and water chemistry that allows calcium carbonate and other minerals to deposit on metal surfaces is a delicate balance. Over the years, a number of indexes have been developed to help predict the corrosion/scaling balance points. These include the:

- Langelier Saturation Index
- Ryznar Stability Index
- Puckorius Scaling Index
- Larson-Skold Index
- Stiff-Davis Index
- Oddo-Tomson Index.
-

The type of treatment depends on the quality of the makeup water supplied to the tower and the desired cycles of concentration. The water can be treated (1) before it is fed to the cooling tower, (2) while the water is in the tower or piping system, or (3) by "side stream" systems that treat a portion of the circulating water in the tower.

1. The treatment of makeup water depends on the water chemistry and biology of the makeup water. The most common methods of treatment of makeup water before it is fed to the tower include:
   - Filtration where particulates are an issue
   - Biocides such as chlorine if biological growth is an issue
   - Softening if hardness is an issue
   - Chemical treatment to remove precipitants and silica where applicable
   - Demineralization such as nanofiltration or reverse osmosis where total dissolved solids are an issue.

   Treatment of makeup water before it enters the cooling tower can significantly simplify in-tower treatment and allow for the use of tower chemical and physical treatment devices that may not otherwise be effective.

2. Treatment of cooling tower water circulating in the tower depends on the type of problem to be addressed.

Scale Control: For scale-forming substances, the following types of treatment to reduce or prevent deposition are common:

- Deposition inhibitors that prevent scale by solubilizing it, preventing precipitation or modifying precipitates to prevent adhesion, and
- Dispersants that use polymers and large molecules that adsorb solids and keep them in suspension.

Examples of chemicals used include phosphonates to prevent scale formation, acids to increase solubility, chelents, and polymers. The use of acid should be carefully considered. Most commercial sites do not have the trained staff needed to handle these dangerous chemicals. Where used, pH controllers are recommended to control the addition of acid. Special storage must also be provided.

Corrosion Control: Corrosion is a major concern to metal components. For concrete basins, many of the same conditions that cause corrosion can also cause the concrete to deteriorate. Phosphate-based compounds (ortho-phosphate, polyphosphate, etc.) and similar chemicals are often used for steel surfaces. In the past, other metals ranging from chromates to zinc and molybdate compounds were used. Chromates were banned years ago and zinc and molybdenum compounds are now phased out since these can cause environmental contamination, and they can be toxic. For copper, azole compounds have been used.

Salinity and pH levels are also important. Some treatment techniques maintain pH levels in the range of 8.0 to 9.0 to help reduce corrosion. Conductivity controllers help by keeping salinity levels at acceptable levels for the tower’s materials of construction. Ceramic and plastic materials are often used because they do not corrode.

Biological Control: Bacteria can cause slime growth on heat exchange and cooling tower surfaces, promote certain types of corrosion, and cause significant chemical imbalances. Algae grow wherever sunlight is present and can cause similar problems. Cooling towers are also classic sources of pathogen growth, such as legionella. Common methods of biological control include chlorine and bromine compounds and ozone to control bacteria and algae in the water column. Even the use of shade to keep sunlight from entering the tower can help limit algae growth. Many new methods such as the use of ultraviolet light are now on the market.

3. Side-stream treatment of cooling tower water has been used for years and is effective for control of sediment, hardness, silica and other constituents that may impact water quality. Filtration, softening, chemical precipitation, and other methods are available on the market.

Choosing the optimal treatment process or combination of processes requires specific scientific knowledge. Entities with cooling towers are strongly encouraged to consult reputable cooling tower treatment experts.

Best Management Practices to Reduce Water Use for Cooling

Best management practices for cooling systems occurs as several levels:

1. Ways to reduce energy input to cooling system
2. Choice ***heat sink*** (water, air or ground based)
3. Use of alternate sources of water
4. Water Cooled Systems Best Management Practices.

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Reducing Energy Input

Simply put, the purpose of a cooling system is to *get rid of unwanted energy*. Any action that can reduce the amount of energy to be "gotten rid of" will reduce heat rejected to a cooling system. Where water is the cooling medium, these actions will reduce water use. There are three ways to reduce the load on a water-based cooling system.

- Energy conservation reduces the amount of waste heat generated and thus the cooling load regardless of the type of cooling system used. For example, for every ton-hour of energy savings for an air conditioning system using a cooling tower, 1.48 less gallons of water are evaporated and at five cycles of concentration, about 2.25 gallons of makeup water are saved. Recovery of energy for water or space heating, operation of a desiccant drying operation as part of a desiccant cooling system, and preheating of material in an industrial operation are all examples of this strategy.

- Replacing processes or equipment with systems that do not require water cooling is the most obvious and one of the best ways to eliminate water use and save energy.

Discussion of the technology and technical feasibility of energy efficiency measures and their cost is beyond the scope of this document.

Choice of Heat Sink

Waste or unwanted energy can be discharged to the air, ground, or water. It is common to use cooling systems that reject waste heat (unwanted energy) directly to the atmosphere or to the ground. Direct expansion (DX) air conditioning, technologically similar to home air conditioning, is the most common type of system used worldwide. The DX systems cost less than chilled water - cooling tower systems per ton, but they are limited in size and have lower energy efficiency. A commercial example of the use of DX systems would be for a large department store. Multiple units would most likely be mounted on the roof. Because there are multiple units, only the units needed to achieve comfort in the building would be operated, so the units that are operating would be working at their optimal operational level. If one unit needs repair, the other units can continue to operate. With large cooling tower systems, either expensive excess capacity must be installed or the facility must take the risk of being without adequate cooling if one chiller or tower must be taken out of service.

Ground source heat exchange, often call geothermal heat exchange, is a rapidly growing segment of the air conditioning and heat pump market. According to the US Energy Information Administration, sales tripled between 2004 and 2009. The ground can absorb significant amounts of thermal energy (hot or cold). In addition, summertime ground temperatures are always below daytime air temperatures. In California, average ground temperatures increase from below 60^{O}F in the north to the mid 70^{O}F range in the south. Ground source heat pumps are being used for a multitude of commercial operations ranging from schools to hospitals. These systems offer energy efficiencies similar to cooling towers in many cases, but they do not have the maintenance and liability issues associated with cooling towers. These systems can be operated in reverse in the winter for heating, thus eliminating the need for a dual cooling tower and boiler system. For office, school, and similar commercial operations, ground source heat exchange offers both convenience and energy savings combined with no evaporative water use.

In recent years, variable refrigerant volume systems have come on the market. These systems use a working fluid such as Freon in place of the chilled water loop. They can be air cooled, ground cooled or water cooled, and they offer larger capacity and more application in commercial settings. The whole system is more efficient than older DX systems but less efficient than systems with cooling towers. These systems can also be used with ground source heat exchange systems making their energy efficiency levels similar to that of cooling tower systems without the use of water.

World's Largest GHP System

U.S. Department of Energy (DOE)
Office of Geothermal Technologies

Geothermal Heat Pumps for Medium and Large Buildings

The Galt House East Hotel and Waterfront Office Buildings in Louisville, Kentucky, use a 4,700-ton GHP system to meet the heating and cooling needs of the complex. Completed in 1984, the 750,000-square-foot (70,000 m2) hotel uses a 1,700-ton GHP system that cost $1,500 per ton to install. In comparison, a conventional system would have cost between $2,000 and $3,000 per ton. As a bonus, the system saves about $25,000 per month in reduced energy costs and frees up about 25,000 square feet (2,323 m2) of additional commercial space that would have been needed to house conventional HVAC equipment. The Waterfront Office Buildings, built in 1994, add about 960,000 square feet (89,000 m2) of office space and almost 3,000 tons of GHP capacity to the project, making it the world's largest commercial GHP project. According to Marion Pinckley, Galt House designer and construction manager, "Galt House East has been running for 15 years with no system problems. The GHP system has performed even better than expected."

Water Cooled Systems Best Management Practices

If air-cooled or ground-cooled systems are not used, and cooling with water is the only option, it is important to choose the correct system. Water based cooling systems include:

- Single -pass cooling,
- Evaporative cooling
- Cooling towers.

Single-pass systems Best Management Practices

The Best Management Practice (BMP) for single-pass systems should be eliminated entirely. The only possible exceptions should be in the case of medical emergencies. These systems can be connected to a chilled water or cooling tower loop, or a standalone reticulating refrigeration system may be used. Recirculating refrigeration systems (Figure 8) are commonly found in laboratory and medical settings. They simply cool and recirculate water.

Figure 8. Recirculating Refrigeration System in a Chemistry Laboratory

These systems typically use 0.5 to 1.0 kWh per hour of energy. Water use, based on actual audit data for such uses, averages 1.0 to 3.0 gallons per minute or 60 to 180 gallons per hour. Based on combined water and sewer rates for the six largest cities in California for 2010, water costs an average of $7.77 per thousand gallons. Thus, the value of the water saved by installing a chiller system ranges from $.47 to $1.40, while cost of the electricity to operate the system equals only $.05 to $.15.

Evaporative Coolers Best Management Practices

The US Environmental Protection Agency's 2009 WaterSense Single-Family New Home Specification sets specific standards for evaporative coolers. WaterSense recommendations are as follows:

Evaporative cooling systems – Evaporative cooling systems shall:

1. Use a maximum of 3.5 gallons (13.3 liters) of water per ton-hour of cooling when adjusted to maximum water use;
2. Blowdown shall be based on time of operation, not to exceed three times in a 24-hour period of operating (every 8 hours);
3. Blowdown shall be mediated by conductivity or basin water temperature-based controllers;
4. Once-through or single-pass cooling systems, systems with continuous blowdown/bleedoff, and systems with timer-only mediated blowdown management shall not be used.

In addition to the WaterSense Best Management Practices, for large systems of more than 50,000 cubic feet of air per minute, it is recommended that the systems be equipped with the following:

- Makeup meter on water supply
- Overflow alarms for water level in the basin
- Automatic water and power shutoff systems for freezing.

Cooling Towers Best Management Practices

Operational considerations are the first consideration in the efficient operation of a tower. For towers larger than 500 tons, a continuous electrical record of operations should be available for downloading. If that record is not available, the operator should maintain a written shift log. A logbook also provides a written shift log. At a minimum, the shift log should contain:

- Details of make-up and blowdown quantities, conductivity, and cycles of concentration;
- Chiller water and cooling tower water inlet and outlet temperatures;
- A checklist of basin levels, valve leaks, and appearance;
- A description of potential problems.

Above all, ensure that the employee responsible for the cooling tower operations, is knowledgeable of what to look for when examining records and what to look for when visually examining the cooling tower.

Choose a Water Treatment Vendor that will work with your facility.

- Select a water treatment vendor that focuses on water efficiency. Request an estimate of the quantities and costs of treatment chemicals, volumes of make-up and blowdown water expected per year, and the expected cycles of concentration that the vendor plans to achieve. Specify operational parameters such as cycles of concentration (CC) in the contract. Increasing cycles from three to six reduces cooling tower make-up water by 20 percent and cooling tower blowdown by 50 percent.

- Work with the water treatment vendor to ensure that clear and understandable reports are transmitted to management in a timely manner. Critical water chemistry parameters that require review and control include pH, alkalinity, conductivity, hardness, microbial growth, biocide, and corrosion inhibitor levels.

Design and Retrofit Best Management Practices include proper instrumentation and tower design and operation.

- Install a conductivity controller that can continuously measure the conductivity of the cooling tower water and will initiate blowdown only when the conductivity set point is exceeded. Working with the water treatment vendor, determine the maximum cycles of concentration that the cooling tower can sustain, then identify and program the conductivity controller to the associated conductivity set point, typically measured in microSiemens per centimeter (µS/cm) necessary to achieve that number of cycles. Conductivity controller systems cost from $3,500 to $100,000 depending on the nature of the facility in which it is installed. Possible savings possible depend on the increase in cycles of concentration.

- Install flow meters on make-up and blowdown lines. On most cooling towers, meters can be installed at a cost of between $1,000 and $50,000.[1] Manually read meters can be used for smaller towers, but if the tower is 500 tons or more, meter readings should be automated and be connected to an electronic data management system.

- Install automated chemical feed systems on large cooling tower systems of 100 tons or more. The automated feed will monitor conductivity, control blowdown, and add chemicals based on make-up water flow. These systems minimize water and chemical use while protecting against scale, corrosion, and biological growth.

- Install overflow alarms on cooling tower overflow lines, and connect the overflow alarm to the central location so that an operator can determine if overflows are occurring. This alarm can be as simple as a flashing light in the control area. More sophisticated systems may include a computer alert.

- Consider contacting the water utility to determine if the facility can receive a sanitary sewer charge deduction from the potable water lost to evaporation. If the utility agrees to provide this deduction, calculate the difference between the city-supplied potable water make-up and the blowdown water that is discharged to the sanitary sewer.

Alternate Sources of Water

The use of alternate sources of water, especially for cooling towers and cooling reservoirs, is one of the most effective ways to reduce the use of potable water in commercial, institutional and industrial (CII) operations. The sections on Recycled Water and on Alternate On-Site Sources of Water describe how these freshwater sources can be used in place of potable water. In all cases, it must be remembered that these freshwater sources should also be used efficiently.

Air conditioning condensate is of specific interest since it is produced as part of the air conditioning process.

Boilers

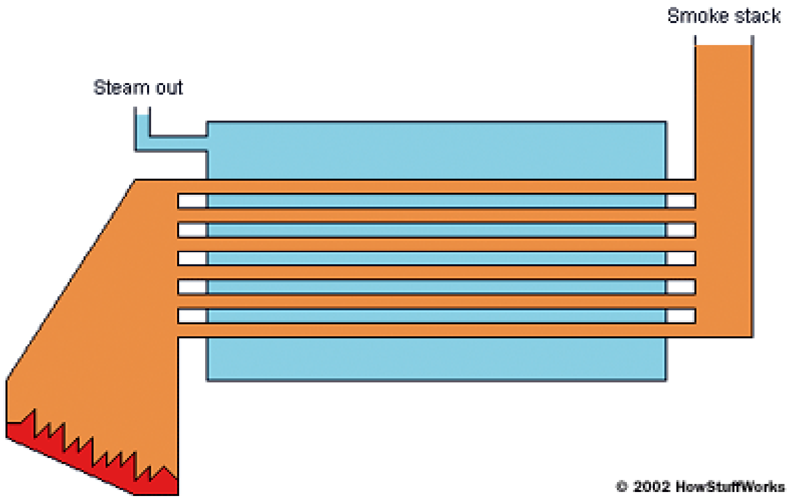
Introduction

The term boiler can mean several things in the CII setting. Large water heating systems that do not "boil" water but simply heat it are often called boilers even though no steam is produced. These are not the focus of this discussion. The focus of this section is steam-producing boilers.

For hot water "boilers," energy and water conservation for equipment, appliances, and fixtures that use hot water is the first major component to reducing hot water use. Most hot water boilers in use are of the fire tube configuration. The simplest example is the gas- or oil- type home water heater with the fire tube (smoke stack) running through the middle of it. The heat generated by burning the fuel is transferred through the tube directly into the water. Fixing leaks and reducing other losses is the second most important factor. With the exception of the use of hot water for space heating and equipment heat transfer, most hot water is consumptively used and not returned to the boiler. Where a recirculating loop is used for space or equipment heating, it is also important to place a meter on the makeup line to determine if that line is leaking.

Steam boilers are used in large building heating systems for cooking, operating steam turbine, or heating industrial operations. There are two main configurations for boilers. Water tube boilers are found in very large operations such as power plants. In these facilities, the water is contained in tubes that line a combustion chamber where gas, oil, or coal are burned. The second and most common type is the fire tube boiler. Water surrounds a bundle of tubes. The heat from the fuel's combustion passes through the tubes and turns the surrounding water to steam (see Figure 9).[133] Waste heat boilers are most often of the fire tube type in smaller operations. The basic water conservation considerations for these two types of boilers are the same.

[133] New Mexico Office of the State Engineer. July 1999. *A Water Conservation Guide for Commercial, Institutional and Industrial Users*. Page 68.



Boiler Water Use

To understand how to maximize water efficiency for a steam boiler, it is first necessary to understand how water is used in a typical boiler operation. Eight separate water uses and losses are typically associated with a steam boiler. These include:

1. Makeup water to deaerator - fresh water makeup to boilers is heated in a "deaerator" to remove air that can cause corrosion prior to feed to boiler.

2. Condensate return to deaerator or boiler - Condensed steam that is returned to the boiler.

3. Condensate loss - Condensed steam that is not returned to the boiler

4. Steam loss - Steam that is lost through leaks and other avoidable losses

5. Boiler water blowdown - Water from just below the top of the water level in the boiler that is discharged to control the buildup of dissolved minerals in the boiler.

6. Flash tank cooling water - When the boiler water is discharged, it must be cooled to under 140^{o}F before it can be sent to a sanitary sewer. Once-through cooling is often used for this purpose.

7. Sampler cooling water - The boiler blowdown must be cooled so it will not damage the conductivity controller probes. Single-pass cooling is often used for this.

8. Mud blowdown - Sediments that collect at the bottom of the boiler need to be periodically purged by opening a valve at the bottom of the boiler. The frequency of this operation depends on the rate at which these sediments collect.

The water balance for the actual boiler can be written as a simple mass balance:

<u>Equation 1.</u>

$$M = BD + CL + L$$

Where:
M = Freshwater Makeup

BD = Blowdown
CL = Condensate Loss
L= All other losses

Equation 1 does not address the water used to cool blowdown or to cool the sampler. These factors must be considered separately. As with cooling towers, the ratio of the minerals in the makeup water to the boiler water is used to determine the cycles of concentration (CC).

It can be expressed as:

Equation 2.

Cycles of Concentration (CC) = Total Dissolved Solids (TDS) in Blowdown ÷ TDS in Makeup Water

CC=TDS (*blowdown water)* ÷ TDS (*makeup water)*

Where conductivity is used in place of TDS, as it is for all cooling tower controllers, the following equivalent equation should provide the same results.

Equation 3.

Conductivity can be used as an approximate substitute

CC=µS (*blowdown water)* ÷ µS (*makeup water)*

If leaks, and other losses are negligible, Equation 1 can be rearranged to provide an estimate of cycles of concentration:

Equation 4.

M = BD + CL

In most cases, some condensate loss is inevitable. This loss is typically expressed as a percent of actual makeup to the boiler that is supplied by steam condensate. The calculation of the impact of this requires that the pounds of steam produced be known. The facility may wish to consult an engineer to help with these calculations. In many cases, condensate loss is known. In those situations, the cycles of concentration provide the percent of blowdown.

Best Management Practices for Boilers

This discussion of best management practices (BMPs) for boilers contains two sections. The first is a discussion of reducing water use by controlling cycles of concentration, condensate return, and energy efficiency. The second involves a discussion of water efficiency with blowdown and sampler cooling tempering water.

Energy efficiency is the first BMP for consideration. Steam is used to provide energy. Any reduction in energy use will result in reduced steam use and thus reduced water use.

Steam management is an area where significant reductions in both energy and water use can be observed. BMPs in this area include:

- Maximizing condensate return
- Steam trap maintenance
- Proper insulation of pipes

From a water-efficiency standpoint, installing and maintaining a condensate recovery system to capture and return condensate to the boiler for reuse is the most effective way to reduce water use. Recovering condensate:

- Reduces the amount of make-up water required.
- Eliminates or significantly reduces the need to add tempering water to cool condensate before discharge.
- Reduces the frequency of blowdown, as the condensate is highly pure and adds little to no additional TDS to the boiler water.

In addition, since the steam condensate is relatively hot when it is added back to the boiler, it requires less energy to re-heat to produce steam again.

Metering, Measurement, and Control are critical to good boiler operations and to minimizing water use. The following are BMPs recommended for boilers:

- Install an automatic blowdown control system, particularly on boilers greater than 200 horsepower, to control the amount and frequency of blowdown rather than relying on continuous blow down.[134] Control systems with a conductivity controller will initiate blowdown only when the TDS concentrations in the boiler have built up to a certain concentration.

- Install a flow meter on make-up water line to monitor the amount of make-up water added to the boiler. Refer to the Operation, Maintenance, and User Education section of this BMP for recommendations on how to use the meter once it is installed.

- Install condensate return meters for all boilers of 200 horsepower or more.

- Install automated chemical feed systems to monitor conductivity, control blowdown, and add chemicals based on make-up water flow. These systems minimize water and chemical use while protecting against scale and corrosion.

[134] East Bay Municipal Utility District. 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses.* <www.allianceforwaterefficiency.org/uploadedFiles/Resource_Center/Library/non_residential/EBMUD/EBMUD_WaterSmart_Guide_Photo_Film_Processing.pdf>.

Significant water savings can result from improving the boiler system management scheme. A key mechanism to reducing water use is to maximize the cycles of concentration. Installing an automatic blowdown control system is one way to minimize blowdown and maximize cycles of concentration.

Switching to an automatic control system can reduce a boiler's energy use by 2 to 5 percent and reduce blowdown by as much as 20 percent. A system can cost between $2,500 and $100,000. In some facilities, the water and energy savings can provide payback within one to three years.

Proper control of boiler blowdown water is also critical to ensure efficient boiler operation and minimize make-up water use. Insufficient blowdown can lead to scaling and corrosion, while excessive blowdown wastes water, energy, and chemicals. The optimum blowdown rate is influenced by several factors, including boiler type, operating pressure, water treatment, and quality of make-up water. Generally, blowdown rates range from 4 to 8 percent of the make-up water flow rate, although they can be as high as 10 percent if the make-up water is of poor quality with high concentrations of solids.[135]

Operation, Maintenance, and User Education - To improve water efficiency of boiler and steam systems, consider the following:

Choose a Water Treatment Vendor

- Select a water treatment vendor that that focuses on water efficiency. Request an estimate of the quantities and costs of treatment chemicals and the volumes of make-up and blowdown water expected per year. Choose a vendor that can minimize water use, chemical use, and cost while maintaining appropriate water chemistry for efficient scale and corrosion control.

Read Water Chemistry Reports

Ensure the water treatment vendor produces a report every time he or she evaluates the water chemistry in the boiler. Upon receiving these reports, read them to ensure that monitoring characteristics such as conductivity and cycles of concentration are within the target range. Problems within the system can be identified quickly if proper attention is paid to the water chemistry reports.

Maintain Boilers, Steam Lines, and Steam Traps

- Regularly check steam lines for leaks and make repairs promptly.
- Regularly clean and inspect boiler water and fire tubes.
- Develop and implement an annual boiler tune-up program.

[135] U.S. Environmental Protection Agency and the U.S. Department of Energy, Energy Efficiency and Renewable Energy, Federal Energy Management Program. June 2001. Energy Tips—Steam. <www1.eere.energy.gov/industry/bestpractices/pdfs/steam9_blowdown.pdf> and <www1.eere.energy.gov/industry/bestpractices/pdfs/steam8_boiler.pdf>.

- Provide proper insulation on piping and the central storage tank to conserve heat.
- Implement a steam trap inspection program for boiler systems with condensate recovery.

When steam traps exceed condensate temperature, this program can indicate that the trap is leaking. Temperature can be monitored using an infrared temperature device. [136] Repair leaking traps as soon as possible.

Minimize Blowdown

- Calculate and understand the boiler's cycles of concentration. Check the ratio of conductivity of blow down water and the make-up water. (Use a handheld conductivity meter if the boiler is not equipped with permanent meters.) This ratio should match the target cycles of concentration.
- Work with the water treatment vendor to prevent scaling and corrosion and to optimize cycles of concentration.

Improve Make-Up Water Quality

- Consider pre-treating boiler make-up water to remove impurities, which can increase the cycles of concentration the boiler can achieve. Water softeners, reverse osmosis systems, or demineralization are potential pre-treatment technology options.

The American Boiler Manufacturers Association (ABMA) publishes maximum recommended concentration limits for makeup water for boilers (Table 2).

Table 2. Recommended Maximum Concentration of Constituents in Boiler Feed Water

Boiler Operating Pressure (psig)	Total Dissolved Solids (ppm)	Total Alkalinity (ppm)	Total Suspended Solids (ppm)
0 - 50	2,500	500	N/A
51 - 300	3,500	700	15
301 - 450	3,000	600	10
451 - 600	2,500	500	8
601 - 750	1,000	200	3
751 - 900	750	150	2
901 – 1,000	625	125	1

[136] North Carolina Department of Environment and Natural Resources. May 2009. *Water Efficiency Manual for Commercial, Industrial and Institutional Facilities*. Pages 49-52. <www.p2pays.org/ref/01/00692.pdf>.

Boiler water must be treated before use for all but the very low-pressure-type boilers. Table 3. summarizes recommend boiler water concentrations from the American Boiler Manufacturers Association (ABMA).

Table 3. ABMA Standard Boiler Water Concentrations for Minimizing Carryover

Drum Pressure (psig)	Boiler Water		
	Total Silica* (ppm SiO2)	Specific** Alkalinity (ppm CaCO3)	Conductance (micromhos/cm)
0-300	150	700	7000
301-450	90	600	6000
451-600	40	500	5000
601-750	30	400	4000
751-900	20	300	3000
901-1000	8	200	2000
1001-1500	2	0	150
1501-2000	1	0	100

Refer to the *Water Purification BMP* for more information.

Tempering of Sampler and Blowdown Water

Conductivity Probe Cooling Water - To properly control blowdown, measure the conductivity of the water in the boiler with a conductivity probe, bearing in mind that the boiler water is very hot and can damage the probe. Use a sampler cooler to cool the water to a temperature that is suitable for the probe. These simple devices simply pass water through a heat exchanger that takes a small side stream of boiler water from the boiler either on a continuous or intermittent basis (Figure 10).

Figure 10. Boiler Water Sampler Device

Most samplers are simple single-pass cooling systems. Flow rated in the literature ranges from1.0 to 2.5 gallons per minute. This water should be captured and used as boiler feed water, which may require constructing a collection tank to hold the cooling water until the system needs to send makeup water to the deaerator tank.

Blowdown Tempering Water is water used to cool the water discharged from the boiler to control dissolved solids buildup. For smaller boilers, it is the author's experience that large holding tanks that allow the blowdown to cool to below 140^{o}F may be used. For larger systems, heat recovery systems are commercially available that capture the heat and thus eliminate the single pass cooling entirely.

Both sampler and blowdown heat recovery systems save water and energy. The following example is from the US Department of Energy's Energy Efficiency and Energy Renewable publication entitled

Recovery Heat from Boiler Blowdown - www.eere.energy.gov.

Example: In a plant where the fuel cost is $8.00 per million Btu ($8.00/MMBtu), a continuous blowdown rate of 3,200 pounds per hour (lb/hr) is maintained to avoid the buildup of high concentrations of dissolved solids. What are the annual savings if a makeup water heat exchanger is installed that recovers 90% of the blowdown energy losses? The 80% efficient boiler produces 50,000 pounds per hour (lb/hr) of 150-pounds per-square-inch-gauge (psig) steam. It operates for 8,000 hours per year. The blowdown ratio is: Blowdown Ratio = 3,200 = 6.0% 3,200 + 50,000 From the table, the heat recoverable corresponding to a 6% blowdown ratio with a 150-psig boiler operating pressure is 1.7 MMBtu/hr. Since the table is based on a steam production rate of 100,000 lb/hr, the annual savings for this plant are:

Annual Energy Savings = [1.7 MMBtu/hr x (50,000 lb/hr/100,000 lb/hr) x 8,000 hr/yr]/0.80 =

8,500 MMBtu Annual Cost Savings = 8,500 MMBtu/yr x $8.00/MMBtu = $68,000.

Table 4. Recoverable Heat from Boiler Blowdown

Blowdown Rate % Boiler Feed water	Steam Pressure, PSIG				
	50	100	150	250	300
2	0.45	0.5	0.55	0.65	0.65
4	0.90	1.0	1.1	1.3	1.3
6	1.3	1.5	1.7	1.9	2.0
8	1.7	2.0	2.2	2.6	2.7
10	2.2	2.5	2.8	3.2	3.3
20	4.4	5.0	5.6	6.4	6.6

Source: Recovery Heat from Boiler Blowdown - www.eere.energy.gov

Based on a steam production rate of 100,000 pounds per hour, 60^{o}F makeup water & 90% heat recovery.

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7C4: Cleaning Industrial Vessels, Pipes and Equipment

Proper cleaning and sanitation represent a critical practice for such industries as food processors and pharmaceutical and cosmetics manufacturers. For food and pharmaceutical facilities, the U.S. Food and Drug Administration, U.S. Department of Agriculture, and State and local health agencies all have regulations overseeing these processes.

Cleaning and sanitizing is one of the more human-interactive operations within a facility. The use of hoses and spray equipment, physical removal of waste materials, timing of cleaning cycles, and the way in which cleaning equipment is used are all controlled by the employees responsible for the operation. Any modification of these cleaning and sanitizing procedures requires that employees are part of the improvements. They must be trained, be aware of the need to reduce water use, and most importantly, be allowed to participate in the accomplishments. Some cleaning techniques, such as hand cleaning, the use of spray hoses, 'manual scrub and wash down,' and 'fill and flush' are effective, but they can use excessive amounts of water. This section examines ways to design facilities for ease of cleaning while reducing water use in the process.

Cleaning in these industries can be divided into several different areas:

- **Clean in place** (cleaning of pipes, tanks, processing vessels and transport tanks and trucks without taking them apart.)
- **Clean out of place** (removing and cleaning and sanitizing parts)
- **Can/bottle/package cleaning**
- **Crate and pallet washing**
- **Equipment and Floor Cleaning**

Clean in place:

Process Description **-** Clean in place (CIP) systems use water, chemicals, and recirculation systems to clean pipes and vessels. Factors that determine the cleaning effectiveness include circulation time, temperature, degree of agitation or spray action, and the formulation of cleaning solutions. Modern, efficient CIP systems typically include multiple tank including chemical solutions tanks, and rinse water and water recycle vessels. Single- and two-tank systems are not considered to be as water efficient as multiple tank systems and are therefore not recommended as a BMP. The versatility and ability for water and chemical solution recovery of multi-tank systems (three or more tanks), mean that these multi-tank CIP system are now considered the norm for most efficient facilities.

An example would be a five thank system in a brewery. It would include a caustic/surfactant tank, a phosphoric acid tank, caustic and acid wash recovery tanks, and a rinse water tank. Filtration and even membrane processes can be used to clean washing fluids for reuse.

Multi-tank CIP systems are available on the market. Costs depend on the size of the equipment needed, the nature of the substances to be cleaned, and the type of vessels and pipes to be cleaned. Costs range from $20,000 to over $1,000,000 depending on the application. Literature indicates that water use reductions of 30 percent to 50 percent are possible.

Best Management Practices for CIP Systems **-** One of the most common cleaning and sanitizing operations is the cleaning of pipes, tanks, mixing vessels, cooking vessels and other equipment that is permanently installed. Three factors that promote water efficiency are:

1. Good design,
2. Product recovery, and
3. Efficient cleaning methods.

Good design in the layout of the process, type of materials used and construction will make "clean in place" operations more efficient. These include:

- Ensuring that piping systems do not have sharp curves, joints, bolts and protrusions, and areas where materials being processed can accumulate. Butt and flange welding, ball valves, and long radius elbows are examples of good piping systems. Tanks and vessels should also be easy to clean.
- Eliminating "low places" in systems where material can accumulate.
- Using only easy-to-clean materials.
- Providing good access to all areas of equipment so it can be inspected and hand cleaned where necessary.
- Automating cleaning procedures to ensure constant operation.

Product recovery for clean in place systems refers to methods of recovering product from vessels, pipes, and tanks so that sellable product is recovered and the amount of material that must be cleaned is reduced. In food processing, options for product recovery include recovering edible product, recovering product for animal feed, and recovering product for other uses. All of these have the impact of reduce the amount of water needed to clean and sanitize and reduce wastewater loading. Cost considerations for clean in place include cost of product lost, cost of water, solvent, chemicals, energy used, and waste disposal. In chemical and cosmetics plants, solvent use can also lead to air quality issues.

Methods to increase product recovery from large **vessels including transport trucks and tank cars** include:

- Allowing adequate drain time. Using a small amount of water or solvent to quickly spray the vessel encouraging better drainage of product adhering to the vessel. If the amount is small enough, the product recovered can often be incorporated into the final product.
- In the chemical industry and similar non-food industries, solvent used for washing can be recovered and product separated. Where the solvent is used to carry the product, the tank purge solvent can be used for the next batch of product.

For **pipe systems**, recovering product includes:

- Using air to blow product out.
- Slug or pulse rinsing where a small initial slug or pulse of water will carry a significant concentration of recoverable product.
- Pigging, which is the process of running a device, usually a soft rubber plug, through the piping to push and squeegee the product out. Pigging requires the installation of a "launch and recovery" system that allows the rubber device to be inserted at the front end and caught and recovered at the back end. The cost of these devices depends on the size of the pipe, the type of pig, and system design characteristics. The installed cost for such devices starts at under $20,000 but can go much higher for large diameter pipes. The product is pushed out of the pipe and can be recovered. Ice pigging is the process of using flake ice to push the material ahead of it through the piping system. It has gained favor in some situations since the ice only needs a launcher and can be incorporated in the product since only small amounts of ice are needed. The pig is most often pushed with water, air or the next product to be processed. An example of a pig pushed by a product is the switch from white to chocolate milk, the pig can help separate the products in the pipe without having to waste any product. Pigging systems – launcher, sensor, and retrieve and return systems – can be purchased for $20,000 and higher. Installation costs depend on the specific layout of the plant where installed. Water savings achieved by pigging system depend on the type of material being processed. Thick or semi-solid products, such as sour cream, are hard to rinse from pipes, so they can contaminate large volume of water. Pigging both recovers marketable material and reduces the amount of water needed to flush the product out.

Efficient cleaning methods for clean in place systems are somewhat different for pipe systems and tank and vessel systems.

For **vessels and tanks**, the first step to efficient cleaning starts with good process control and design. Optical devices determine when rinse water is clear. Level controls and other methods ensure efficient operation. Clean in place technology includes the use of manual spray hoses including water jetting, or high-pressure sprays for hand cleaning of vessels such as tanks. These methods tend to be labor intensive, they often require entry into confined spaces, and they may consume large amounts of water, energy and chemicals. Automated clean in place systems offer many advantages.

Clean in place systems for tanks and vessels typically employ spray ball technology. These devices range from simple balls with holes in them to high-pressure devices with multiple high-pressure nozzles that actuate turning devices that spray in multiple directions. The more pressure and directed force the ball has, the more efficiently it can clean. Some systems use booster pumps to increase pressure. Selection of the type of system to use depends on many factors, and many models are available. These systems are also useful for cleaning beer and wine casks, barrels, and vessels.

For **pipe systems**, cleaning and rinsing fluids are pumped through the pipes. Turbulence, time, temperature, and chemical cleaning agents are the factors that determine the time required to clean pipe systems.

For both vessel and pipe cleaning, the clean in place system (CIP) uses a combination of several steps to clean and sanitize pipes, tanks, and other vessels. The design of these systems and the sequence of cleaning determine their water, chemical, and energy use. Most CIP systems clean with a four step process: (1) first flush, (2) chemical cleaning, (3) sanitizing, and (4) intermediate and final rinses. In the parlance of the industry, CIP systems include wash and dump systems, which are the most wasteful kind, and single and multi-tank systems, which allow for better control, water recycling, and other advantages.

- The first flush is designed to flush out remaining product from the pipe or tank. As the name implies, it is a way of "getting rid of" good product. The amount and intensity of this process is directly related to the amount of product left in the pipe or vessel and the characteristics of the product being flush out. That is why product recovery is important to water efficiency.
- Chemical cleaning formulations vary with the type of product being processed. Beer stone, milk stone (solid residues left behind in beer and milk processing), and food solids are examples of materials to be removed. Cleaning formulations include alkaline and acidic detergent washes.
- Sanitizing involves either hot water or sanitizing chemicals. Peroxides, chlorine and bromine compounds, ozone, quaternary ammonia compounds, peroxyacetic acid, iodine compounds, and anionic acids have all been used.
- Intermediate and final rinses are used to remove chemical and sanitizing agents.

Clean in place equipment can have several configurations. Old wash and dump systems have given way to multi-tank systems that carefully control water use, capture and reuse water, and treat and filter water to be recirculated within the cycle. Membranes and other treatments may be used to maximize recycling of water. The recycling of filtered detergent water is common. Multi-tank operations also save energy and allow for maximum recycling.

In some systems, ozone is used as a sanitizer. It is powerful, and it does not leave a residue, so rinse cycles may be eliminated, thus saving water and reducing wastewater strength. Table 1.shows how ozone can reduce rinse steps in CIP operations.

With all of these systems, modern control technology and real-time analytical equipment help control temperature and determine optimal detergent and chemical concentrations, as well as the amount of waste products in rinse water, all of which contribute to both energy and water efficiency.

Table 1 Example of a CIP Cycle Using Ozone

Typical 5-Step CIP Process

1) Ambient temperature water rinse: removal of water-soluble residues
2) Alkaline wash: removal of water-resistant residues
3) Ambient-temperature or hot water and intermittent draining: removal of the bulk of the alkaline cleaning agent
4) Peracetic Acid wash: neutralization of residual alkaline cleaning agent, de-mineralizes the surfaces of process equipment, and provides some corrosion control by neutralizing the caustic cleaning fluids.
5) Final rinse and sanitization: hot water passed once through the circuit in bursts with intermittent drains, removing the acid cleaning agent and all other residues passivation. Final air blowing and draining

Three-Step Ozone CIP Process

1) Ambient temperature water rinses water-soluble residues from process equipment and interconnecting piping
2) Alkaline wash: removal of water-resistant residues
3) Ozone sanitization, rinse and flush. Final air blowing and draining

Source: Web: www.mksinst.com

Clean out of Place Systems:

Process Description - As the name implies, "Clean out of Place (COP)" equipment is taken apart and washed. The simplest systems consist of vats that parts are placed in for hand cleaning. Modern equipment includes tunnel, cabinet, and emersion tank mechanical recirculation systems as well as ultrasonic cleaning can also be used.

Best Management Practices for COP Systems **-** As with CIP, It is important to test the water regularly so it is not discharged until its useful life is over. It is also important to minimize the vat size. Employee training and awareness helps workers pay attention small details. The pharmaceutical industry commonly uses automated systems with verification-of-cleaning software. These systems may be applicable in other industries as well. Sanitizing baths – clean water with sanitizer – are often used to "soak" parts. Again, analyzing the water is important so sanitizer strength can be maintained instead of dumping. Sanitizer water can also be reused as first flush rinse water or even as wash water for the parts to be cleaned or for floor and area washing.

For both CIP and COP systems, the use of whitewater or ozone for cleaning and sanitizing offers opportunities to reduce the amount of rinse water needed in cleaning operations ranging from CIP, COP, and other equipment cleaning and sanitation. Since hot water use can often be reduced, hot water energy use may be reduced, but energy is also needed to produce ozone. Ozone applications require a benefit/cost analysis to determine their economic applicability on a case-by-case basis.

Bottle/Can/Container Cleaning

Process Description - Bottle washers have two basic configurations: soaker washers and hydro-spray-washers. Steps in bottle washing include:

- Pre-rinse
- Label removal

- Caustic wash
- Rinse

Water use depends on such variables as the type of bottle being washed and the organic matter in the bottle. Water efficiency efforts have centered on caustic water recovery, recycling of final rinse water for caustic makeup, and reuse of water for the pre-rinse and label removal stages.

Best Management Practices - For bottle washing systems, the water used for first flushing is often recovered and reused. Membrane technology has also been used in some instances to recover water and chemicals used in the bottle washing process. The use of disposable bottles and cans has eliminated the dominance that returnable bottles used to have in the market. (www.faculty.ait.ac.th/visu/data/AIT.../Anna%20pdf%2096.pdf)

Even new bottles and cans can contain foreign debris, however. Air blowing saves water while ensuring that particles are removed before the bottles are filled.

Crate and Pallet Washers:

Process Description - Crates and pallets are integral parts of the food processing industry. Although they do not come into direct contact with the food, they need to be cleaned and kept free of debris so they do not soil the food containers. Crate washers and pallet washers should be designed to recirculate water within the individual wash phases and to capture and reuse final rinse water for wash water use. Crate and pallet washers have much in common with commercial dishwashers and laboratory cage washers. While both tunnel and cabinet washers are in use, tunnel washers are more common in larger operations.

Best Management Practices Tunnel washers offer both water and energy saving potential. High-volume efficient models use five stages of cleaning. The pallets or crates enter through a pre-rinse stage. Water used for this phase may be recycled from the detergent wash stage overflow. The next stage is the detergent wash. Water efficient machines recirculate the hot detergent water through strainer and filter systems at high volumes. Internal water flow rates of over 100 gallons per minute are common. The pallets or crates then move to a rinse stage. Some efficient models have a two-stage rinse process in which the final rinse is done with clean water that is then captured and used in a first rinse stage. Following the first rinse, that water may then reused as makeup for the detergent wash.

Water efficiency standards for crate and pallet washers have not been established. The company purchasing this equipment should compare equipment. These systems use significant volumes of water, energy, and detergent. The same considerations apply to tub, tote (wheeled container), and basket washers. Baskets allow liquids to drain while tubs and totes are designed to contain liquids.

Tunnel washers costs are in the $100,000-plus range.

Equipment and Floor Cleaning:

Process Description - A variety of situations require manual cleaning with spray hoses, pressurized spray rigs, cleaning brushes, cloths, and squeegees.

Best Management Practices - Areas that cannot be cleaned by a clean in place (CIP) or clean out of place (COP) system, require manual cleaning, which can be one of the most labor and time intensive operations in a facility. Good layout and design of such areas as floors, exteriors of tanks and pipes, conveyor systems, and flumes are key to having facilities that are easy to clean.

Four principles should be incorporated into the design and layout of floors and walls:

- Proper sealing of floors and walls so that soil is easily removed and water does not penetrate.
- Sloping floors to floor drains so water can be removed easily.
- Minimizing floor joints and joints between floor and walls.
- Designing easily cleanable, well sealed troughs and grates.

Floor drains are a necessary component of this process, but once the waste enters the drain, it costs money. Physical removal of waste product before washing saves water, chemicals, energy, and reduces pollution loading and pre-treatment costs. Floors should be dry cleaned with vacuum systems, brooms, or squeegees depending on the type of material being removed.

Equipment design and layout are also critical for good cleaning. As with CIP and COP systems, crevices, sharp turns, and "nooks and crannies" where dirt and materials can accumulate should be avoided. For example, it helps to use welded tubes instead of bolted together angle iron supports, tanks and equipment with smooth easily accessible surfaces, and to leave room between equipment for ease of cleaning.

For mixers, extrusion and molding equipment, conveyor belts, and other open equipment to which one can gain direct access, cleaning should start with physical removal of residual materials and then be followed by wet washing.

Where water is used for cleaning, it is important to employ the “multiple aliquots” concept, in which it is better to use a number of smaller volumes of water to clean than one very large volume. Four principles of wet cleaning are:

- Use high-pressure, low-volume sprays.
- Install shutoffs on all cleaning equipment.
- Use detergents and sanitizing chemicals that are easily removed with minimum water.
- Install and locate drains and sumps so water and wastes enter quickly to prevent the need for extensive use of a hose as a broom to move the waste to the drain.

7C5: Commercial Landscape

BACKGROUND

Introduction

This section addresses and makes recommendations for landscape Best Management Practices (BMPs) for commercial, industrial, and institutional (CII) water users. Many of the landscape BMP recommendations contained in this section come from the Model Water Efficient Landscape Ordinance (MWELO) found in the California Code of Regulations, Title 23, Division 2, Chapter 2.7, which became effective in January 2010. The MWELO document applies primarily to new and rehabilitated landscapes of 2,500 square feet or more. It is important to note that the landscape standards contained in MWELO were developed through input and full vetting of the issues from a broad base of stakeholders including public interest groups, water providers, and the landscape industry. For that reason, many of the standards or BMPs contained in the MWELO form the basis for the recommended BMPs contained in this report. Since the MWELO standards do not apply to existing landscapes or to rehabilitated landscapes of less than 2,500 square feet, the BMPs recommended in this report would also apply to this category of CII landscapes. In addition to MWELO, other pertinent landscape BMP resources are cited at the end of the section. The MWELO document may be found at www.water.ca.gov/wateruseefficiency/docs/MWELO09-10-09.pdf.

This report also includes a number of BMPs not addressed in the MWELO document including the use of alternative water sources, graywater, artificial turf, alternative turf types, subsurface (also called in-line) irrigation, site review prior to design, site inspections during landscape installation, record keeping, and communication plans.

In addition to MWELO, the California Urban Water Conservation Council (CUWCC) has adopted a landscape BMP (#5) that, among other elements, requires signatory water providers to offer and conduct site water audits and to make recommendations for water use efficiency. Since CUWCC signatories account for approximately 90 percent of the urban water use in California, recommending that CII customers contact their water provider for a free site survey appears to represent an opportunity to capture additional water savings and thus is considered a CII BMP.

Water Use

CII landscape water use represents approximately 9-10 percent of urban water use and 25 percent[137] of total CII water use. However, landscape water use can range from zero to 100 percent at individual CII sites.

Available Data

While much has been written about landscape BMPs, studies on actual water savings for a particular BMP are somewhat limited and water savings for a given BMP can have a wide range . This report provides the water savings from the known studies.

Feasibility

The landscape BMPs discussed in this report are all technically feasible. However, the cost-effectiveness of implementing a particular BMP may vary considerably from site to site, and, in

[137] (data source-East Bay Municipal Utility District and City of San Diego Water Department)

some cases, such as graywater use, may not be practical. However, all of the BMPs discussed should, at least, be considered for implementation.

Employment
Landscape industry businesses are involved with production, distribution and services associated with ornamental plants, landscapes and garden supplies, and equipment. Their activities involve nurseries and growers, landscape architects, contractors and maintenance firms, and horticultural distribution centers. In addition, the public sector is involved with parks, botanic gardens, and roadway landscaping. According to a 2011 study[138] conducted by the California Landscape Contractors Association (CLCA), the landscape industry in California employees nearly 260,000 full and part-time people. This figure does not include a large unreported underground element of landscape related activity.

Value
The 2011 CLCA study determined that the landscape industry contributed $25 billion to the California economy in 2007, representing just over 1% of the entire state economy. Labor earnings were estimated at $8.28 billion. These figures do not include the economic contribution from a large underground landscape industry in California.

Landscape BMPs

Description
Unlike indoor use in the CII sector, BMPs for landscape water use efficiency apply across all CII sectors and NAICS codes with only the cost-effectiveness varying from site to site.

For the purpose of this report, the topics referenced below are considered landscape best management practices. The use of recycled water is also considered a BMP and is discussed in Section 11 of this report. Recycled water used in the landscape needs to meet certain water quality standards that address human and plant health concerns.

On-Site Water Sources
Reusing on-site water can represent a significant water source available for landscape use. Potential on-site CII water sources include cooling tower blowdown water, reverse osmosis (RO) reject water, graywater, retention basins and rainwater harvesting. Potential sources of water from CII facility processes for use on the landscape include the waste streams from cooling tower blowdown and reverse osmosis (RO) reject water. However, both of these waste streams are high in total dissolved solids (TDS) and may require further treatment or blending with other water sources before they may be used on the landscape. In addition, cooling tower blowdown water may contain biocides as part of the treatment process, which could be harmful to plants if not treated.

Rainwater Harvesting
Rainwater harvesting, as the name implies, relies on catching and storing rainwater. It involves both the use of cisterns and catchment basins. Catchment basins may include the construction of berms and/or swales and they are referenced in MWELO, Section 492.15. Detailed information on rainwater harvesting may be found at www.arcsa.org.

[138] Palma, Marco A.,2011, Economic Contributions of the Green Industry to the California Economy, California Landscape Contractors Association

Retention Basins

Retention basins serve as a reservoir to collect rainwater and indoor water for such multiple purposes as soil percolation, runoff control, and landscape irrigation. There are standards and codes that address the construction of retention basins. Information on storm water retention can be found at a website sponsored by the California Storm Water Quality Association where there is a fact sheet for free downloading; <https://www.casqa.org/store/products/tabid/154/p-171-fact-sheet-se-2.aspx>.

The Regional Water Quality Control Board (RWQCB) governs storm water discharges via a permitting process. The permit requirements can vary from one RWQCB region to another. Permit information may be found at the RWQCB website at www.waterboards.ca.gov/water_issues/programs/stormwater/docs/stormwater_factsheet.pdf.

Graywater

The use of graywater is allowed in the CII sector per Appendix G,Title 24, Part 5, of the California Administrative Code. Technically, since graywater is defined as "untreated wastewater" from bathroom sinks, showers and baths, and clothes washers, it is generally most practical for institutional use. Information on California graywater standards may be found at:

www.water.ca.gov/wateruseefficiency/docs/Revised_Graywater_Standards.pdf

Landscape Design

The importance of appropriate landscape design cannot be overstated since a well designed landscape can save water and minimize long-term maintenance costs. Based on estimates from several large California urban water providers[139], turf accounts for approximately 50 percent of outdoor plant material and is responsible for approximately 70 percent of outdoor water use. Limiting turf to functional areas during landscape design, therefore, would reduce outdoor water use significantly. Landscape design BMPs are found in MWELO, Section 492.61. BMP landscape elements not addressed in MWELO are discussed below and include the use of synthetic turf, alternative turf choices, and subsurface irrigation.

Site Inspection

Prior to beginning the design process a physical site inspection will help designers understand and address such issues as underground utility lines, overhead structures, grading, etc.

Plant Material

A landscape should be designed to use low water-requiring plants best suited to the California climate. For example, the use of alternative turf types, such as warm season turfs and buffalo grass can result in significant water savings. Warm season grasses are more typically found in southern California where the dormancy period, which results in a brown color, is much shorter than in northern California. Buffalo grass has a clumping or pasture look and may be an appropriate solution for some CII sites. More information may be found at http://www.ucrturf.ucr.edu/home/anrcatalog.htm or http://usgatero.msu.edu/v05/n21.pdf. A list of plants and their water requirements may be found in a document titled "Water Using Classifications of Landscape Species" (WUCOLS), located at www.water.ca.gov/wateruseefficiency/docs/wucols00.pdf.

Hydro-zone

[139] East Bay Municipal Utility District and the City of San Diego Water Department

Plants should be grouped based on similar water requirements, called hydro-zones to help with irrigation design and application. The hydro-zone BMP is found in the MWELO document in section 492.6.

Microclimates

A plant's water requirement can vary widely due to such influences as the amount of solar radiation (sun verses shade), wind, humidity, and temperature. These influences, called microclimates, need to be considered in the landscape and irrigation design process and are referred to in the MWELO document in section 492.6.

Landscape Alternatives

An important BMP includes consideration for the incorporation of permeable hardscapes into the landscape. Permeable hardscapes include the use of:

- synthetic or artificial turf (which reduces water use over conventional turf by approximately 70%)
- decking
- gravel pathways or pervious pavers (used for driveways, walkways, patios, etc.)

A number of websites contain information on synthetic (artificial) turf. They may be found by searching under "artificial turf".

Subsurface Irrigation

Subsurface irrigation, also called in-line irrigation, is becoming increasingly widely used. Subsurface irrigation minimizes soil evaporation, water loss due to wind drift, overspray, and runoff. It also reduces pests and disease. An increasingly popular installation technique for subsurface drip irrigation for ground cover and shrubs involves placing the drip line on the surface and covering it with several inches of mulch. A filter fabric can be placed a few inches below the drip line to help slow the downward movement of water due to gravity and to spread out the water horizontally. Because of the benefits of subsurface irrigation, it is recommended as a BMP, where practical. Information on subsurface drip irrigation systems may be found at www.geoflow.com/design_l.html, www.ext.colostate.edu/pubs/crops/04716.html and http://www.rainbird.com/documents/drip/XFSeriesDesignGuide.pdf.

Soil Management

Proper soil management is an important BMP because healthy soil can improve water use efficiency, plant health, and moisture retention. Information on soil management may be found in MWELO, Section 492.5.

Grading

Appropriate grading should include a strategy to reduce runoff and retain more water on the site. BMP information on grading may be found in MWELO, Section 492.8.

Irrigation System Design

Proper irrigation system design is critical to efficient water use and involves numerous components ranging from the use of weather-based controllers to drip irrigation. BMP information may be found in MWELO, Section 492.7. Additional information on irrigation systems and design (including information on water budgets, and scheduling) may be found at www.irrigation.org/Resources/Turf___Landscape_BMPs.aspx and at http://www.irrisoft.net/downloads/manuals/Landscape%20Water%20Management%20Training%20Manual.pdf

Project Installation

Installation BMPs include:

- communication between the designer, installers, and the end user
- installation per the approved specifications
- use of trained or certified workers
- installation of plants and irrigation system per BMPs
- as-built documentation
- approved check-off list of installation

Metering/Submetering

Landscape water use needs to be metered or submetered[140] to determine water use efficiency for site water management. The MWELO document highly recommends the installation of a dedicated water meter for new and rehabilitated landscapes 5,000 square feet or greater. A BMP for existing landscapes should also include the installation and the monthly reading of a submeter. Additional flow monitoring and management options for flow may be found at ftp://ftp.calsense.com/Cutsheets/16_flow_monitoring.pdf, http://www.rainbird.com/landscape/products/central/flowSensors.htm or http://www.rainmaster.com/PDF/500658a.pdf.

Maintenance

Proper landscape maintenance is critical to capturing a site's potential water savings over time. Maintenance BMPs include the development of a work schedule that addresses the need for:

- mulching
- irrigation system leak detection and repair
- review of the irrigation schedule
- winterization (if appropriate)
- inspection of the site's back flow prevention device and water pressure

In addition to the regular review of a landscape's various components, sites should also develop a communication plan between site staff and management that includes an emergency action plan for water shutoff.

Record Keeping

Proper record keeping involving the storage of design and as-built plans is important in detecting irrigation system problems and for making repairs. Retaining information on advances in irrigation technology is also important as it can lead to further water savings if incorporated into the landscape.

Management: *Communication*

An important BMP includes continuous monitoring of the site and communication between site staff and management to ensure that the irrigation schedule is correct, the irrigation system is functioning properly, the necessary repairs are being made, and the site is meeting its water budget.

Landscape Budgets

Water budgets involve the concept of developing a maximum applied water allowance (MAWA) for a given site. A landscape budget should be defined between the site owner and manager, water purveyor and landscape maintenance staff. The water budget formula may be found in

[140] A submeter is defined as any meter downstream of a water provider master meter

Section B1 of the MWELO document. Other information on landscape budgets may be found in MWELO, Section 492.4 and at the sites referenced in the “Irrigation System Design” section.

Irrigation Audits

Irrigation audits represent an opportunity to review the system’s water useefficiency and make the necessary repairs and adjustments. Information on irrigation audits may be found in MWELO, Section 492.12.

Irrigation Scheduling

The proper management of a site’s irrigation schedule is a critical component of efficient landscape water use. Information on irrigation scheduling may be found in MWELO, Section 492.10 and at the sites referenced in the “Irrigation System Design” section. Information on irrigation scheduling using weather data can be found at <http://wwwcimis.water.gov/cimis/data.jsp>.

Metrics

The metric deemed appropriate for determining landscape water use efficiency is “water use divided by the irrigated area” and may include the following units of measure over time:

- o Hundred cubic feet (CCF) per square foot
- o Gallons per square foot
- o Acre feet per acre

By knowing the area being irrigated and the water use, an efficiency standard can be applied using known evaporation-transpiration (ET) data. ET data is accessible throughout California through a internet available through the California Department of Water Resource’s weather station network.

Summary of Landscape Case Studies

Studies deemed appropriate for determining landscape water savings from various measures are itemized below.

Study Title: Summary of Smart Controller Water Savings Studies
Conducted By: U.S. Bureau of Reclamation
Study Summary: This study, completed in 2008, was a literature search summarizing the water savings associated with 14 smart controller studies, nine soil moisture studies, and two combined studies. Water savings associated with the use of smart controllers averaged around 25% with the low outlier at 7 % and the high outlier at 41%. Water savings associated with soil moisture sensors ran between 10% and 82% with an average of around 35%. Lastly, there were two studies that combined the water savings from both smart controllers and moisture sensors. In one study the reported savings from moisture sensors ranged between zero and 63% and from 36% to 59% for the smart controllers. In the other study, the combined savings was approximately 10%.

Study Title: Xeriscape Conversion Study
Conducted By: Southern Nevada Water Authority with funding from U.S. Bureau of Reclamation
Study Summary: This study, completed in 2005, found a 76.4% savings with the xeric landscapes. Study participants with turf used 73 gallons per square foot annually compared to 17.2 gallons per square foot annually for xeric landscapes. The average cost to convert the

landscape from turf to xeric was $1.55 per square foot. The cost to convert the landscape using a contractor was $1.93 per square foot and $1.37 per square foot without a contractor.

Study Title: Evaluation of California Weather-Based "Smart" Irrigation Controller Programs
Conducted By: East Bay Municipal Utility District and the Metropolitan Water District of Southern California with participation from other water providers and partial funding from the California Department of Water Resources
Study Summary: This study, completed in 2009, found a statewide water savings of 6.1% from the installation of weather-based irrigation controllers. Interestingly, the professionally installed controllers led to a 3.6% average savings and homeowner self-installed controllers resulted in a 9.0% savings. The higher self-installed controller water savings was attributed to the homeowner being more familiar with the programming and, thus, better management of the new controllers.

Study Title: A Comparison in Santa Monica
Conducted By: Sustainable Sites Initiative
Study Summary: This study, completed in 2004, compared the water use and maintenance requirements in adjacent single family front yards of similar size, one resident having a traditional landscape and the other a climate appropriate, sustainable design. The traditional site had a standard, user controller sprinkler irrigation system and a lawn with plants from Northern Europe and the Eastern US. The other site had native plants, a weather based irrigation controller, and low-volume drip irrigation. The water efficient site used 77% less water, had 62% less green waste, and had 68% less maintenance costs. The native site cost 30% ($4,000) more to construct owing mostly to the installation of a cistern system.

Study Title: Landscape Conversion Study
Conducted By: Los Angeles Department of Water and Power
Study Summary: This study, completed in 2011, compared the difference in water use at an institutional site after turf was removed at the 7.7 acre site and replaced with climate appropriate plant material. Water use was reduced by approximately 90%.

Study Title: California Single-Family Water Use Efficiency Study
Conducted By: Irvine Ranch and nine participating California water providers
Study Summary: This study, completed in 2011, involved an assessment of indoor and outdoor water use efficiency. The study concluded that the potential for outdoor water savings in the single-family sector was between 0.6 MAF and 1.0 MAF annually. The study found that about 42% of all homes were over irrigating by a margin of 138% or 164 gallons per day.

Study Title: Lawns and Water Demand in California
Conducted By: Public Policy Institute of California
Study Summary: This study cited reports and personal communications in discussing factors affecting landscape water use, in general, and lawn water use, in particular. This report estimated that lawns comprise approximately 50% of irrigated urban landscape plant material. The report also cited a 2001 study (Maddaus and Mayer) which found landscapes with automatic sprinkler systems used 50% to 60% more water than sites without automatic irrigation systems.

Study Title: The Bigger Picture of Water Conservation
Conducted By: City of San Diego Water Department
Study Summary: This study, partially funded by the U.S. Bureau of Reclamation, used geographical information system (GIS) data to estimate that 53% of the plant material in the City of San Diego Water Department service area was turfgrass and groundcover and 47% was trees and shrubs. It was calculated that 41% of the water use in FY 2006 was outdoor use. Using consumption, ET, and irrigated landscape area data it was estimated that, on average, customers over irrigated by approximately 25%.

Report Title: Irrigated Area in EBMUD Service Area
Conducted By: EBMUD
Report Summary: This unpublished report, completed in 2006, using geographical information system (GIS) and consumption data, estimated that lawn comprises 46% of the irrigated area within the EBMUD service area and accounts for 71% of the outdoor water use. Based on the information in the report, it indicates that water is applied to lawns in an amount three times that of other plant material and that significant water savings can be realized by reducing lawn area.

Study Title: Data Mining Five Years of Commercial Landscape Audits Shows the Pros and Cons of the Audit Program
Conducted By: City of San Diego Water Department
Study Summary: This study estimated the water savings from conducting water audits on commercial landscapes. The study, evaluating five years of data, found approximate average water savings from the commercial landscape audit program in the 5%-6% range.

Water Savings Potential

The water savings from various landscape conservation measures can vary significantly due to the many variables affecting landscape water use. For example, the water savings from the largest study of "smart" ET controllers conducted in California cited an average water savings statewide of 6.1 percent. However, a summary of 14 studies compiled by the U.S. Bureau of Reclamation cited "smart" controller water savings up to 41 percent with an average savings of around 25 percent. In a study conducted by the Southern Nevada Water Authority, water savings of 75 percent was cited by converting traditional landscapes to Xeriscapes. In a study conducted by the City of San Diego Water Department, water savings of 5%-6% was cited as a result of City sponsored water audits for commercial landscapes. A water use survey conducted on hundreds of single-family residences in California found that 42% of the properties over irrigated by 138%. However, taking the single-family sector as a whole, the potential water savings was just over 15%. The City of San Diego Water Department estimates a potential landscape water savings of 25% from its customer base. Less percent water savings can be expected from golf courses which tend to be very well managed since water is a large part of their operating costs.

The studies appear to indicate that sites properly managed following a landscape conversion can achieve significant water savings. However, an average savings of 15 percent in CII landscape water use appears to be achievable using the conservation measures available. Based on landscape water use data[141] in the CII sector, this would indicate a potential annual average landscape water savings of approximately 70 MGD in California.

[141] CII landscape use = Total urban use x 35% (CII use) x 25% (CII landscape use)

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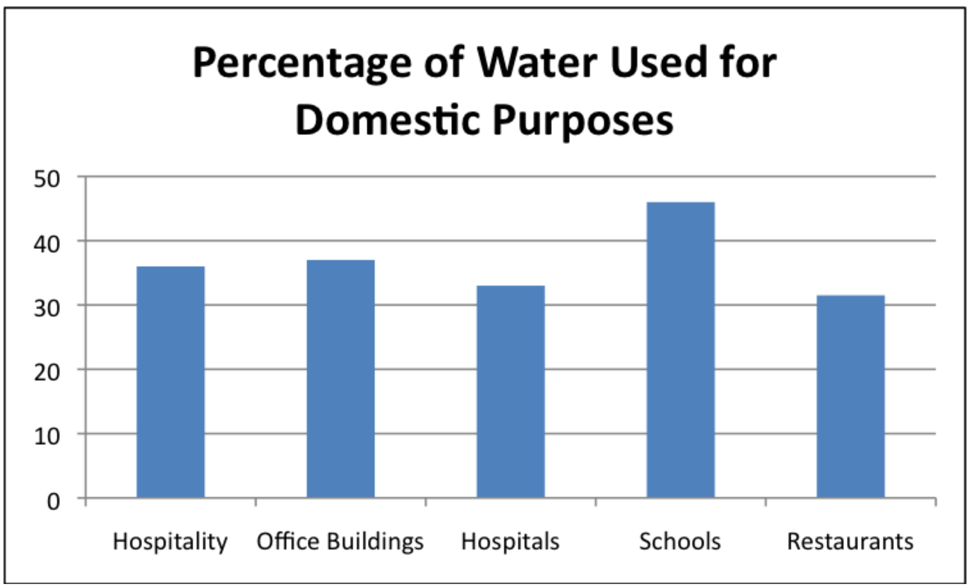
7C6: General Building Sanitary and Safety Applications

Background

CII customers can account for anywhere from 15 to 25 percent of the total urban municipal water demand, according to the 2000 report *Commercial and Institutional End Uses of Water.*[142] As significant water users, commercial and institutional facilities have the opportunity to conserve this precious resource, save energy, and minimize facility operational costs in the process.

Domestic water uses in sanitary fixtures can account for as much as 45 percent of total water use within a facility. Depending upon the type of facility and its occupancy, restroom and other sanitary uses such as laundry can provide significant opportunities to reduce water use.



Created from analyzing data in: New Mexico Office of the State Engineer, *Water Conservation Guide for Commercial, Institutional, and Industrial Water Users*, July 1999 (original source: City of San Jose Environmental Services Department); Dziegielewski, et. al., *Commercial and Institutional End Uses of Water*, 2000; East Bay Municipal Utility District, *WaterSmart Guidebook: A Water Use Efficiency Plan Review Guide for New Businesses*, 2008; American Water Works Association, *Helping Businesses Manage Water Use, A Guide for Water Utilities*.

[142] Dziegielewski, et. al. *Commercial and Institutional End Uses of Water*. 2000. American Water Works Association Research Foundation.

Technical Feasibility

All of the practices, products and technologies described in this report section have been in existence for an extended period of time and found to be technically feasible. In each case, however, economic feasibility must be evaluated within the context of the physical condition and demands of the specific property or building being considered for high-efficiency sanitary fixtures and fixture fittings.

Toilet Fixtures (Water Closets)

Overview

The Energy Policy Act (EPAct) of 1992 established the maximum allowable flush volume for gravity tank-type, pressure assisted, electromechanical hydraulic, and flushometer-valve-type toilets sold in the United States at 1.6 gallons per flush (gpf)[143]. The maximum flush volume for blow-out toilets, used primarily in locations subject to high traffic or heavy use (stadiums and other event venues), was set at 3.5 gpf. However, blow-out toilets[144] are no longer permitted in California. Due to the long useful life of toilets[145], many toilets in CII use today are older and have flush volumes exceeding 3.5 gpf.

California's CalGreen code[146], effective beginning in 2011, limits effective flush volumes for toilets (water closets) to 1.28 gallons per flush[147] (gpf) in new construction and renovations. In addition, Senate Bill 407 (2009) requires that ALL other commercial facilities be equipped with toilets flushing at 1.6 gpf or less on or after January 1, 2019[148].

Although most early versions of the toilet fixtures flushed at 1.6 gallons or less, they did not necessarily perform well and, thus, did not always result in satisfied customers and users. As a result of these early problems, the plumbing industry embarked upon fresh product development to improve performance and thereby restore customer confidence and satisfaction. Through extensive re-engineering of bowl hydraulics in the mid-1990s, manufacturers achieved significantly improved fixture performance. However, some fixtures remain today that do not meet user expectations for performance. As a result, the reputation of some early "low flow" toilet fixtures still exists, even though the products now available in the marketplace are superior

[143] California preceded this date with its own mandate for the 1.6 gpf maximum by about 2 years.

[144] Blowout toilets are defined in the national standard ASME A112.19.2-2008/CSA B45.1-08 as follows: Blowout bowl — a non-siphonic water closet bowl with an integral flushing rim, a trap at the rear of the bowl, and a visible or concealed jet that operates with a blowout action.

[145] Generally, the economic life of toilets is assumed to be 20 years for gravity-fed fixtures, 25 years for pressure-assist fixtures, and 30 years for flushometer valve-bowl combinations. In all cases, the physical life of these fixtures (when properly maintained) will be longer.

[146] California Building Standards Commission (CBSC), 2010. California Green Building Standards Code – 2010 – CalGreen, CCR, Title 24, Part 11.

[147] Effective flush volume as defined in CBSC, 2010. An exception to the 1.28 gpf maximum can be proposed where the project applicant chooses the performance path rather than the prescriptive path for indoor water use. Refer to paragraph 5.303.2 in the code. Some jurisdictions mandate the 1.28 gpf maximum without exceptions.

[148] CUWCC, 2010. *Interaction Among AB715 (Laird 2007), SB407 (Padilla 2009), and CALGreen Building Standards*, August 26.

to those early versions. Unfortunately, this carry-over reputation still influences the decisions of facility managers and design professionals as they attempt to implement water efficient practices and replace older fixtures with new high-efficiency products. It is critical that facility managers use the information available today on fixture performance and durability to make their product purchase and replacement decisions. Performance information on many different models of toilets, gathered through independent laboratory testing, may be found at www.map-testing.com.

Physical design and function

Two common types of toilet, or water closet, designs are installed in CII settings, including tank-type toilets and flushometer valve and bowl combination toilets.

Tank-type toilets are designed with a tank that stores and dispenses water to the toilet bowl to flush waste. Varieties of tank-type toilets include the standard gravity-fed units (found in most homes), pressure-assisted (also termed flushometer-tank toilets), and electrohydraulic-assisted toilets. Tank-type toilets are available as single, constant volume flushing models or as dual-flush models, which include a full flush for solids and a reduced flush for liquids. Tank-type toilets are commonly found in residential and light commercial settings.

Flushometer valve and bowl combinations are tankless fixtures with either wall- or floor-mounted bowls attached to a lever- or sensor-activated flushometer valve. The valve releases a specific volume of water at a high flow rate directly from the water supply line (at line pressure) to the bowl to remove (flush) waste. Unlike tank-type toilets, which store water in the tank to provide the necessary head pressure and flow to remove waste from the bowl, flushometer combinations instead rely upon larger diameter water supply piping and high water supply line pressures to remove waste. These fixtures are also available as single, constant volume flushing models, or as dual-flush models. Flushometer-valve-type toilets are used predominantly in public use facilities and high-use commercial settings.

A toilet flush can be actuated by manual mechanical levers, push buttons, or electronic sensors that trigger the flushing mechanism when a user has finished using the fixture. The hands-free sensors eliminate the need for human contact with the valve, but very often flush needlessly while the toilet is still in use[149] as well as at other times. Studies have shown that hands-free sensor-activated valves actually increase water use when replacing conventional manually activated valves. As such, sensors themselves provide no additional water-efficiency benefits; however, they provide health and sanitation benefits in public use facilities since they offer an entirely hands-free option.

User expectations for minimizing water use in a toilet operation: (1) flush the toilet bowl clear, (2) transport waste through drainlines to the sanitary sewer, (3) operate reliably, and (4) have a leak-proof discharge valve.

[149] Known as "phantom flushes"

Operation and Maintenance

In addition to replacing all CalGreen non-compliant toilet fixtures within a building, facility managers can also reduce water use by taking simple steps to educate users on proper toilet use and maintenance:

- Train users to report continuously flushing, leaking, or otherwise improperly operating toilets to the appropriate management or maintenance personnel.
- Educate and inform users with restroom signage and other means to discourage the flushing of inappropriate objects such as feminine products, wrappers, or other trash. Train custodial staff on how to handle the inappropriate disposal of such objects.

Tank-Type Toilets

For optimum tank-type toilet operation, consider the following:

- Periodically check to ensure the fill valve is working properly and the water level is set correctly. Check to see if water is flowing over the top of the overflow tube inside of the tank. Ensure that the refill water level is set approximately ¼-inch below the top of the overflow tube by adjusting the float to a lower position if the water level is too high. If the toilet continues to run (fill) after the float is adjusted, replace the fill valve. In order to prevent changes in tank water levels due to line water pressure fluctuations, only replace existing fill valves with pilot-type fill valves.
- No less frequently than annually, check to ensure the flapper is not worn, a condition that will allow water to seep from the tank into the bowl and down the sewer. To perform this check, drop a dye tablet or several drops of diluted food coloring in the tank. After 10 minutes, if the dye has leaked into the bowl, then check for a tangled chain in the tank or replace a worn flapper. If leaking does not subside after a flapper valve is replaced, consider replacing the flapper seat and overflow tube assembly, which could also be worn. Further information and tips may be found at www.snwa.com/consv/leaks_toilets.html.

Flushometer Valve and Bowl Combinations

For optimum flushometer-valve-type toilet operation, consider the following:

- No less frequently than annually, inspect diaphragm or piston valves in flushometer-valve-type toilets, and replace any worn parts. To determine if the valve is in need of replacement, determine the time it takes to complete a flush cycle. A properly functioning flush valve should not have a flush cycle longer than four seconds.
- If replacing valve inserts, confirm that the replacements are consistent with the valve manufacturer's specifications, including the rated flush volume. If replacing the entire valve, ensure it has a rated flush volume consistent with manufacturer specifications for the existing bowl, including the rated flush volume.
- Periodically check to ensure the control stop (which regulates the flow of water from the inlet pipe to the flushometer valve and is necessary for shutting off the flow of water

during maintenance and replacement of the bowl or valve) is set to a fully open position during normal operation.

- Upon installation of a flushometer toilet, adjust the flush volume in accordance with manufacturer's instructions to ensure optimum operation for the facility's specific conditions. Periodically inspect the flush volume adjustment screw to ensure the flush volume setting has not been modified from the original settings; if it has, it could change the water use and performance of the product.
- Ensure that the line pressure serving the fixture meets the minimum requirements of the fixture manufacturer (minimums are commonly specified as 35 psi).
- If installed, check and adjust automatic sensors to ensure proper settings and operation to avoid double or phantom flushing. Alternatively, remove sensor systems and replace with manually activated flush valves, which are shown to significantly reduce water consumption at the toilet.

Retrofit Options

Tank-Type Toilets

Avoid retrofitting existing tank-type toilets with displacement dams or bags, early-closing toilet flappers, or valves with different flush volumes, as these devices could impede overall performance and could require increased operation and maintenance. Do not attempt to convert a single-flush 1.6 gpf toilet fixture to a dual-flush fixture with an after-market device.

The installation and use of these devices and other retrofit products can seriously affect fixture performance and could void manufacturer warranties.

Flushometer Valve and Bowl Combinations

In general, it is best to avoid valve retrofit options, such as valve inserts, that reduce the flush volume of flushometer-valve-type toilets. These products might not provide the expected performance when the original bowl is not hydraulically designed to function on a reduced flush volume. Double flushing commonly results when such a retrofit is made, negating any expected water use reduction. In addition, the use of these devices could void valve manufacturer warranties.

Dual-flush conversion devices are also available for flushometer toilets. These devices usually replace the existing flush valve handle with a handle that provides a reduced flush volume for liquids and a standard flush for solids[150]. It should be noted that two types of dual flush handles exist for such a retrofit, one in which the ‘down’ position of the handle activates a reduced flush and the ‘up’ position of the handle activates a full flush, and one with opposite positions. Water savings can be significantly different between the two types, inasmuch as the ‘normal’ flush action by most users is a ‘down’ activation. Before embarking upon a full-scale retrofit, test the

[150] When considering this type of retrofit, verify that the product has been certified to either ASME A112.19.10 *Dual Flush Devices for Water Closets* or IAPMO PS 50-2008 *Flush Valves with Dual Flush Device for Water Closets or Water Closet Tank with an Integral Flush Valves with a Dual Flush Device*.

product on a select number of toilets to verify it achieves and maintains the desired performance.

Replacement Options

Replace all toilets within the building to meet the California requirements as specified in CalGreen[151].

Tank-Type Toilets

When installing new tank-type toilets or replacing older, inefficient tank-type toilets in accordance with CalGreen requirements[152], choose WaterSense labeled models (www.epa.gov/watersense/products). WaterSense labeled tank-type toilets are independently certified to have an effective flush volume of 1.28 gpf or less and pass a performance test to remove at least 350 grams or more of solid waste in a single flush.

Flushometer Valve and Bowl Combinations

When installing new or replacing older, inefficient flushometer-valve-type toilets, choose models that are designed to use 1.28 gpf or less in accordance with the requirements of CalGreen. When considering 1.28 gpf or less flushometer toilets, carefully evaluate the physical conditions of existing drainlines and the availability of supplemental water flow upstream from the toilet fixtures to ensure that the conditions are appropriate for effective waste transport.

For maximum water savings and performance, purchase the flushometer valve and bowl in hydraulically matched combinations that are compatible in terms of their designed flush volume. A listing of matched and tested combinations may be found at www.map-testing.com/about/maximum-performance/flushometer.html.

Water Savings Potential

Water savings can be achieved by replacing existing 1.6 gpf and greater tank-type and flushometer toilets with high-efficiency models. Existing tank-type toilets can be replaced with WaterSense labeled high-efficiency toilets, which can save between 1,400 and 2,100 gallons of water per user per year. Flushometer models can be replaced with high-efficiency models functioning at 1.28 gpf or less. To estimate facility-specific water savings and payback, use the following information.

Current Water Use

To estimate the current water use of an existing toilet, identify the following information and use Equation 1 below:

[151] CBSC, 2010
[152] CBSC, 2010

- Flush volume of the existing tank-type toilet: Toilets installed after the mid 1970's typically have standard flush volumes of 3.5 gpf or 5.0 gpf.[153] Toilets installed in California in 1992 and later generally have standard flush volumes of 1.6 gpf.
- Average number of times the toilet is flushed per day: This figure depends upon the facility's male to female ratio. Female occupants use toilets three times per day on average, while male occupants use the toilet once per day on average.[154]
- Days of facility operation per year.

Equation 1:
Water Use of a Toilet (gallons/year) = Flush Volume (gallons/flush) X Number of Flushes (flushes/day) X Days of Facility Operation (days/year)

Water Use After Replacement

To estimate the water use of a replacement tank-type toilet, use Equation 1, but substitute the flush volume of the replacement tank-type toilet. WaterSense-labeled toilets use no more than 1.28 gpf on average.

Water Savings

Calculate the expected water savings by subtracting the water use after replacement from the current water use.

California Water Savings Potential

An estimate of total potential statewide water savings that could result from the replacement of existing CII toilets with high-efficiency toilets was made in 2005[155]. That analysis estimated the savings potential as being between 26,000 and 38,000 acre-feet per year (AFY) of water. Another 3,000 to 5,000 AFY could be saved through legislation, codes, and standards applied to new construction[156].

Resources and References

Alliance for Water Efficiency, 2011. Toilet Fixtures Introduction. www.allianceforwaterefficiency.org/toilet_fixtures.aspx

American Water Works Association, *Helping Businesses Manage Water Use, A Guide for Water Utilities*.

[153] North Carolina Department of Environment and Natural Resources. May 2009. *Water Efficiency Manual for Commercial, Industrial and Institutional Facilities*. Page 28. www.p2pays.org/ref/01/00692.pdf

[154] Amy, Vickers, *Handbook of Water Use and Conservation*, WaterPlow Press, 2001.

[155] California Urban Water Conservation Council , 2005. Evaluation of Potential Best Management Practices – High-Efficiency Plumbing Fixtures – Toilets and Urinals, November.

[156] Provisions for HETs were subsequently mandated by the California Building Standards Commission through the provisions of CalGreen.

California Building Standards Commission (CBSC), 2010. California Green Building Standards Code – 2010 – CalGreen, CCR, Title 24, Part 11. www.bsc.ca.gov/CALGreen/default.htm

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CASE STUDY – San Francisco Hotel

Significant water savings and reductions in maintenance service calls resulted from a major toilet retrofit project in the Park 55 Wyndham Hotel in downtown San Francisco. The hotel was originally constructed in 1984 and opened for business as a Ramada Inn. With 1,012 guest rooms and 1,030 guest room toilet fixtures, the Parc 55 is one of the largest hotels in the city. At the time of construction, all guest rooms were fitted with 3.5 gallons per flush gravity-fed toilet fixtures.

In late 2007, hotel management undertook the toilet replacement project by selecting a pressure-assist HET to replace the older non-efficient gravity-fed fixtures. The selected fixture functions at 1.0 gallon per flush and was ideally suited to guest room use. In December 2007, the physical replacement of fixtures began, concluding in October 2008, a rate of about 100 replacements per month.

At the conclusion of the retrofit project and after the 2008 holiday season, the per unit (or per guest room toilet) reductions attributable to the retrofit program were determined as follows:

Water Consumption – "Before" and "After" Replacement

	Water Consumption
"BEFORE" - Water use prior to retrofit project (22 months – January 2006 to October 2007)	4,707 units per month[157] = 3,521,000 gallons per mo.
"AFTER" – Water use following retrofit project (8 months November 2008 to June 2009)	3,474 units per month = 2,598,000 gallons per mo.
Water use reduction – 1,030 guest room toilet fixtures[158]	1,233 units per month = 923,000 gallons per month
Water use reduction – per guest room toilet fixture	893 gallons per month = 10,700 gallons per year (29 gallons per day)

The daily per fixture water savings of 29 gallons amounts to a savings of approximately $170,000 annually on water and sewer charges at 2009 rates in San Francisco.

The secondary major benefit to the replacement program was the reduction in service calls to hotel maintenance (and associated labor cost reductions), due to improved flush performance and fixture reliability. Annually, the replacement is projected to reduce maintenance labor by several hundred hours per year.

[157] A unit is equal to 100 cubic feet or 748 gallons, and is used for utility billing purposes.
[158] Savings based upon a nominal 90% occupancy

Urinal Fixtures

Overview

The Energy Policy Act (EPAct) of 1992 established the maximum allowable flush volume for all urinals sold in the United States in 1994 or after as 1.0 gallons per flush (gpf). Many urinals in facilities nationwide were installed prior to 1994, and thus flush at higher rates, often between 1.5 and 3.5 gpf.

Many urinal fixtures being installed today are high-efficiency urinals (HEUs). An HEU is defined as a fixture that flushes at 0.5-gallons or less. This definition includes existing 0.5-gpf urinals and non-water urinals as well as the one-quart (0.25 gpf) and one-pint (0.125 gpf) urinals currently available in the marketplace from several manufacturers.

California's CalGreen code[159], effective beginning in 2011, effectively limits flush volumes for urinals to 0.5 gallons per flush[160] (gpf) in new construction and renovations, thus mandating HEUs as the only urinal design allowed.

A current listing of HEUs available in the marketplace may be found at: www.map-testing.com/info/menu/urinals-and-heus.html.

Flushing Urinal

A flushing urinal is defined in the American national standard as "a plumbing fixture that receives only liquid waste and conveys the waste through a trap seal into a gravity drainage system."[161] Flushing urinals use water to remove (i.e., flush) the liquid waste from the fixture. Flushing urinals are available in several different designs and technologies. The most commonly used urinals found in California CII applications are *washdown (or washout) urinals* and *siphonic urinals.* Both require the user to depress a flush handle to activate a flushometer valve. Both types rely upon the supplied building water pressure for effective evacuation of waste. *Gravity tank-type urinals* are much less common and, similar to a tank-type toilet, rely upon the release of water stored in an in-wall cistern to provide the necessary head pressure to remove waste from the urinal. *Siphonic jet urinals* have an elevated flush tank and operate by using a siphon device to automatically discharge the tank's contents when the water level in the tank reaches a certain height. This type of urinal requires no user assistance.

Flushing urinals can be equipped with electronic sensors that activate the flushing mechanism when a user has finished using the fixture. Sensors that activate a urinal flush valve provide no additional water-efficiency benefits; however, they provide health and sanitation benefits in public use facilities because they offer a hands-free option. If not properly maintained, however, automatic flush sensors can cause double or 'phantom flushing' of the urinal, actually increasing the water used at a facility.

[159] California Building Standards Commission (CBSC), 2010. California Green Building Standards Code – 2010 – CalGreen, CCR, Title 24, Part 11.

[160] Effective flush volume as defined in CBSC, 2010. An exception to the 0.5 gpf maximum can be proposed where the project applicant chooses the performance path rather than the prescriptive path for indoor water use. Refer to paragraph 5.303.2 in the code. Some jurisdictions mandate the 0.5 gpf maximum without exceptions.

[161] American Society of Mechanical Engineers. ASME A112.19.2-2008/CSA B45.1-08*, Ceramic Plumbing Fixtures*.

Flushing urinals come in two basic types—standard, single-user and trough-type, multi-user fixtures. Trough urinals are large fixtures designed for multiple users in high-traffic places, such as stadiums and sports arenas. Trough urinals are sold in 36-, 48-, 60-, and 72-inch lengths. Some older models were designed to run continuously, and consequently consumed large amounts of water. New trough urinals use flushometer valves on preset timers or they are equipped with electronic sensors.

Non-water urinal

Some urinals do not use water to flush the liquid waste from the fixture. A non-water urinal is "a plumbing fixture that is designed to receive and convey only liquid waste through a trap seal into the gravity drainage system without the use of water for such function."[162]

Most non-water urinals use a specially designed trap that allows liquid waste to drain out of the fixture, through a trap seal, and into the drainage system. Some use a cartridge that contains a liquid barrier seal to prevent the escape of odors and sewer gases. Other models feature cartridge-less designs that use a liquid barrier seal in the urinal's trap. A third type uses a self-sealing mechanical waste valve trap that does not require a liquid barrier seal. Currently, U.S. plumbing codes prohibit these self-sealing mechanical trap designs.

<u>Operation, Maintenance, and User Education</u>

Flushing Urinals

For optimum flushing urinal performance, consider the following:

- No less frequently than annually, inspect the flushometer diaphragm or piston valves, and replace any worn parts. If replacing valve inserts, verify that the replacements are consistent with the valve manufacturer's specifications, including the rated flush volume. If replacing the entire valve, ensure it has a rated flush volume consistent with manufacturer specifications for the urinal fixture itself. That is, the urinal fixture should be designed to function at the lower flush volume of the high-efficiency valve.
- Annually check and adjust automatic sensors, if installed, to ensure they are operating properly to avoid double or phantom flushing.
- Flushing urinals equipped with automatic flush sensors will often have an override switch, allowing maintenance personnel to activate the flush manually. Activating the override switch may release a larger volume of water than is typical for the standard flush. Train custodial and maintenance personnel on how to clean and maintain urinals with automatic flush sensors to ensure that the urinal is returned to its intended flush volume after maintenance operations are completed.
- Train users to report continuously flushing, leaking, or otherwise improperly operating urinals to the appropriate management or maintenance personnel.

[162] American Society of Mechanical Engineers. ASME A112.19.19-2006, November 30, 2006, *Vitreous China Nonwater Urinals*, and International Association of Plumbing and Mechanical Officials. February 19, 2004. IAPMO Z124.9-2004*, American National Standard for Plastic Urinal Fixtures*.

Non-Water Urinals

If non-water urinals are selected for the facility, regularly clean and replace the seal cartridges or other materials as specified by the manufacturer, and rigorously follow all other manufacturer-provided instructions. Proper maintenance is vital to long-term performance of non-water urinals. Furthermore, facility managers should be aware that non-water urinals are subject to rapid build-up of struvite[163] in the urinal drainline, which may lead to complete blockage of the drain. Preparation for such potential blockage issues must be accounted for making the decision to replace older water inefficient urinals with high-efficiency urinals (HEUs). Consideration should also be given to the enzyme products currently available in the marketplace for urinals; these tablets and pucks are specially formulated with the enzymes needed to forestall or prevent drainline buildup and, in some cases, the odors associated with non-water urinals.

Retrofit Options

In general, avoid aftermarket parts for urinal retrofits that are designed to reduce the flush volume of valves. This includes aftermarket flushometer valve inserts that result in a lower flush volume, unless those inserts are rated to provide a flush volume compatible with the existing urinal fixture. Confirm compatibility with the urinal fixture manufacturer, as many new urinal fixture models are designed to function at several different flush volumes. If the flush volume of the valve insert is not compatible with the urinal fixture, it may not provide the expected performance, potentially leading to double flushing.

Replacement Options

If feasible, replace all urinals in the building to meet the California requirements as specified in CalGreen[164].

When installing new flushing urinals or replacing older, inefficient flushing urinals, choose WaterSense-labeled models (www.epa.gov/watersense/products). WaterSense-labeled flushing urinals have been independently tested and certified to function at no more than 0.5 gpf. In addition, WaterSense-labeled flushing urinals must meet specific criteria for flush performance and drain trap functionality and they are designed to be non-adjustable above their rated flush volume. These features provide for the longevity of water savings. The WaterSense specification is applicable to the:

- Urinal fixtures
- Pressurized flushing devices that deliver water to urinal fixtures
- Flush tank (gravity-type) flushing devices that deliver water to urinal fixtures.

[163] The inorganic mineral sediments found in non-water urinal plumbing drain pipes are comprised primarily of struvite (MgNH4PO4.6H2O) Magnesium Ammonium Phosphate Hexahydrate, also known as MAP. Other inorganic mineral sediments occur as well, such as Hydroxyapatite Ca5(PO4)3(OH) and Calcite (CaCO3) but at much lower concentrations. These sediments are soft, whereas sediments left in drainlines by flushing urinals are of entirely different material (calcite) and are hardened to the wall of the drainline and more difficult to remove. However, sediments resulting from flushing urinals require a much longer time than non-water urinals to build up and close off a drainline.

[164] CBSC, 2010

To ensure high performance and water savings, choose a valve and fixture combination with matching rated flush volumes.

Drainline transport

Non-water urinals can also be considered during urinal installation or replacement. When considering the installation of non-water urinals or very low volume flushing urinals (e.g., one pint per flush urinals), it is critical that the condition and design of the existing plumbing system be evaluated and the expected usage patterns be assessed in order to ensure that these products will meet the expectations of the facility manager and users. As a good rule of practice, adhere to the guidelines outlined in the IAPMO Green Plumbing and Mechanical Code Supplement[165], which requires at least one water supply fixture unit (i.e., a faucet or some other water using fixture) to be installed on the drainline upstream of the urinal fixture drain to facilitate drainline flow and rinsing. Supplemental water or even periodic manual flushing of the drainlines is important because these non-water and very low volume urinals deliver little to no water to the drain to flush out any solids that may build up over time. It is also important to carefully adhere to manufacturer-recommended cleaning and maintenance requirements to ensure products continue to perform as expected.

Savings Potential

Water savings can be achieved by replacing existing flushing urinals with WaterSense labeled flushing urinals, which use no more than 0.5 gpf. If an older, existing flushing urinal is replaced with a WaterSense labeled model, a facility may save between 200 and 1,600 gallons of water per user per year. Assuming that the average urinal is flushed approximately 18 times per day and is in use 260 days per year, replacing a single inefficient 1.5 gpf flushing urinal with a WaterSense labeled 0.5 gpf model could save more than 4,600 gallons of water per year. However, a large number of HEUs being offered by various manufacturers function with one pint of water (0.125 gpf). The savings estimate should reflect the rated flush volume of the urinal selected.

To estimate facility-specific water savings and payback, use the following information:

Current Water Use

To estimate the current water use of an existing flushing urinal, identify the following information and use Equation 2 below:

- Flush volume of the existing urinal. Urinals installed prior to 1994 have flush volumes that typically range between 1.5 and 3.5 gpf. Urinals installed in 1994 or later generally have flush volumes of 1.0 gpf or less.
- Average number of times the urinal is flushed per day, which depends upon the number of male occupants in the building. Male occupants use the urinal two times per day on average.[166]

[165] International Association of Plumbing and Mechanical Officials, 2010. *Green Plumbing & Mechanical Code Supplement.* Page 9, February.
[166] Amy, Vickers, *Handbook of Water Use and Conservation*, WaterPlow Press, 2001.

- Days of facility operation per year.

Equation 2:

Water Use of a Urinal (gallons/year) = Flush Volume (gallons/flush) X Number of Flushes (flushes/day) X Days of Facility Operation (days/year)

Water Use After Replacement

To estimate the water use of a replacement urinal, use the same equation, substituting the flow rate of the replacement urinal.

Individual Water Savings

The expected water savings is determined by subtracting the water use after replacement from the current water use.

California Water Savings Potential

An estimate of total potential statewide water savings that could result from the replacement of existing CII urinals with high-efficiency urinals was made in 2005[167]. That analysis estimated the savings potential to be between 20,000 and 24,000 acre-feet per year (AFY) of water. Another 2,000 to 3,000 AFY could be saved through legislation, codes, and standards applied to new construction[168].

Additional Resources and References

Alliance for Water Efficiency. 2010. Urinal Fixtures Introduction. www.allianceforwaterefficiency.org/Urinal_Fixtures_Introduction.aspx

California Building Standards Commission (CBSC), 2010. California Green Building Standards Code – 2010 – CalGreen, CCR, Title 24, Part 11. www.bsc.ca.gov/CALGreen/default.htm

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[167] California Urban Water Conservation Council , 2005. Evaluation of Potential Best Management Practices – High-Efficiency Plumbing Fixtures – Toilets and Urinals, November.

[168] Provisions for HEUs were subsequently mandated by the California Building Standards Commission through the provisions of CalGreen.

CASE STUDY – UNIVERSITY OF CALIFORNIA, IRVINE

UC Irvine (UCI) is the first of the California university campuses participating in the Strategic Energy Partnership (SEP) to join with the local water utility to reduce potable water use. Through joint funding with the Irvine Ranch Water District (IRWD), UCI's Plumbing Shop retrofitted 70 toilets in high-traffic restrooms with High-Efficiency Toilets (HETs). The HETs use 1.28 gallons per flush compared to the 3.0 gallons per flush used by the targeted toilets, equating to a 57 percent reduction in potable water consumption per toilet, totaling 2.6 million gallons and $11,800 in annual savings.

UCI has also taken advantage of the Metropolitan Water District of Southern California's "Save Water – Save A Buck" program to retrofit 83 urinals with High-Efficiency Urinals (HEUs). The HEUs flush with one pint (0.125 gallons) of water compared to the 1.5 and 3.5 gallons per flush used by the targeted urinals that were removed. This resulted in an average 95 percent drop in potable water consumption per urinal, totaling 3.4 million gallons and $15,700 in annual savings.

To determine the value of the water savings, UCI and IRWD commissioned a third party to calculate the

average usage and savings per fixture based on the campus population and number of fixtures on campus. With this report and an audit of all the restrooms on campus, UCI developed a work plan to replace the most inefficient toilets and urinals in those restrooms that get the most traffic and then estimate the water savings resulting from such replacements. The result was an average savings per fixture that IRWD could use to calculate the incentive value and UCI could use to calculate the annual savings in their operating budget for water.

Shower Systems

Overview

Residential-type showerheads are employed in a number of institutional and commercial applications, including dormitories, military housing, mixed-use commercial-residential projects, incarceration facilities, and transient lodging (hotels and motels). Specialized showers installed for safety purposes (eyewash and similar applications) are not included in this discussion.

Showerheads come in a variety of shapes, sizes, and configurations, including:

- *fixed showerheads*, affixed overhead and permanently attached to the wall;
- *handheld showerheads* attached to a flexible hose that can be detached from the wall and moved freely by the user; and
- *body sprays* (including spas and jets) that spray water onto the user from a direction other than overhead, usually from a vertical column on the shower wall.

Each type is uniquely suited to perform a specific function.

To reduce overall water use, the Energy Policy Act (EPAct) of 1992 established the maximum allowable flow rate for all showerheads sold in the United States as 2.5 gallons per minute (gpm). California's CalGreen code[169], effective beginning in 2011, limits flow for residential showers to 2.0 gpm[170] in new construction and renovations. It also prohibits multiple-head shower systems.

Since this standard was enacted, manufacturers have designed and now market showerheads that use significantly less water, some as low as 1.0 gpm.

Recent consumer market research identified three key performance attributes that are necessary to ensure user satisfaction under a variety of conditions: flow rate across a range of pressures, spray force, and spray coverage. Each of these criteria can be tested using a specific protocol that measures accuracy and reliability. All three criteria must be met to produce a "satisfactory" shower without using more water.

Operation, Maintenance, and User Education

For optimum showerhead operation, system pressure should be tested to ensure that it is within the operating parameters of the showerhead, usually between 20 and 80 psi, necessary to ensure that the showerhead will deliver the expected flow and performance. In addition, consider the following:

- Verify that the hot and cold water plumbing lines to the showerhead are routed through a shower compensating valve that meets the temperature control performance requirements of the American Society of Sanitary Engineers (ASSE) 1016 or American Society of Mechanical Engineers (ASME) A112.18.1/Canadian Standards Association (CSA) B125.1 standards when tested at the flow rate of the showerhead installed[171]. The compensating valve will prevent against significant fluctuations in water pressure and temperature and can reduce risks of thermal shock and scalding. A plumber can verify the compatibility of the showerhead and shower valve and, if necessary, install a valve that meets the recommended standards for the flow rate of the showerhead.
- Periodically inspect showerheads for scale buildup to ensure flow is not being restricted; remove scale as needed.
- Train users to report leaking or malfunctioning showerheads to the appropriate maintenance or management personnel.

[169] California Building Standards Commission (CBSC), 2010. California Green Building Standards Code – 2010 – CalGreen, CCR, Title 24, Part 11.

[170] Effective flush volume as defined in CBSC, 2010. An exception to the 0.5 gpf maximum can be proposed where the project applicant chooses the performance path rather than the prescriptive path for indoor water use. Refer to paragraph 5.303.2 in the code. Some jurisdictions mandate the 0.5 gpf maximum without exceptions.

[171] For example, a 1.5 gpm showerhead must be accompanied by a compensating valve rated and certified to the standard at 1.5 gpm in order to safely protect the bather.

Retrofit and Replacement Options

Because showerheads are relatively inexpensive, replacement is often more economical and practical than a retrofit. In general, avoid retrofitting existing inefficient showerheads with flow control inserts (which restrict water flow) or flow control valves (which can be activated to temporarily shut off water flow) to reduce the flow rate and save water. These devices may not provide adequate performance or physical safety in some facilities and can lead to user dissatisfaction.

In certain circumstances, single shower stalls may have been outfitted with multiple showerheads that can be activated simultaneously or individually by the user. In many cases, when these showerheads operate simultaneously, water consumption exceeds the federal maximum flow rate of 2.5 gpm for an individual showerhead. In such cases, the showering system can be retrofitted to operate individually rather than simultaneously, or so total consumption is equal to or less than 2.5 gpm at any given time.

When installing new showerheads or replacing older, inefficient showerheads, choose WaterSense-labeled models. WaterSense-labeled showerheads (www.epa.gov/watersense/products) are designed to consume 2.0 gpm or less, 20 percent more water-efficient than standard showerheads. In addition, WaterSense-labeled showerheads are independently certified to meet or exceed minimum performance requirements for spray coverage and intensity (force). WaterSense has established maximum and minimum flow rates at three different building line pressures: 80, 45, and 20 psi (the upper, mid, and lower range of potential household pressures)[172]. In addition to the pressure and flow rate requirements, WaterSense created criteria for spray coverage and intensity to ensure product performance under conditions of lower flow rates[173]. WaterSense-labeled showerheads are independently tested and certified to meet these criteria before they receive the label.

While remodeling, avoid purchasing and installing multiple showerheads systems unless the heads cannot be operated simultaneously *or* the total volume of water flowing from all showerheads is never greater than the 2.0 gpm maximum prescribed by CalGreen.

Savings Potential

If an older, existing showerhead is replaced with a WaterSense labeled model, a facility may save up to 1,200 gallons per showerhead per year. This replacement could result in payback in as little as one year.[174] To estimate facility-specific water savings use the following information:

[172] The minimum flow rate is defined as a percent deviation from the maximum flow rate of the showerhead. For instance, the showerhead's flow rate at 20 psi cannot be less than 60 percent of the maximum flow rate (i.e., a showerhead with a maximum rated flow rate of 2.0 gpm will not flow at less than 1.2 gpm even in a living unit with very low water pressure).

[173] WaterSense requires that minimum spray force shall not be less than 2.0 ounces (0.56 newtons [N]) at a pressure of 20 ± 1 psi (140 ± 7 kPa) at the inlet when water is flowing. Also, the total combined maximum volume of water collected in the 2- and 4-inch annular rings shall not be less than 25 percent or more than 75 percent of the total volume of water collected.

[174] U.S. Environmental Protection Agency's WaterSense Program. March 4, 2010. *WaterSense Specification for Showerheads Supporting Statement*. www.epa.gov/watersense/docs/showerheads_finalsuppstat508.pdf

Current Water Use

To estimate the current water use of an existing showerhead, identify the following information and use Equation 3 below:

- Flow rate of the existing showerhead. Showerheads installed since 1994 will usually flow at 2.5 gpm or less. Older showerheads may flow as high as 3 to 5 gpm. A simple measurement with a calibrated device can be used to determine the flow.
- Average duration of each shower. The average shower duration is approximately 8 minutes.[175]
- Average number of showers each person takes per day (usually 1).
- Number of building occupants.
- Days of facility operation or residency per year.

Equation 3:
Current Water Use of a Showerhead (gallons/year) = Flow Rate (gallons/minute) X Duration of Use (minutes) X Uses per Person per Day X Number of Building Occupants X Days of Operation (days/year)

Water Use After Replacement

To estimate the water use of a replacement WaterSense labeled showerhead, use Equation 3, substituting the rated flow rate of the replacement showerhead. WaterSense labeled showerheads use no more than 2.0 gpm.

Water Savings

The expected water savings is determined by subtracting the water use after replacement from the current water use.

Additional Resources and References

Alliance for Water Efficiency, 2011. Residential Shower and Bath Introduction. www.allianceforwaterefficiency.org/Residential_Shower_Introduction.aspx

California Building Standards Commission (CBSC), 2010. California Green Building Standards Code – 2010 – CalGreen, CCR, Title 24, Part 11. www.bsc.ca.gov/CALGreen/default.htm

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[175] Peter W. Mayer and William B, DeOreo. 1998. *Residential End Uses of Water*. Aquacraft, Inc. Water Engineering and Management. American Water Works Association. Page 102.

Faucets

Overview

Faucets can be found in restrooms, kitchens, break rooms, and service areas in all CII applications. Lavatory—or restroom— faucets are designed for either private or public use. Private use faucets are generally found in homes, hotel guest rooms, dorms, barracks, and hospital patient rooms. Public use lavatory faucets are found in all other applications and are intended for unrestricted use by more than one individual (i.e., employees, visitors, or other building occupants) in facilities such as public restrooms in offices, malls, schools, restaurants, or other commercial, industrial, or institutional buildings. Different code requirements apply to public and private applications as noted below.

When it comes to improving faucet water efficiency in lavatories, there are two different ways to apply technology: optimizing faucets and using faucet accessories. A faucet accessory is defined as a component that can be added, removed, or replaced easily and, when removed, does not prevent the faucet from functioning properly[176]. Faucet accessories include flow restrictors, flow regulators, aerators, and laminar flow devices[177]. While faucet accessories can be incorporated into new faucet design to control the flow rate, most often, accessories are external components that attach to an existing faucet's end spout.

In addition to typical, hand-operated components, lavatory faucets can also be equipped with automatic sensors to trigger the on/off mechanism when a user places their hands under and removes them from the fixture. It is important to note that automatic sensors do not provide additional water savings when compared to manually operated faucets[178], but provide important health and sanitary benefits as a hands-free option. Some jurisdictions mandate the use of automatic sensors by code in certain applications for sanitary reasons.

Some restrooms can also be equipped with metered or self-closing faucets. Metered faucets, when activated by the user, dispense a pre-set amount of water before shutting off. Self-closing faucets, operated with a spring-loaded knob or other mechanical device, automatically shut the water off when the user releases the knob or lever.

The standard flow rate of a faucet is dictated by its intended end use, as described below:

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[176] American Society of Mechanical Engineers (ASME) A112.18.1/Canadian Standards Association (CSA) B125.1 *Plumbing Supply Fittings*

[177] Aerators may be added to faucets to entrain air, reduce splash, and reduce the water flow. Common aerator flow rates are 0.5, 1.0, and 2.2 gpm. Aerators are circular screen disks attached to the faucet end spout. Vandal- and tamper-proof aerators should be installed in non-residential buildings. Aerators with manual flow adjustment are available for kitchen faucets. Because aerators entrain air that may insert pathogens into the water stream, and the pathogens may reside on the internal aerator screens, aerators should not be used in medical facilities. California regulations prohibit aerator use in hospitals, but laminar-flow restrictors may be used to prevent splash and reduce flow without air entrainment.

[178] Gauley, Bill and John Koeller. March 2010. *Sensor-Operated Plumbing Fixtures, Do They Save Water?* In most cases, automatic sensors open the faucet valve completely when in use, whereas users of manually controlled faucets typically do not turn the tap fully on. All independent studies performed to date of faucet use in non-residential applications show that water use is significantly higher at installations equipped with sensor activation when compared to traditionally manually operated faucets.

Private Use Lavatory Faucets

The Energy Policy Act (EPAct) of 1992 originally established the maximum flow rate for all private use lavatory faucets sold in the United States as 2.5 gallons per minute (gpm) at 80 psi of line pressure. In 1994, the ASME A112.18.1 national standard lowered the maximum flow rate for lavatory faucets and lavatory faucet replacement aerators to 2.2 gpm at 60 psi in response to industry requests for conformity with a single standard. In 1998, the U.S. Department of Energy (DOE) adopted the 2.2 gpm at 60 psi maximum flow rate standard for all faucets (see 63 FR 13307; March 18, 1998). This national standard is codified in the *U.S. Code of Federal Regulations* at 10 *CFR* Part 430.32. *Public Use Lavatory Faucets*

Public Use Lavatory Faucets

The ASME A112.18.1 American national standard was further amended in the mid-1990s to change the maximum flow rate for public faucets to 0.5 gpm; the three major model plumbing codes[179] all incorporated that standard by reference. Though not a federal regulation, 0.5 gpm became the national maximum permitted flow rate in all public use applications governed by one of the three plumbing codes, irrespective of EPAct. Despite these code requirements, many old and new public use faucets still possess higher flow rates, typically between 2.0 and 2.5 gpm in violation of the prevailing national standard and implementing plumbing codes.

Metering Faucets

Metering faucets are frequently found in public use applications, especially in high-traffic volume rest rooms. EPAct of 1992 further addresses these types of faucets and sets a maximum water use of 0.25 gallons per cycle (gpc). It is important to note that there is no maximum flow rate per minute for metering faucets[180].

Kitchen Faucets

Similar to lavatory faucets, EPAct 1992 originally established the maximum allowable flow rate for kitchen faucets as 2.5 gpm at 80 psi pressure. The ASME A112.18.1/CSA B125.1 national standard lowers the maximum flow rate for kitchen faucets and kitchen faucet replacement aerators to 2.2 gpm at 60 psi (CalGreen at 1.8 gpm at 60 psi). In response to industry requests for conformity with a single standard, DOE adopted the 2.2 gpm at 60 psi maximum flow rate standard for all faucets in 1998 (see 63 FR 13307; March 18, 1998). This national standard is codified in the *U.S. Code of Federal Regulations* at 10 *CFR* Part 430.32.

Thus far, national codes and voluntary standards have not attempted to further address the efficiency of kitchen sink faucets because their use is largely volume-dependent. State and local jurisdictions have, in some cases, adopted lower threshold maximums. However, lowering the flow rate of kitchen faucets could lead to increased wait times for filling containers or for receiving hot water, which would affect performance and likely create user dissatisfaction.

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[179] International Plumbing Code (IPC), Uniform Plumbing Code (UPC), and National Standard Plumbing Code (NSPC)

[180] While EPAct, CalGreen, and the national standards and model codes all set a maximum quantity of water per cycle (event), there is no time period nor maximum flow rate specified. Therefore, one cycle of use could consist of operating for 15 seconds at 1.0 gpm and be fully compliant with EPAct (12 seconds for CalGreen), OR operate for 30 seconds at 0.5 gpm (24 seconds for CalGreen), or any other combination that yielded a quantity of water at or below the prescribed maximum.

Service Sink Faucets

Sinks present in some facilities have purposes other than traditional kitchen or lavatory uses. These sinks can be found in janitorial closets, laundries, laboratories, classrooms, or other areas. There are no federal regulations limiting the flow rate of these faucets, but flow rate should be carefully considered with the intended end use, expected performance, and water efficiency in mind.

Other Specialized Faucet Types

In addition to the service sink faucets noted above, there are other faucet functions that do not fall within the regulated categories of lavatory and kitchen faucets and, as such, have no Federal maximum flow rate. For example, these include sinks used for removing make-up in a theater setting, sinks used for washing athletic gear in a gymnasium, and sinks used for bathing infants, all of which require higher flow rates to accomplish the intended tasks.

CalGreen

California's CalGreen code[181], effective beginning in 2011, limits flow rates for faucets in new construction and renovations as follows[182]:

Lavatory faucets (non-residential)	0.4 gpm
Lavatory faucets (residential[183])	1.5 gpm
Kitchen faucets	1.8 gpm
Metering faucets[184]	0.2 gallons/cycle

<u>*Operation, Maintenance, and User Education*</u>

For optimum faucet operation, test the system water pressure to ensure that it is between 20 and 80 psi, necessary for the faucet to deliver the expected flow and performance. In addition, consider the following:

- Periodically inspect faucet aerators for scale and sediment buildup to ensure flow is not being restricted. Inspection should occur every 6 to 12 months, depending upon local water quality. Clean or replace the aerator or other spout end device, if necessary.
- If installed, check and adjust automatic sensors to ensure they are operating properly to avoid faucets from running longer or more frequently than necessary.
- Post materials in restrooms and kitchens to educate users of the facility's water-efficiency goals. Remind users to turn off the tap when they complete their use.

[181] California Building Standards Commission (CBSC), 2010. California Green Building Standards Code – 2010 – CalGreen, CCR, Title 24, Part 11.

[182] An exception to the faucet maximums can be proposed where the project applicant chooses the performance path rather than the prescriptive path for indoor water use. Refer to paragraph 5.303.2 in the CalGreen code.

[183] Applies to residential uses within an institutional setting and to residential within mixed use commercial structures.

[184] No gpm flow rate maximum.

- Train users to report continuously running, leaking, or otherwise malfunctioning faucets to the appropriate maintenance or management personnel.
- Do not use running water to thaw food products and discourage this practice in food service operations.

Retrofit and Replacement Options

To retrofit or replace an existing faucet to increase water efficiency, consider the following:

- For lavatory faucet retrofits in public restrooms, install faucet aerators or laminar flow devices that function at no more than 0.4 gpm, the CalGreen maximum.
- For lavatory faucet retrofits in private restrooms, look for WaterSense labeled lavatory faucets and faucet accessories (aerators or laminar flow devices) (http://www.epa.gov/watersense/products), which have flow rates of 1.5 gpm or less at 60 psi and no less than 0.8 gpm at 20 psi and are compliant with CalGreen.
- For kitchen faucet retrofits, install aerators or laminar flow devices that achieve a flow rate of no greater than 1.8 gpm in accordance with CalGreen.
- Install temporary shut-off or foot-operated valves for kitchen faucets and faucets in food service operations. These valves close during intermittent activities such as scrubbing or dishwashing. The water flow can be reactivated at the previous temperature without the need to remix hot and cold water.
- For all faucet retrofits in medical facilities (including medical research and patient care facilities), install laminar flow devices instead of faucet aerators. Since laminar flow faucets do not inject air into the water, there is a lower risk of bacterial contamination.[185]
- For service sinks and specialized applications, install retrofit devices that reduce the water flow, but without inhibiting the function of the sink (i.e., if the sink's function is volume dependent, do not reduce faucet flow rate to the point that it has to be used significantly longer).

Savings Potential

Water savings for both private and public use lavatory faucets can be achieved by retrofitting existing faucets with aerators or replacing existing faucets. The same amount of water savings can be expected for a retrofit or replacement; however, retrofitting existing faucets with aerators will yield the shortest payback period due to minimal costs. Retrofitting private use lavatory faucets used in dorms, barracks, hotels or hospital patient rooms with WaterSense-labeled faucet accessories (such as an aerator) may save a facility between 160 and 220 gallons of water per user per year. Since WaterSense-labeled faucet accessories typically cost less than $10, these devices normally pay for themselves in less than one year. At the same time, retrofitting public use faucets to reduce the flow rate to the CalGreen maximum of 0.4 gpm could save a facility between 150 and 600 gallons of water per user per year.

[185] Federal Energy Management Program. Water Management Training, Faucets and Showerheads. http://femptraining.labworks.org/mod/resource/view.php?id=60

To estimate facility-specific water savings and payback, use the following information:

Current Water Use

To estimate the current water use of an existing lavatory faucet, identify the following information and use Equation 4 below:

- Flow rate of the existing lavatory faucet. Faucets installed in 1996 or later generally have flow rates of 2.2 gpm or less (commercial applications may be as low as 0.5 gpm). Faucets installed between 1994 and 1996 generally have flow rates of 2.5 gpm or less. A simple measurement with a calibrated device can be used to determine the existing flow.
- Average daily use time. The average residential lavatory faucet use is approximately 8 minutes per person per day.[186] For commercial and industrial applications, usage is approximately one-fourth of that amount.
- Number of building occupants.
- Days of facility operation per year.

Equation 4:
Water Use of a Faucet (gallons/year) = Flow Rate (gallons/minute) X Daily Use Time (minutes/day) X Number of Building Occupants X Days of Facility Operation (days/year)

Water Use After Retrofit or Replacement

To estimate the water use after retrofitting or replacing an existing faucet with a water-efficient model or aerator, use Equation 4, substituting the flow rate of the retrofit or replacement. WaterSense labeled aerators use no more than 1.5 gpm. Manually operated public use lavatory faucets can be retrofitted with 0.5 gpm aerators.

Water Savings

The expected water savings is determined by subtracting the water use after replacement from the current water use.

Additional Resources and References

Alliance for Water Efficiency. Faucet Fixtures Introduction. www.allianceforwaterefficiency.org/Faucet_Fixtures_Introduction.aspx

California Building Standards Commission (CBSC), 2010. California Green Building Standards Code – 2010 – CalGreen, CCR, Title 24, Part 11. www.bsc.ca.gov/CALGreen/default.htm

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[186] Mayer, Peter W., and DeOreo William B. 1998. *Residential End Uses of Water*. Aquacraft, Inc. Water Engineering and Management. American Water Works Association.

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www.sydneywater.com.au/Publications/CaseStudies/StAndrewsCollegeConserver3.pdf

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7C7: Pools and Spas

Background

Pools, spas, and ornamental fountains with recirculating filtration and disinfection equipment can be found at homes, schools, gymnasiums, hotels, apartments, public parks, water parks, hydrotherapy pools, and businesses. These features provide recreational opportunities and aesthetic and artful attractions that can benefit the community.

According to one recent study, over 90 percent of all in-ground pools and almost all above-ground pools and hot tubs are in residential settings, and thus represent the most significant portion of water use in this sector. According to a 2009 Kenilworth Media, Inc. study[187], there are 5.1 million in-ground pools, 3.7 above-ground pools, and 6.6 million hot tubs in the United States. In 2007, approximately 131,000 new in-ground pools were sold with the Southwest (California, Nevada, Arizona, and Utah) accounting for 23 percent of sales nationally. Commercial pools (apartments, hotels, and motels) and public pools account for only three (3) percent of existing pools, but these commercial and institutional pools are the largest in size and water capacity. While the number of ornamental fountains is much smaller, they use essentially the same type of filtration and disinfection technology as pools.

According to the California Urban Water Conservation Council's report, **Evaluation of Potential Best Management Practices - Pools, Spas, and Fountains Purpose,** the number of commercial and institutional pools including apartment complex pools in California is estimated to be 115,100 (Table 1.). The report further estimates that there are 1.4 million hot tubs in California. If 90 percent of these hot tubs are residential, then there may be as many 140,000 commercial hot tubs in the state.

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[187] Pool & Spa Marketing, March 2009 www.poolspamarketing.com

[2] Evaluation of Potential Best Management Practices - Pools, Spas, and Fountains Purpose, California Urban Water Conservation Council, September, 2010

Table 1. Estimated Number of Pool and Spa Facilities in California	
Type	Number
Hot Tubs	1,400,000
In-ground Pools (residential)(single family)	1,062,000
In-ground Pools (multi-family, apartment)	50,000
In-ground Pools (commercial, public)	55,000
In-ground Pools (hotels & lodging)	10,000
Above-ground Pools (residential)	1,000,000
Olympic Pools	100
TOTAL (estimated)	3,577,100

This document describes water use by commercial and institutional pools, spas, and fountains, and it focuses on ways to achieve a higher degree of water use efficiency including information on: (1) evaporation, (2) filtration, (3) leaks, people use, and maintenance, and (4) total dissolved solids control.

Overview

Water use is the common denominator for swimming pools, hot tubs, splash pools, ornamental fountains, and similar water features. Although some "fill and dump" type systems (dumped and refilled ever day or two) are still unfortunately found, the use of recirculating filtration and disinfection equipment has been the industry standard for years. The few existing fill and dump facilities are being eliminated, so this report concentrates on pools, fountains, and other facilities equipped with recirculation systems.

Evaporation, backwash, control of total dissolved solids - TDS, and cleaning and vacuuming of pools all are common, necessary elements associated with pools and fountains. Leaks, poor chemical and equipment maintenance, drag and splash-out, and other wasteful practices all result in preventable water loss.

The first step in understanding how to reduce water use for pools, hot tubs, fountains or water features is to examine how modern systems work. Components of a modern recirculating system include a strainer, filter, pump, dump valve and intake (drain and skimmer), return flow connections, and piping. Figure 1 illustrates these features for a typical swimming pool. The illustration represents perhaps the most complicated type of system since it includes a heater.

Figure 1. Diagram of a Swimming Pool Mechanical System

The overflow and fill system of a pool can include perimeter-type overflow gutters, surface skimmers, other surface water collecting system components, and their interconnecting piping. Most pools are also equipped with an equalization tank that operates at the same level as the water in the pool, providing a place that is separate from active pool use so it is not turbulent. The equalization tank prevents the fill or float valve from bouncing around when the pool is in use, which would result in wasting water. Figure 2 illustrates such an equalization tank and float valve.

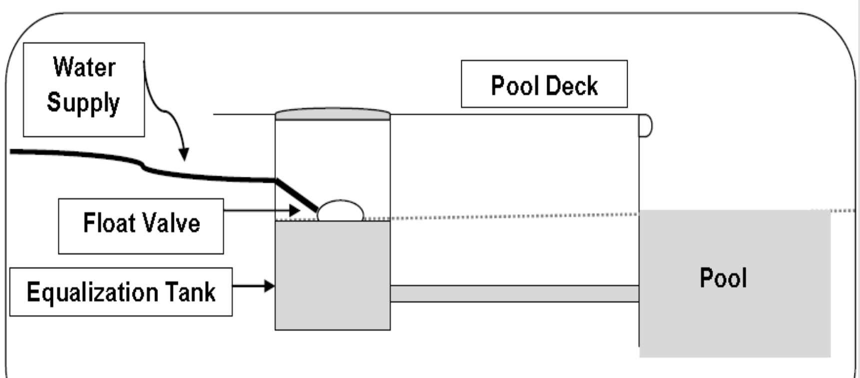

Figure 2. Refill assembly showing fill valve and equalization tank

The fill valve is most often a simple float assembly, but other water level devices, ranging from sonic sensors to elevation pressure sensors, are available. Pool overflows are usually simple stand pipes or overflow thresholds that allow water to flow freely into the sanitary sewer or drain when the prescribed water level is exceeded.

The type and size of pools and spas varies depending on intended use and location. With the exception of official Olympic pool dimensions, there is no "standard size." However, Table 2 summarizes a "typical size" for pools and spas for various intended uses ranging from above-ground residential pools to public pools to hot tubs.

Table 2. Typical Pool Sizes*

Type of Facility	Area Sq. Ft.	Depth Feet	Volume Gallons
Hot tub	40	3	1,122
Above-ground	252	4	7,540
In-ground residential (single family)	450	4.5	15,147
In-ground apartment	800	4.5	26,928
In-ground hotel	1,000	4.5	33,660
In-ground public	4,000	5	149,600
Olympic	14,432	8	863,611

* Based upon examination of multiple pool installer web sites and conversation with officials from the Association of Pool and Spa Professionals - Southern California Chapter.

Equipment and Design Options

Pools, spas, and fountains with recirculation equipment have many ways in which water is consumed, including:

1. Evaporation
2. Leaks
3. Splash out
4. Disinfection, cleaning and maintenance and water quality control
5. Filter operations

Controlling these losses is critical to reducing water use, and especially to reducing waste. Likewise, good pool maintenance is essential. The trilogy for maintaining water quality is filtration, sanitation (disinfection and pool cleaning), and circulation (keeping the water circulating through the filter and disinfectant feed system).

Evaporation

Evaporation occurs naturally from all water surfaces. Evaporation includes natural evaporation and evaporation from indoor heated pools and hot tubs.

Natural evaporation: In California, evaporation ranges from 40 inches per year in the northwest to 140 inches per year in the in the southeastern portion of the state along the Arizona border. In the populated areas where most of the pools and fountains are located, the evaporation rates are in the range of 50 inches to 75 inches per year, or 0.085 to 0.128 gallons per square foot per day.

The size of the pool surface area and its location will determine how much evaporation occurs naturally. Pool and hot tub sizes range from 40 square feet for hot tubs to over 14,432 square feet for Olympic pools. Table 4 summarizes natural evaporation from pools in various locations across California.

Table 4. Approximate Average Annual Evaporation from Pools and Hot Tubs (gallons/year)

Typical Pool Area Square Feet		Pool Size (surface area in square feet)						
		40	252	450	800	1,000	4,000	14,432
City	Natural Evaporation (inches per year)	Hot tub	Above-ground pool	In-ground residential	In-ground apartment	In-ground hotel	In-ground public	Regulation Olympic
Sacramento	65	6,278	10,210	18,233	32,413	40,517	162,067	584,737
San Francisco	50	6,278	7,854	14,025	24,933	31,167	124,667	449,797
Berkeley	60	6,278	9,425	16,830	29,920	37,400	149,600	539,757
Fresno	75	6,278	11,781	21,038	37,400	46,750	187,000	674,696
Los Angeles	60	6,278	9,425	16,830	29,920	37,400	149,600	539,757
San Diego	60	6,278	9,425	16,830	29,920	37,400	149,600	539,757
Bakersfield	75	6,278	11,781	21,038	37,400	46,750	187,000	674,696
California Average	63.6	6,278	9,986	17,832	31,701	39,626	158,505	571,885
Source: Evaluation of Potential Best Management Practices - Pools, Spas, and Fountains Purpose, California Urban Water Conservation Council, September, 2010								

A 2008 NRDC report[188] states that only about 10 percent of pools nationally are heated. By contrast, hot tubs are nearly always heated. Table 5 provides estimates of water loss from heated indoor pools, spas, and hot tubs. As the data show, most heated swimming pool evaporation rates are similar to pan evaporation rates of 0.085 and 0.128 gallons per square foot per day. The exception is the hot tub, which has a significantly higher evaporation rate of 0.41 to 0.45 gallons per square foot per day. Therefore, the average pan evaporation rate of 63.6 inches or 0.109 gallons per square foot per day is used for all pools and 0.43 gallons per square foot per day is used for hot tubs.

[188] http://www.scribd.com/doc/17720453/NRDC-Report-Synergies-in-Swimming-Pool-Efficiency

Table 5. Evaporation from Heated Indoor Pools							
Type of indoor heated pool	**Water temp °F**	**Air temp °F**	**Evaporation Factor (gal/hr/sq ft)**		**Activity Factor**	**Gal/day/ Sq ft at 60% humidity**	**Gal/day/ Sq ft at 50% humidity**
			60% humidity	50% humidity			
Residential	85	87	0.02	0.028	1	0.06	0.08
Hotel	82	84	0.019	0.026	1.3	0.07	0.10
Hot Tubs	104	88	0.071	0.079	2	0.41	0.45
Health/Competition	79	81	0.018	0.023	1.6	0.08	0.11
Heated Public	85	87	0.02	0.028	2	0.12	0.16

Source: Derived from Dehumidifier Corporation of America, Cedarburg WI[189]

One factor that results in evaporation from fountains and water features in pools is spraying. Spraying creates additional water surface, which in turn, causes additional evaporation. Although wetted surface and the sprays create surfaces of water from which evaporation occurs, fountains and pools typically store the majority of their water in covered pool sumps, thus significantly reducing evaporation when the spray features are not in use. Table 5 summarizes evaporation estimates for different size of pools taken from Table 1.

Leaks

All pools, hot tubs, fountains and water features are subject to leaks. The most common locations for leaks are where the pool and pipes are joined, at separations along the pool top and the bond beam, in the piping either on the suction or return lines to the filtration system, and in the liner of the pool itself. Another area where leaks are found is around the pump seals such as "O" rings. Installing a meter on the pool makeup line is the most effective way of monitoring pool or fountain water use as well as for checking for leaks[190]. The cost of adding a meter on the make-up line of a typical residential pool is under $150 at the time of construction, but can ultimately result in saving thousands of gallons of otherwise wasted water. For commercial and

[189] www.dehumidifiercorp.com
[190] This is not necessary on very small fountains pools, above-ground pools, or hot tubs, but if the pool or fountain holds over 10,000 gallons it should be considered.

public pools, and for larger water fountains containing 10,000 gallons of more, a makeup meter is essential to efficient operation and is strongly recommended for in-ground residential pools[191].

Some pool websites and pool "experts" suggest that if a pool is losing more than two inches of water per week, it may have a leak. For high evaporation areas, this threshold may be increased to three inches per week. Also, air bubbles in either the pump strainer basket or the water in the return line where the water enters the pool (even after three or four minutes of the pump running) may indicate that a leak exists in the suction side of the piping, resulting in sucking in air. The most obvious indicator of a pool leak is when wet spots appear around the pool, filter, or piping.

Splash-Out Reduction

"Splash-out" is the water lost as people in the pool cause water to move and splash against and over the sides. Similarly, "drag-out" is the water lost as swimmers exit the pool. The design of the edge of the pool and the "freeboard" or level of the pool water below both the edge and the top of the pool overflow help reduce water loss. One of the simplest ways to reduce splash-out is to set the pool level several inches lower than the edge of the pool and the overflow. In addition to reducing the amount of water splashed-out, this practice also allows for the retention of rainfall when it occurs. Some pool officials recommend retaining at least four inches of freeboard.

The other directly helpful design feature is beveling the edge of the pool so it slightly overhangs the edge. Doing so helps redirect splashes into the pool. It is important to remember, however, that the area slightly back from the pool edge must be raised in order to prevent dirty rainwater from flowing across the lawn and deck into the pool.

Most commercial pools and many residential pools have gutter and grate systems around the edge of the pool to catch splashes. These are troughs that are built into the wall of the pool and drain back into the pool or can be used as skimmer-type devices. Figure 3 illustrates such a device. The system shown here is a Duro Tech system[192].

[191] Owners and operators may also check for a leak in a pool by placing a five gallon bucket on a step in the pool where the bucket will be at least seventy percent submerged. The water supply to the pool should be turned off and the bucket filled to the exact same level as the water in the pool. After 12 to 24 hours, the bucket and pool water levels should be checked again. If there is no leak, the water levels should still be the same, but if the pool level is lower than the bucket level, it indicates that there is a leak below the water line of the pool. However, this method will not disclose leaks in plumbing above the water line.

[192] http://www.renosys.com/duratech.html

Figure 3. Pool Gutter and Grate System

Disinfection and Water Quality Control

Properly maintaining pool water quality saves in three ways.

1. It reduces the number of times the pool must be drained to maintain total dissolved solids levels.
2. It reduces the number of backwashes needed.
3. It reduces the potential for corrosion or other factors that can cause leaks.

Disinfection: Disinfection is an absolute necessity for all pools, hot tubs, and ornamental recirculating fountains. Without it, the water would harbor harmful bacteria, grow algae, and require frequent dumping and refilling. The most common chemical used for disinfection is chlorine in one of its several forms. Larger pools sometimes use chlorine gas, while other pools may use chlorine that contains chemicals such as chloramines or sodium and calcium hypochlorite. These chemicals can come in powder, tablet, gas, or liquid form. Other chemical disinfections include iodine and bromine. Chlorine stabilizers, such as cyanuric acid, are frequently added to help retard the loss of chlorine.

A new type of chlorine disinfection system uses salt dissolved in the pool water and an electrolysis-type device to generate chlorine from that salt. These systems are called "salt pools" and require the addition of salt to keep total dissolved levels between 2,000 and 3,500 ppm for proper operation of the equipment. Exact numbers are not available, but the percent of all pools currently using this method is assumed to be very small.

Ozone and ultraviolet light (UV) have also found applications in pool disinfection. With recent concern for cryptosporidium in some commercial pools, systems that include precoat filters, such as perlite or diatomaceous earth (DE), followed by UV disinfection, have been installed in addition to chlorine disinfection.

Algaecides are sometimes used to control both green and mustard-type algae problems. Some of the first to be used were cooper compounds. While they work, they are toxic to plants and can stain pool surfaces. Quaternary ammonia compounds have been used successfully for a long time and do not have the plant toxicity of cooper if the pool water is ever to be used for irrigation.

Water Quality: Table 6 summarizes recommended minimum and maximum levels for constituents for conventional swimming pools.

Table 6. Recommended Ranges for Selected Parameters for Conventional Swimming Pools[193]		
Constituent	Minimum*	Maximum*
Total Dissolved Solids (TDS) - Regular Pools	300 ppm	2,000 ppm
Total Dissolved Solids (TDS) - Salt Pools	2,000 ppm	3,500 ppm
Cyan uric Acid	10 ppm	100 ppm
Free Chlorine	3 ppm	10 ppm
Hardness	150 ppm @$CaCO_3$	500ppm @$CaCO_3$
Total Alkalinity	60 ppm @$CaCO_3$	180 @$CaCO_3$
pH	7.2	7.6

*-ppm: parts per million and is equal to milligrams per liter (mg/L)

Source: Center for Disease Control (CDC), Healthy Housing Reference Manual

Maintaining proper pH, alkalinity, and hardness levels to reduce corrosion and prevent damage to pool surfaces extends equipment and pool life and reduces the number of times pools must be dumped and refilled. Total dissolved solids control is another major factor in how much water is used in pool operations. All pools will eventually require the water to be either exchanged or treated to remove dissolved contaminants in the pool, such as body salts, sun tan lotions, other substances applied to the body, the salts in the chemicals added to the pool to control biological growth, windblown dust and salts, and the increases in salt concentrations in the pool water\ resulting from evaporation.

Maintaining proper balances within the pool chemistry not only benefit the comfort and health of the swimme, they also indicate when it is time to exchange the water in the pool (dump and fill the pool). Cleaning the pool and maintaining proper chemical balance and disinfection levels all play a major role in delaying the time that the water in the pool must be exchanged.

In warmer climates, such as much of California and the southwest, pools are typically kept full with circulation systems working year round. Some larger pools are equipped with conductivity controllers that act to dump water at a predetermined level of total dissolved solids. These systems have the advantage of not having to dump the entire pool, and they produce a frequent source of water that could be used for irrigation or other purposes. In all of these cases, water

[193] http://www.cdc.gov/nceh/publications/books/housing/cha14.htm

with high dissolved solids is simply dumped to drain and replaced with fresh water. The volume of water depends on four factors:

- The volume of the pool
- The dissolved solids in the makeup water
- The type and amount of treatment chemicals added
- The local evaporation rate.

Treatment chemicals, such as cyanuric acid, which is used to retard chlorine loss, can also build up to unacceptable levels since it does not evaporate like chlorine. The use of calcium hypochlorite tablets can add calcium hardness.

Figure 4. Pool Reverse Osmosis System

In recent years, the use of Reverse Osmosis and Nanofiltration (RO and NF) have shown significant promise for reducing water lost through the necessary dumping of pool water to reduce dissolved minerals buildup. These products have become more sophisticated. For example, Clean Water Products[194] of Tucson, Arizona, one of the first in this market, reports that they can recover up to 78% of the water that was previously wasted.. In addition, as shown in Figure 4, the system is portable. Other companies throughout the Southwest are beginning to offer similar services.

The same considerations hold for fountains, which often reach high TDS levels faster than pools, because spraying and increasing evaporation rates. Finally, the Association of Pool and Spa Professionals (APSA) recommends that hot tubs be drained several times a year.

Based on California evaporation rates and the water quality recommendations of the Center for Disease Control, California pools would have to be dumped and refilled on an average of once every 27 months.[10] Table 7 summarizes the water use implications for that.

Table 7. Water Typically Used to Control Total Dissolved Solids by Dumping Pool

Type of Pool	Pool Volume	Gallons per year *(Dump every 27 months on average)*
Hot Tub	1,122	499

[194] http://www.cleanwaterproducts.net/Swimming_Pools.html

Above Ground*	7,540	3,351
In Ground Residential	15,147	6,732
Apartment	26,928	11,968
Hotel/Motel	33,660	14,960
Public	149,600	66,489
Olympic	863,611	383,827

Filtration Equipment

At the heart of all pool water treatment systems are filters to remove particulate matter from the water and keep the water clear. The filter systems consist of a pump to circulate water and the actual filter. All of these systems are normally preceded by strainer baskets to catch larger debris both in the pool skimmers and just before the pump, significantly extending the time between backwashes and cleanings, saving both water and labor.

Figure 5. Large Sand Filters a Public Pool

There are three basic filter configurations. The most common filter in use for both residential and commercial pools is the sand filter. Precoat filters (diatomaceous earth - DE, perlite, and cellulose) and cartridge filters have also gained ground in recent years. The precoat filters include industrial systems that can significantly reduce water use in larger facilities. Each is described below.

Sand and zeolite filters: Sand filters such as the two shown in Figure 5 are found in large commercial and public pools. As the name implies, they use sand or zeolite as the filter medium. The water is pumped under pressure into the top of the filter. It passes through the sand, which filters out particulates. As it operates, a layer of material filtered out of the water builds up on the top of the sand bed. When the pressure difference from the top of the bed to the bottom of the bed exceeds 8-10 pounds per square inch, the filter should be backwashed.

Special valves allow this backwashing to happen. The water moves from the bottom of the filter up through the filter material to the top, discharging the accumulated dirt. A sight glass is used to determine when the dirt has been removed, which is revealed when the water in the sight glass appears clear. Sand filters are used on all size pools. Larger pools can use horizontal filters, which are simple tanks on their sides.

Cartridge filters: Cartridge filters use pleated paper-type material. The filter elements need cleaning only a few times a year. Old, wasteful disposable filter cartridges should not be re-used. However, modern re-usable cartridges need only to be washed off with a hose and returned to the filter housing. Since these filters do not need to be backwashed, they are the most water-efficient type available for all but the largest pools, and they are finding wide acceptance in the residential and smaller apartment pool market. Because they are water efficient, some local governments are encouraging their use.

According to a 2008 National Resource Defense Council report to the California Energy Commission[195], properly sized cartridge filter systems use less energy than comparable sand and DE filters in home use.

Precoat filters: Precoat filters include conventional diatomaceous earth[196] (DE), cellulose[197], or perlite[198] filters, as well as regenerative filters that reuse the filter media. These filters remove particles down to 5 microns in size, while sand and cartridge filters work in the 10- to 40-micron removal range[199]. Precoat filters have hundreds to sometimes over 1,000 fabric-coated tubes inside a pressure container. The filter media (DE, cellulose or perlite) is made into a slurry and mixed with the water in the filter. The media is then deposited on the tubes by the water being pumped through the filter. Conventional precoat filters must have the DE or perlite replaced after each backwash.

With regenerative precoat filters, the media is periodically "bumped" off of the filter tubes by backflow, air agitation, mechanical shaking, or a combination of the three. It is then recoated onto the filter cloth. Regenerative filters save significant volumes of water and filter media since the media can be recycled up to 30 times before it is ultimately discharged to waste.

For large commercial pools, automated precoat, regenerative filter systems are available. These systems are also sometimes called industrial filters since their use originated in food process and water treatment operations. A significant water saving factor with these filters is that the internal filter media recycling occurs about thirty times before the medium is dumped and replaced. No water is lost in the recoating process. When the media is flushed, the only water dumped is the water in the filter plus one additional filter volume to make sure the vessel is completely rinsed. This means that the backwash water needed is equal to about twice the

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[195] http://www.scribd.com/doc/17720453/NRDC-Report-Synergies-in-Swimming-Pool-Efficiency

[196] Diatomaceous earth is a white powder made from the "skeletons" of small aquatic plants in the algae family called diatoms. It is inert, but breathing the powder can be harmful since the skeletons are made up of silica materials. Residential and commercial filters typically use either DE or perlite media. In recent years, many wastewater utilities have placed bans on the discharge of diatomaceous earth to sanitary sewers since it tends to settle out and clog sewer lines. Settling tanks and bag filters are often required to remove the DE before the water can be discharged. The DE can either be disposed of in the trash or used as a soil amendment. DE has a bulk density of 19 pounds to 22 pounds per cubic foot.

[197] Cellulose is made from plant fibers. It is not widely used for pools, but is used in some food and beverage operations.

[198] Perlite is made from a silicon-based material found in volcanic deposits. When heated, it expands to form a very lightweight, chemically inert material that is used for filtration, as a soil conditioner, and insulation. Because it is so light weight, it tends to float on water when dry. It does not have the strong tendency to settle out in sewer lines that DE does. For this reason, many wastewater utilities have allowed filter backwash water from perlite-coated filters to be discharged to sewers. Many utilities collect the backwash water and use the perlite as a soil amendment. Perlite has a bulk density of two to eight pounds per cubic foot.

[199] poolplaza.com

volume of the filters themselves. This is different from home DE filters that use the pool pump to force water through the filter.

In addition, these large industrial units sometimes use air to "bump" the filter media off of the filter elements, thus eliminating another water use[200]. This air bumping makes regenerative precoat (industrial) filters very water-efficient. Since the perlite media can be bumped and redistributed about thirty times before needing to backwash, the elapsed time between backwashing stretches to months rather than weeks or even days for large commercial pool sand filter systems. Table 7 summarizes selection factors for filtration systems for smaller apartment and hotel swimming pools.

Table 7. Filter Selection Factors for Pools[201]

	Sand	Coated Media	Cartridge
Frequency of Cleaning	Every week	4-8 weeks	Depends on unit
When to clean *(Difference in pressure across filter)*	5-10 psi	8-10 psi	8-10 psi
How cleaned	Backwash	Backwash[(a)]	Take apart & wash with hose
Filtration *(microns)*	20-40	5	10 (can vary on cartridge)
Time between media replacement	3-6 years	Every backwash	2-4 years depending on filter
Cost of media	\$0.50 to \$1.00/lb	\$0.15 -\$0.50/lb	\$15-\$100 each
Residential use	Yes	Yes	Yes
Commercial use	Yes	Yes[(b)]	Not Recommended
Backwash flow time	2-5 minutes[(c)]	1-5 minutes[(c)]	Remove & wash

(a) DE and Pearlite filters should be "bumped and swirled" whenever pressure drop across filter reaches 8-10 psi.

(b) DE not recommended for apartments, condominiums or hotels since the filters quickly become clogged with the high rate of use. Specially designed DE and Pearlite filters are made for high volume use though.

(c) Typical times. Filter must be backwashed until sight glass is running clear.

[200] http://www.defenderfilter.com/
[201] Personal communications, 2010. Robert Hawkin and Scott Hyland, Neptune Benson, Coventry, RI

Figure 6 summarizes water use for various types of filtration systems for commercial pool operation. From this information, it is clear that sand filters need more water for backwashing than other filter types.

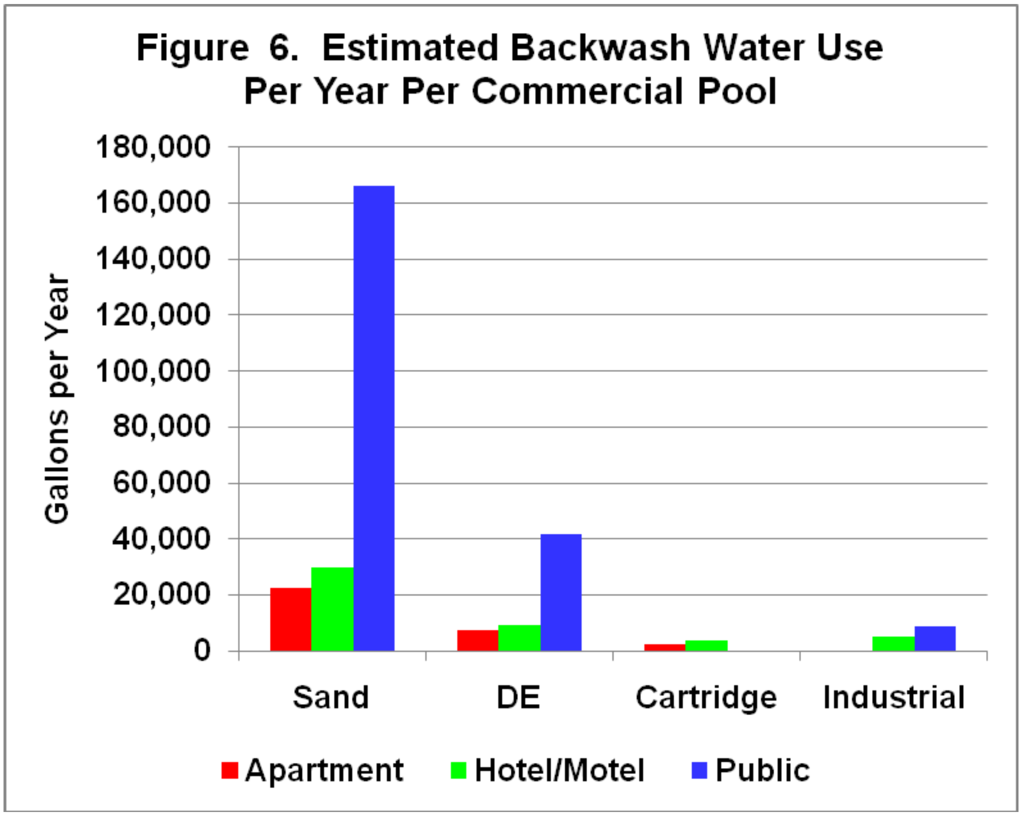

Figure 6. Estimated Backwash Water Use Per Year Per Commercial Pool

Pool cleaners: Pool vacuum cleaning equipment removes debris from the bottom and sides of pools. This equipment includes hand-held vacuum hoses that an operator draws along the bottom of the pool and automatic systems that move around the pool on their own. There are four system types. The suction type is attached to the suction port on the pool and uses the pool filter to capture debris. This system is effective, but because the debris and dirt are captured on the filter, the filter requires more frequent backwashing, thus using more water.

Three others do not use the filter to catch the removed dirt. One works off of the pressure side. The water flowing through a small turbine operates the vacuum system that discharges into a strainer bag attached to the discharge from the system. Another type is powered by electricity and uses a similar bag-type system. Stand-alone systems are powered by a separate pump and have filter bags to catch the debris for disposal. The filtered water is returned to the pool.

Equipment Operations

Commercially operated pools, ranging from apartment pools to public community pools, must comply with the operational requirements of the health codes. In California, pools used by the public must have turnover rates as shown in Table 8.

Table 8. Required Public Pool Turnover Rates*

Type of Pool	Turnover Rate
Swimming Pool	Every 6 hours
Wading Pool	Every hour
Spa	Every 30 minutes

**California Health and Safety Code, Sections 116025-116068*

For residential pools, the situation is very different. The Centers for Disease Control recommends that residential pools follow the same requirements as public pools, but in recent years, the emphasis on both energy and water conservation has resulted in other recommendations. For example, the following recommendation from the Los Angeles Department of Water and Power states[202]:

> *Rather than computing the turnover time, you may prefer to follow the pool filter operating recommendations established by the California Swimming Pool Industry Energy Conservation Task Force - which are as follows:*
>
> *"Reduce filter operating times to no less than 4 to 5 hours per day during the summer and 2 to 3 hours per day during the winter period.* ***This will reduce annual electrical consumption by 40 to 50 percent. Normal and heavier swimming use may require as much as eight or more hours filtration per day. Should water clarity or chemical imbalance indicate inadequate filtration, immediately operate the filter until acceptable water clarity has again been established. If additional filtration is still indicated, increase filter operating time in one-half hour increments until the water remains clear and properly balanced chemically. When the pool is being heavily used, it is recommended that the pool be operated manually and that the filtration system be run under such conditions. Under no circumstances should the water quality of any swimming pool be so poor that the main drain cover is not clearly visible from the deck."***

In fact, some sources state that the turnover rate for a private residential pool can be as low as once per day.

Draining pools, spas, and fountains must be performed in accordance with local ordinances. Most require that water from swimming pools, spas, or decorative fountains be dechlorinated or

[202] www.naturalhandyman.com/iip/infpool/infpoolconservation.html

debrominated prior to discharge to the street, storm drain, or sanitary sewer. Chlorine or bromine should dissipate within 48 hours for most pools. Draining is the easiest way to dechlorinate or debrominate residential pools. Some commercial pools operators may prefer to use dechlorination chemicals, but instructions must be carefully followed. Ordinances frequently require that the drain water not be discharged to the sanitary sewer. Many residential pool owners can use this water for irrigation if the salinity is not too high. Owners of "salt pools" should consult their local wastewater and storm water officials before draining pools. Regular inspection of equipment, checking for leaks, and keeping debris out of the pool are important components of proper pool operation. For pools with meters, readings of water use should be made at least every other week and records kept. All of these help ensure that both water and energy are used most efficiently.

Best Management Practices for Pools, Fountains, and Spas

Reducing water use by pools, hot tubs, and ornamental recirculating fountains depends on four factors:

1. Reducing evaporation loss
2. Choosing the most efficient filtration equipment
3. Providing proper maintenance
4. Changing human behavior.

The areas where savings can be found parallel these factors. Evaporation is the most significant component of water use and also drives the use of water for TDS control. The choice of the type of filtration equipment is the second most significant way to reduce water use, but it is the most readily achievable. Providing proper operation of the equipment, maintenance of the pool and equipment, and timely repair of leaks all require more human intervention on a regular basis. The following section will examine the water saving potential for the following five potential measures:

1. Evaporation Reduction
2. Filter Selection
3. Control of TDS
4. Leak Detection and Control
5. Changing Human Behavior

Evaporation Reduction

There are three basic ways to reduce pool water evaporation. The first is to shade the pool and reduce wind movement across the pool with fences and walls, non-shedding hedges, or other barriers. The second is to limit sprays, waterfalls, and other features that increase contact area to atmosphere to just those needed for aesthetic value or for aeration of the pool water. The third is to use chemicals or pool covers to retard evaporation.

Pool covers have been used for years to reduce heat loss from heated pools, protect pools in the winter from debris, and to reduce evaporation. Covers can be made from several plastics such as UV-stabilized polyethylene or polypropylene or vinyl. They can be clear or opaque. The designs range from single sheet plastic membranes and bubble wrap type material to specially designed multi-layer insulated covers. In California, Title 24 requires that heated pools be covered when not in use.

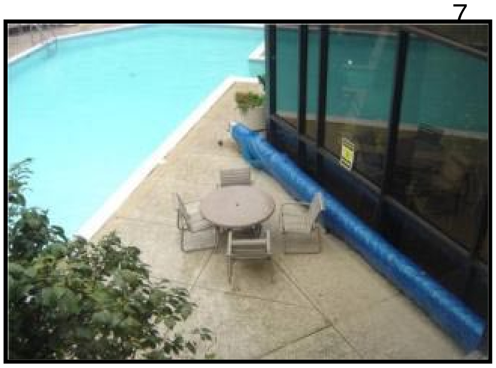

Figure 22. Pool Cover Rolled Up

Traditional pool covers reduce evaporation by simply covering the water surface. Covers also reduce the amount of debris falling into the pool, thus reducing backwash frequency, reduce chemical use, and they save water by extending the time between pool drain-and-fill events by reducing evaporation. Literature varies on how much evaporation pool covers can eliminate, but of the effect generally appears to be in the range of 30 to 60 percent reduction. The US Department of Energy estimates the percent of energy lost by evaporation to be 70 percent[203]. It also reports that energy savings of 50 to 70 percent and water savings of 30 to 50 percent are possible if pool covers are used properly.

However, covers are only effective if they are used. A 2004 study[204] of pool cover usage in an inland area of Southern California revealed that the vast majority of consumers purchasing a pool cover do not use it regularly.

This report assumes an average potential reduction in evaporation of 40 percent for pools with plastic covers.

Liquid evaporation barriers are water-safe chemicals that form a thin layer at the water surface. Some of the more commonly used pool covers use long chain alcohols and an alumina salt. They are non-toxic and do not interfere with pool operations. The liquid must be replenished on a regular basis since it eventually evaporates.

Liquid barriers have been used for years. They offer both heat and evaporation loss, but they work best where there is little movement of the water surface. Although some claims are much higher, studies have shown that liquid barriers reduce heat loss by 15 to 55 percent[205] depending on how the pool is used: the higher energy savings occur in pools that are used the least. Liquid barriers can be assumed to reduce evaporation in the range of 10 to 30 percent. This report assumes an average reduction of 20 percent when using liquid barriers.

The most important thing to consider with liquid barriers is that they are in place and minimizing evaporation as long as the liquid feed equipment is operating, even when the pool is being

[203] www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13140
[204] Koeller & Company for Inland Empire Utilities Agency, 2004. Swimming Pool Cover Rebate Program, Follow-up Customer Survey, April 26.
[205] www.liquidpoolcovers.com/effectiveness.html

used. By contrast, pool covers must be removed and replaced by the pool owner and operator, something that many homeowners are not inclined to do on a regular basis, especially during heavy usage periods in the summer months. The overall evaporation reduction from the use of covers of all types is assumed to be 30 percent.

Backwash and Cartridge Cleaning Water Savings

The water needed for backwash and filter cartridge cleaning varies significantly based upon the type of filter system used. For smaller pools, cartridge filters use significantly less water than sand and DE filters; for larger pools, industrial type filters use the least. Table 8 shows that the most efficient filters use between 68 and 98 percent less water than conventional sand filters.

Table 8. Comparison of Backwash and Cartridge Water Use Per Pool Per Year for Different Types of Filters

	Estimated Use in Gallons Per Pool Per Year				Maximum Possible Reduction
	Sand	DE	Cartridge	Industrial	
Hot Tub	935	468	300		68%
Above-ground	4,189	1,466	800		81%
In-ground	8,415	2,945	1,200		86%
Apartment	22,440	7,480	2,500		89%
Hotel/Motel	29,920	9,350	3,600	5,000	88%
Public	166,222	41,556		9,000	95%
Olympic	959,568	239,892		17,000	98%

TDS Control

If reverse osmosis systems similar to those used by Clean Water Products (Section IV of this report) were employed, water use for this operation could potentially be reduced by 78 percent. Reductions in evaporation also reduce the number of times a pool must be dumped and refilled, which may amount to a 10% to 30% reduction.

Other Savings

Finding and fixing leaks, controlling splash-out and drag-out, providing shade and wind breaks, and similar measures are difficult to quantify. The same is true with leaks; although it is estimated that 5 percent of pools have leaks, the volume cannot be quantified. If modifying human behavior, using properly installed gutters and grates, installing and reading water supply meters to detect leaks, ensuring proper operation of equipment, and similar factors were combined, water use reductions could be in the range of tens of thousands of acre feet per year.

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7C8: Water Treatment

Introduction

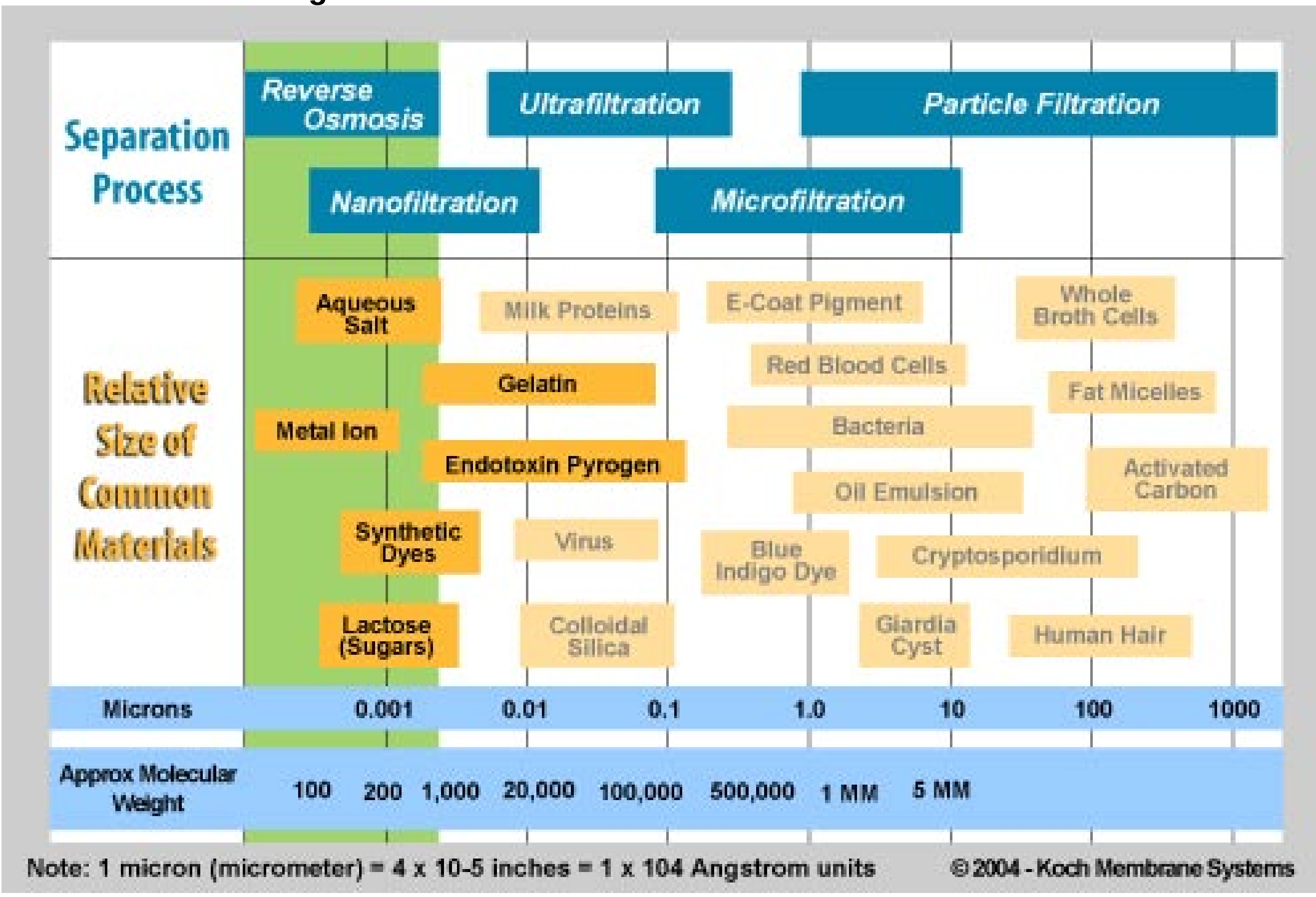
Water treatment is used in many commercial operations, including food services, laundries, laboratories, pharmacies, car washes, and food service establishments. Water treatment technologies for industrial operations are commonplace, but they also often require technologies not found in commercial settings. The type of treatment depends on the application and the required water purity for the intended use. Treatment techniques and levels range from simple cartridge filters and water softeners to the production of ultrapure water for medical, laboratory, and microelectronics operations. Table 1 summarizes common treatment systems.

Table 1. Treatment Technologies		
Type of Treatment		**Brief Description of Application**
1.	Sediment Filtration & Removal	Removes particulate matter and some bacteria
2.	Coagulation & Sedimentation	Removes sediment or precipitates formed in industrial operations and metal finishing operations
3.	Plate and Frame Filtration	Filters sediment and precipitates
4.	Softening	Removes magnesium and calcium hardness
5.	Ion exchange	Removes cations and anions
6.	Distillation	Removes cations and anions
7.	Membrane technology	Reverse osmosis and nanofiltration removes pyrogens and cations and anions while microfiltration and nanofiltration remove very small particulates and colloidal material
8.	Disinfection	Kills bacteria and deactivated viruses
9.	Carbon Absorption	Removes organics and some metals

The first three treatment technologies entail filtrations. The next two remove salts and other dissolved minerals including hardness. Membrane technologies include 1) microfiltration, 2) ultra filtration, 3) nanofiltration, and 4) reverse osmosis (RO). The last two technologies represent processes also commonly used by the CII sector.

To illustrate the application of these treatment technologies, Figure 1 shows the types of filtration processes and the types of constituents that the filtration process will remove.

Figure 13. Removal of Particulates and Salts



source: http://www.kochmembrane.com/sep_ro.html

The ultimate use of the water determines the level of water treatment needed. For potable water, removal of particulates to the 20-micron level is often sufficient as long as the water is disinfected and the level of salts is not too high. For many industrial processes and for low pressure boiler feed, it is often necessary to remove hardness. For high-pressure boilers and many industrial operations, the level of needed purity can only be obtained by reverse osmosis, and microelectronics manufacturing and many pharmaceutical and laboratory operations require "ultra-pure" water. Removing organic material is also a common practice.

Treatment systems provide the ability to use water that would be discharged as wastewater, reusable either directly in the facility where it was generated, or used by municipal water recycling. The following section describes the major technologies used to treat water in the CII sectors.

The California Building Standards Commission is currently working on new standards for graywater and intends to include other on-site sources. The process is in the beginning stages.

Sediment Filtration and Removal Processes (non-membrane)

Removing sediment, suspended solids, and other particulate materials from water is one of the most basic forms of water treatment. Many technologies have been developed over the years to accomplish this task. One of the most common processes is filtration. Sand and zeolite, precoat, cartridge, and bag filters are used in many commercial, institutional, and industrial processes. Another sediment removal technology is the use of centrifugal force.

Figure 14 Typical Sand Filter

Sand and Zeolite filters use a bed of sand or zeolite to filter the water. Water is pumped into the top of the filter, where it passes through the sand bed, and particulates are captured. As it operates, a layer of material filtered out of the water builds up on the top of the sand bed. When the pressure difference from the top of the bed to the bottom of the bed exceeds 8-10 pounds per square inch, the filter should be backwashed. Special valves allow this to happen. The water moves from the bottom of the filter up through the filter material to the top, discharging the accumulated dirt on top of the filter. When the water in a sight glass appears clear, the dirt has been removed. Larger pools can use horizontal filters, which are simple tanks on their sides.

Precoat filters include conventional diatomaceous earth[206] (DE), cellulose[207], or perlite[208] filters, as well as regenerative filters that reuse the filter media. These filters remove particles down to 5 microns in size, while sand and cartridge filters work in the 10- to 40-micron removal range[209]. Precoat filters have hundreds to sometimes over 1,000 fabric-coated tubes inside a pressure container. The filter media (DE, cellulose, or perlite) is made into a slurry and mixed with the water in the filter. The media is then deposited on the tubes by the water being pumped through the filter. Conventional precoat filters must have the DE or perlite replaced after each backwash.

With regenerative precoat filters, the media is periodically “bumped” off of the filter tubes by backflow, air agitation, mechanical shaking, or a combination of the three. It is then recoated

[206] Diatomaceous earth is a white powder made from the "skeletons" of small aquatic plants in the algae family called diatoms. It is inert, but breathing the powder can be harmful since the skeletons are made up of silica materials. Residential and commercial filters typically use either DE or perlite media. In recent years, many wastewater utilities have placed bans on the discharge of diatomaceous earth to sanitary sewers since it tends to settle out and clog sewer lines. Settling tanks and bag filters are often required to remove the DE before the water can be discharged. The DE can either be disposed of in the trash or used as a soil amendment. DE has a bulk density of 19 pounds to 22 pounds per cubic foot.

[207] Cellulose is made from plant fibers. It is not widely used for pools, but is used in some food and beverage operations.

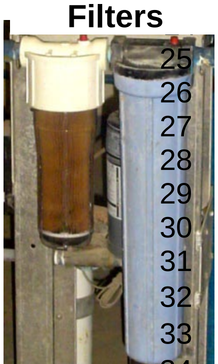
[208] Perlite is made from a silicon-based material found in volcanic deposits. When heated, it expands to form a very light weight, chemically inert material that is used for filtration, as a soil conditioner, and insulation. Because it is so light weight, it tends to float on water when dry. It does not have the strong tendency to settle out in sewer lines that DE does. For this reason, many wastewater utilities have allowed filter backwash water from perlite coated filters to be discharged to sewers. Many utilities collect the backwash water and use the perlite as a soil amendment. Perlite has a bulk density of two to eight pounds per cubic foot.

onto the filter cloth. Regenerative filters save significant volumes of water and filter media since the media can be recycled up to 30 times before it is ultimately discharged to waste.

For large commercial pools and industrial operations, automated precoat, regenerative filter systems are available. These systems are also sometimes called <u>industrial</u> filters since their use originated in food process and water treatment operations. A significant water saving factor with these filters is that the internal filter media recycling occurs about thirty times before the medium is dumped and replaced, and no water is lost in the recoating process. When the media is flushed, the only water dumped is the water in the filter plus one additional filter volume to make sure the vessel is completely rinsed. The backwash water needed is equal to about twice the volume of the filters themselves, which is different from home DE filters that use the pool pump to force water through the filter.

In addition, these large industrial units use air to "bump" the filter media off the filter elements, thus eliminating another water use for this purpose and making regenerative precoat (industrial) filters very water-efficient. Since the perlite media can be bumped and redistributed about thirty times before needing to backwash, backwashing is stretched to months rather than weeks or even days for large commercial pool sand filter systems.

Figure 15 Small Cartridge Filters



Cartridge filters use pleated filter elements made from paper or other material. Most use washable filter elements with a range of filter elements, typically in the range of 1.0 to 20.0 micron particulate removal.

In the past, disposable filter elements were used, with filter replacement taking place each time the pressure across the element built up. Re-usable cartridges are now available. They should be the only type used in most applications since they need only to be washed off with a hose and returned to the filter housing. Because these filters do not need to be backwashed, they are the most water-efficient type available for all but the largest pools and are finding wide acceptance in the residential and smaller apartment pool market. Their water efficiency has led some local governments to encourage their use.

Bag filters, as the name implies, use a filter cloth housed in a cylinder. Bags are generally washable and can be used many times as long as the substance removed does not stick to the bag. Bags of various micron sizes can be purchased. In some cased fine metal mesh can be used instead of cloth.

Figure 16. Cyclone Separator with Bag Filter

Cyclone Separators (hydrocyclones) and centrifuges remove larger particles and sludge from water by centrifugal force. These separators are often used to remove particulates of larger sizes although some manufacturers report that their equipment can remove particulates as small as 20 to 30 microns. When used with a bag filter to filter the purge stream, they are capable of recovering almost all of the "purge water" from the separator (Figure 4). Even if a bag filter is not used, the purge stream can be less than the backwash water requirements of a sand filter according to some manufacturers (***www.therodingroup.co.uk/****cyclone-filtration****-how-it-works.asp)***

Best Management Practices for Sediment Removal

Process Selection: All of the above processes will remove particulates and sediment from water. The choice depends on the type of particulates that need to be removed and a number of operational considerations. Table 3. summarizes these filter options.

Table 3. Non-Membrane Particulate Removal Systems

Type of Filter	Particle Removal range *Microns*	Requires Replacement Elements
Cyclone Separators	> 20	No
Sand Filters	> 20	No
Cartridge Filters	1.0 to 20	Yes
Precoat Filters	>5.0	No
Bag Filters	1.0 to 20	Yes

Cyclone separators (hydrocyclones) are inexpensive and low cost to operate. Their applicability includes areas where cooling tower side stream treatment or industrial continuous solid - liquid separation is needed. They also find use for raw surface water intakes where larger sediment must be removed. Since post filtration of the purge water with the sediments is possible, they can be extremely water efficient. Their application must be evaluated on a case–by-case basis.

For finer filtration, filters are commonly used. The selection and operation of these filters depends on the type of sediment to be removed and the end use of the water. Filtration systems for commercial operations can range from a few hundred dollars to tens of thousands of dollars. For large industrial operations, the cost can be in the $100,000s depending on volume of water treated and design. Sand filters tend to be more expensive that coated media and cartridge filters. To help understand some of the cost consideration, Table 4. shows selection factors for swimming pools. These factors are generally applicable across commercial and institutional lines.

Table 4. Filter Selection Factors for Pool Filters*			
	Sand	**Coated Media**	**Cartridge**
Frequency of Cleaning	Every week	4-8 weeks	Depends on unit
When to clean *(Difference in pressure across filter)*	5-10 psi	8-10 psi	8-10 psi
How cleaned	Backwash	Backwash(a)	Take apart & wash with hose
Filtration *(microns)*	20-40	5	10 (can vary on cartridge)
Time between media replacement	3-6 years	Every recoat	2-4 years depending on filter
Cost of media	$0.50 to $1.00/lb	$0.15 -$0.50/lb	$15-$100 each
Residential use	Yes	Yes	Yes
Commercial use	Yes	Yes(b)	Not Recommended
Backwash flow time	2-5 minutes(c)	1-5 minutes(c)	Remove & wash
*Personal communications, 2010. Robert Hawkin and Scott Hyland, Neptune Benson, Coventry, RI			

(a) DE and Pearlite filters should be "bumped and swirled" to regenerate the porosity of the filter medium. Actual recoat is needed only when pressure drop across filter reaches 8-10 psi, significantly reducing the number of times that new filter media is needed.
(b) DE is not recommended for apartments, condominiums, or hotels since the filters quickly become clogged with the high rate of use. Specially designed DE and Pearlite filters are made for high volume use.
(c) Typical times. Filter must be backwashed until sight glass is running clear.

Figure 5. shows an analysis of potential backwash water use for swimming pools in California. As this figure shows, sand filters are the least water efficient.

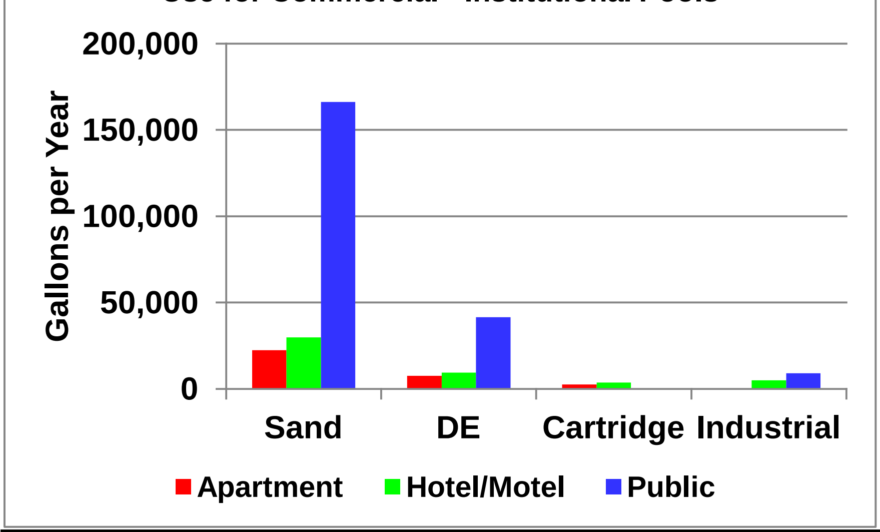


Figure 5. Estimated Annual Backwash Water Use for Commercial - Institutional Pools

<u>The best management practices for filter selections are</u>:

1. Only use filters where needed

2. Choose sediment filters that require the least number of backwashes
3. Examine ways to reuse backwash water or purge water
4. When filters are used, install pressure gauges and use the gauges to determine when to backwash
5. Backwash based on pressure drop instead of by a timer or a schedule.

Physical Sediment and Precipitate Removal

The reuse of water on-site often depends on the removal of sediment and precipitates produced by a process or operation. The two most commonly found examples are coagulation - sedimentation and filter presses and filter belts.

Coagulation - sedimentation is used where large volumes of water need to be treated. This process involves the addition of a chemical that causes particles to "clump" together to form heavy "flocs" which then settle out. A full technical discussion is beyond the scope of this document, but this type of treatment is often used to treat raw surface water or even wastewater streams that can be reused within the facility. Filtration often follows sedimentation.

Precipitation is a chemical reaction that causes a solid to form. Precipitate removal is often found in plating operations and other industrial/commercial operations where metal salts are used. Leaf or belt presses are often employed to remove the precipitate. Technical details are beyond the scope of this document, but these water treatment processes are important to internal water reuse operations.

These water treatment processes are important best management practices themselves when use in conjunction with on-site water recovery and reuse.

Membrane Processes

The development of membrane technologies has revolutionized the way water is treated. Microfiltration and ultrafiltration remove very small particulates and colloidal substances from water. They are also capable of filtering bacteria and some viruses. Nanofiltration and reverse osmosis (RO) actually remove dissolved solids ranging from proteins and sugars to minerals and salts. Micro and ultrafiltration materials include ceramics and polymers of various types. Nanofiltration and RO typically use thin film composites, cellulose acetate, and polysulfonated and polysulfone membranes. These processes can either be made of a bundle of tubes or spiral wound. These assemblies are then placed into long pipe-like pressure vessels. A variant is the submergible microfiltration membrane that works on a vacuum. It is often used in wastewater treatment system called a membrane biological reactor (MBR).

All four of the membrane processes are important ways to recover water for reuse on site or for the treatment of recycled municipal wastewater where very high purity is required. Table 5. compares the general characteristics of the four membrane technologies.

Table 5. Comparison of Membrane Technologies				
Type of filtration	**Microfiltration**	**Ultrafiltration**	**Nanofiltration**	**Reverse Osmosis**
Pore Size Removal (Microns)	1.0 - 0.1	0.01 - 0.001	0.001 - 0.0001	<0.0001
Operating Pressure (psi)	<30	20 - 100	50 - 300	225 - 1,000
Operating Cost ($/1,000 gallons)	$ 0.50 - 1.00	$ 0.50 - 1.00	$ 0.75 - 1.50	$1.50 - 5.00
Source: Cartwright Consulting Company - http://www.cartwright-consulting.com				

Micro and ultrafiltration: Both microfiltration and ultrafiltration remove very small particulate matter from water. They find application in all areas of water treatment especially since these devices are able to remove *Giardia lamblia* cysts, *Cryptosporidium* oocysts, and other pathogens.

Since microfiltration and ultrafiltration are filtration processes, the membranes need to be backwashed periodically to flush sediment from them. They also require periodic cleaning with detergent and either acid or alkaline cleaners. Both filtration processes typically have a sediment filter placed ahead of them to remove larger particles before micro or ultrafiltration, thus extending the time between backwashes and extending membrane life.

Ultrafiltration finds use in food processing operations where water must be removed from a liquid or slurry, such as the removal of whey from milk solids and water from tomato paste.

Nanofiltration and Reverse Osmosis (RO): These technologies are capable of removing dissolved salts, proteins, and materials at the molecular level. They find application in many industries. These two processes differ from filtration in two significant ways. First, only a portion of the water fed to the membrane is actually passed through it. This water is called "permeate." The remaining water is the reject or retenate stream, and it is sent to discharge as a waste stream. It contains the salts and minerals left behind. Like filtration membranes, these membranes must also undergo periodic cleaning with detergent and either acid or alkaline cleaners. The water produced by these processes is exceptionally low in mineral and organic contaminates.

When selecting these membranes that operate at the molecular level, several terms are of particular importance:

- Permeate - the product water that passes through the membrane.
- Retenate - the water containing the dissolved salts, minerals and other substances that is sent to waste.
- Rejection rate - the percent of salts that are removed by the process.

These processes (nanofiltration and RO) should be preceded by particulate filtration. Nanofiltration can be used to remove multivalent ions and is thus a softening process, but most water fed to RO systems has been softened to remove hardness which would quickly foul the membrane. Reverse osmosis technology finds application is many diverse areas, including:

- Desalination of sea water and brackish waters
- Pre-treatment for the production of ultrapure water
- Treatment of water for kidney dialysis
- Laboratory and pharmaceutical water purification
- Plating water treatment and plating solution recovery
- Product recovery for precious metals.

Modern large RO units have rejection rates of 90 percent or better and permeate recovery rates of 75 percent or better. For medical and laboratory operations, the size of the system helps determine the permeate recovery rates. Smaller systems with production rates (permeate) of under 3 to 4 gallons per minute typically have only a 50 percent recovery rate. The reject water is often usable for other purposes.

Best Management Practices for Membrane Processes:

For micro and ultrafiltration membranes:

- Use pressure drop across the membrane to determine when to backwash so that backwashing is done only when necessary.
- Follow manufacturers recommendation on membrane cleaning to minimize the number of cleanings needed.
- Pre filter water to remove larger sediment to minimize backwash and cleaning.
- Follow the best management practices for filtration for the pre filters.

For Nanofiltration and reverse osmosis:

- Choose systems with the maximum permeate recovery rates.
- Clean according to recommendations from the manufacturer.
- Investigate ways of reusing the retenate.
- Ensure good pre treatment to minimize cleaning of the membranes.

Metal-Oxide Filtration (MOF)(Ceramic)

This filtration technology uses cross-flow membrane permeation technology with Metal-oxide Ultrafiltration Membranes (MOF) to separate and remove emulsified oil and grease, heavy metals, biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), volatile organic compounds (VOC), color, total dissolved solids (TDS), and turbidity from industrial wastewater.

The separation process takes place inside the porous ceramic module where macromolecules and particles are continuously rejected on the surface of ceramic and water permeates across the ceramic membrane. Each ceramic module contains parallel flow channels where the feed material is introduced. As the contaminated fluid passes through these parallel flow channels the water is forced through the ceramic wall (filtrate), but pollutants (called concentrate) including fine suspended solids are rejected and returned back to the process feed tank (Figure 6).

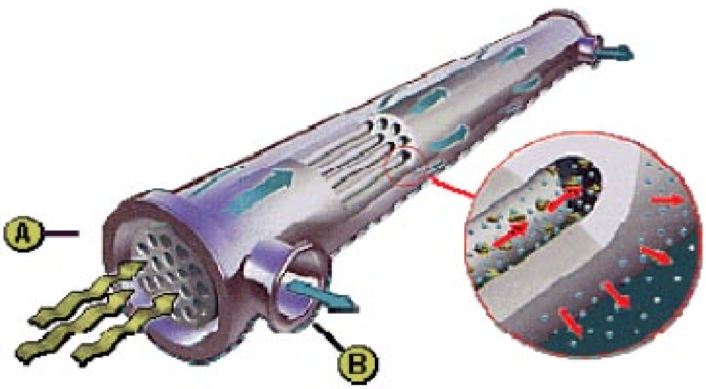


Figure 6: Ceramic Membrane Diagram. The filtrate, retentate or concentrate is labeled A, and the permeate, diffusate or filtrate is labeled B.

The characteristics of Metal-Oxide Filtration is similar to those of Ultrafiltration found on Table MM. See the characteristics of MOF in Table 6. below.

Table 6. Other Membrane Technologies	
Type of filtration	**Metal Oxide Filtration**
Pore Size Removal (Microns)	0.8 - 0.001
Operating Pressure (psi)	50 - 100
Operating Cost ($/1,000 gallons)	$ 0.50 - 1.00

The flow in this type of system is open-ended on both sides of the filter and the permeate is forced through the sides of the filter wall. This means that the filters do not need to be backwashed so they can be used for many years without replacement. This type of construction minimizes membrane fouling and can operate under the following conditions:. Normal operating pressure is from 75 – 80 psi. The filters will operate under the following conditions: 0-14pH and 0-300 degrees F.

Distillation

Distillation works by boiling water to form steam condensate using either an electric or gas water still. Solid contaminants remain behind as the steam is generated, then the steam is condensed into a purified water stream. Distillers can use large volumes of water if once-through cooling water is used in the condenser, or if a reject stream is discharged from the boiler to prevent scale build-up. These systems typically waste 15 to 25 percent of water entering the system.[210]

Best Management Practices for Water Stills:

- Eliminate once-through cooling.
- Maximize product water recovery as a percent of total water input to 75 percent or better.
- Install automatic water and gas or electric cutoffs when the receiving reservoir is full.

Softening

Softening is the process of removing magnesium, calcium, and related multivalent ions from water. Laundries, car washes, boiler feed-water, laboratory water, hot-water systems for restaurants and food-service establishments, and metal-plating operations commonly employ softening. The three most common ways of softening water:

[210] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. <www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook>.

- Nanofiltration (See section on Membrane Processes)
- Lime softening (only applicable to large municipal systems and not discussed in this document)
- Cation exchange resins or zeolite that exchange sodium or potassium for calcium and magnesium.

Cation exchange resins and zeolites are the most commonly found softening processes in industrial, institutional, and commercial operations. Water is passed through a bed of resin from the top. As it passes through, sodium or potassium ions on the resin are released and replaced with the calcium or magnesium cations. As water passes through the bed, spent resin (resin that has given up its sodium or potassium ions) moves down the bed. If the process continues, hard water will use up all the salt and softening will cease, so softeners need to be regenerated with a salt (typically sodium chloride - salt or potassium chloride). Sodium salts damage plants and cause clay soils to deteriorate. Softeners are often a major salt input to wastewater streams that are being recycled. For this reason, the use of softeners or the use of sodium salts has come into question. Many with septic systems are also converting to the use of potassium-based salts to prevent damage to plants and soil.

Best Management Practices for Softeners:

- Do not recharge based on timers.
- Consider demand based softener regeneration. The best systems actually measure the hardness and only backwash when a preset percent of the resin bed is exhausted.
- Use water meters that actuate recharge with a predetermine amount of water has been treated based on the water chemistry of the source water.

Carbon Adsorption

Carbon adsorption is used to remove organic compounds such as those that affect taste and odor., In some cases activated carbon is also used to remove heavy metals from water. The adsorption process depends on the physical characteristics of the activated carbon, the chemical compositions of the carbon and the contaminants, the temperature and pH of the water, and the amount of time the contaminant is exposed to the activated carbon.[211] Carbon adsorption can use either disposable cartridges or packed columns. Disposable cartridges are disposed of once the adsorptive capacity is exhausted. Alternatively, packed columns can be removed and recharged offsite.[212]

Cation and Anion Exchange

[211] North Dakota State University. *Treatment Systems for Household Water Supplies—Activated Carbon Filtration.* <www.ag.ndsu.edu/pubs/h2oqual/watsys/ae1029w.htm#process>.
[212] East Bay Municipal Utility District. 2008. *Watersmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. <www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook>.

Cation and anion processes – also known as strong acid/base resins – are used when extremely pure water is required. The equipment can be recharged off site or on site, and the resin bed should be instrumented to ensure that recharge is done only when a preset percent of the bed's resin has been exhausted.

Other Treatment Methods

Other treatment methods can consume small amounts of water, if chemicals are fed in a liquid or slurry form. Disinfection technologies include use of chlorine compounds, ozone, hydrogen peroxide, and ultraviolet light. Other commonly used chemical feed systems add antioxidants, pH control, oxygen scavengers, and other chemicals used to condition the water for its intended use.

Other processes use water to make up the solutions, but this water becomes part of the product water and is not lost. Cleaning chemical storage areas does consume water, however. The potential for water savings by choosing among disinfection technologies is not great, but wasting water in cleaning equipment and storage vessels is a concern that can be lessened through the use of waterless methods.

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8: Standards and Codes for Water Use Efficiency

8.1 What are standards?

Webster's defines a standard as: "...something set up as a rule for measuring or as a model to be followed..." In the vast world of water-efficient products, standards (or "rules for measuring") are necessary to establish standard dimensional requirements and the minimum performance level for all manufacturers to meet with their products. Compliance with established standards, however, is voluntary. That is, until such time as an ANSI[213] consensus standard is adopted into law by regulation (e.g., building codes) or legislation (e.g., the National Energy Policy Act – EPAct), the standards have no force of law.

Once adopted, however, new products from new manufacturers entering the U.S. marketplace, or new product models introduced by existing manufacturers, must be measured against the relevant standards and meet specified minimum requirements in order to be sold in the marketplace.

Many different U.S. organizations are approved by ANSI as standards-writing bodies, having met certain stringent requirements. Standards committees and project teams are comprised of a variety of stakeholder interests, and they are required by ANSI to maintain a "balance" of those interests. As such, these groups include representatives of manufacturers, laboratories, government, private sector consultants, and others. Generally speaking, standards (and their implementing codes) have focused primarily on protecting public health and safety. In the past 20 years, though, the goal of achieving water use efficiency has been added to the process in many cases.

8.2 What are codes?

In addition to standards, plumbing and building codes play an important role in governing the installation and use of water efficient products. Codes are promulgated by code authorities and adopted by jurisdictions to protect the health and safety of the citizens. It is important to note that, whereas the national standards approved by ANSI are voluntary consensus-based standards, the codes (which may or may not adopt the national standards by reference) are mandatory within the jurisdiction that adopts them.

Like the standards process, the codes process is complex. There once were five different plumbing code development organizations in the U.S., but mergers have reduced this number to only two. The International Association of Plumbing and Mechanical Officials (IAPMO) produces the Uniform Plumbing Code (UPC), and the International Code Council (ICC) produces the International Plumbing Code (IPC). These code-authoring organizations have a 3-year development cycle to update their respective model codes. California, through its Building Standards Commission [214] (CBSC) and the Department of Housing and Community Development (HCD)[215], uses the UPC as the model plumbing code for the State and makes modifications to that model code to address California-specific interests.

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213 American National Standards Institute
214 http://www.bsc.ca.gov/
215 http://www.hcd.ca.gov/

The plumbing codes themselves have no legal status until adopted by jurisdictions such as cities, counties and states. Where adopted, the codes become as local ordinances and laws. All jurisdictions can amend the model code before and after adoption, and some do this to better suit local conditions. Each of the two plumbing codes contains more than 400 pages of complex requirements; few jurisdictions, however, have the ability to review and analyze every single provision before adopting the code as law.

8.2.1 EPAct

The National Energy Policy Act of 1992 (EPAct 92) sets maximum water consumption standards for showerheads, faucets, urinals, and toilets; pre-rinse spray valves (PRSVs) followed in 2005. Just how those standards are manifested in fixtures (toilets and urinals) and fixture fittings (faucets, showers, and PRSVs) is a function of standard setting and the adoption of those requirements into the plumbing codes as noted above.

8.2.2 National Plumbing Standards

The national plumbing standards are developed and administered in a consensus and balanced process[216]. The American Society of Mechanical Engineers (ASME), the American Society of Sanitary Engineering (ASSE), and the International Association of Plumbing and Mechanical Officials (IAPMO) are all accredited by the American National Standards Institute (ANSI) to develop U.S. standards for plumbing fixtures and fittings. Within these organizations, the committees are developing and maintaining standards related to toilets, urinals, showerheads, faucets, pre-rinse spray valves, flushometer valves, and other fixtures and fittings used in indoor plumbing systems. In very recent years, many of these standards have been harmonized with their Canadian counterpart, such that the same requirements apply in both countries.

Plumbing standards approved by ANSI and directly affecting water use efficiency are as follows[217]:

- ASME A112.19.2-2007/CSA[218] B45.1-07 – Ceramic Plumbing Fixtures
- ASME A112.19.5-2011/CSA B45.15-11 – Flush valves and spuds for water closets, urinals, and tanks
- ASME A112.19.14-2006 – Six-Liter Water Closets Equipped with a Dual Flushing Device
- ASME A112.19.10-2003 – Dual Flush Devices for Water Closets
- ASME A112.19.19-2006 – Vitreous China Nonwater Urinals
- ASME A112.18.1-2010/CSA B125.1-10 – Plumbing Supply Fittings
- ASSE 1002 – Anti-siphon Fill Valves (Ballcocks) for Gravity Water Closet Flush Tanks
- ASSE 1016 – Performance Requirements for Automatic Compensating Valves for Individual Showers and Tub/Shower Combinations

[216] Groups represented in the ANSI process as voting members include representatives of manufacturers, laboratories, government, private sector consultants, and others. No one group is allowed to dominate the standards-setting process.
[217] Numerous other plumbing standards exist that have less-than-significant effects upon water use efficiency.
[218] Canadian Standards Association

- ASSE 1037: Performance Requirements for Pressurized Flushing Devices (Flushometers) for Plumbing Fixtures
- CSA B45.5-10/IAPMO Z124-10 – Plastic plumbing fixtures

Water utilities in California have been directly involved in the national standard setting and code authoring processes for nearly 20 years.

8.2.3 National Green Building Standards

Many jurisdictions (municipalities and other local authorities and state governments with the power to mandate, approve, disapprove, or influence project design and construction) are developing guidelines and minimum standards for new construction and renovations. These actions mandate or "suggest" design or construction practices, technologies, performance thresholds, and metrics in a variety of categories including water use efficiency.

Typical water use efficiency categories within many of the national green building programs (guidelines and standards) include:

- Plumbing fixtures and fixture fittings
- Residential appliances (clothes washers, dishwashers)
- Water treatment equipment (softeners, filtering systems)
- Landscape & landscape irrigation
- Pools, fountains, and spas
- Cooling towers
- Decorative and recreational water features
- Water reuse & alternate sources of water (graywater, rainwater and stormwater, cooling condensate and cooling tower blowdown, foundation drain water)
- Specialty processes, appliances and equipment (food service, medical, laboratories, laundries, others)
- Metering & submetering
- Once-through cooling
- Vegetated green roofs
- Building water pressure

It is important to understand the difference between green building standards and green building guidelines. While guidelines provide thresholds for efficiency, they are not generally written in code-adoptable language, and compliance is usually voluntary. Standards, on the other hand, provide definitive efficiency thresholds, are written in language that is enforceable, and are readily adopted by reference into codes and other regulations as mentioned above.

For example, the well-entrenched LEED Program consists of a set of guidelines that designers and builders may choose to comply with (although some jurisdictions are choosing to mandate compliance with LEED to some level and use credits as the measure of compliance). As such, these guidelines are not generally written in language suitable for direct adoption or reference as codes or other regulations.

Currently, national green building ANSI standards intended for application within CII sectors include these initiatives:

- ASHRAE[219] ANSI Standard 189.1 Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings
- Green Globes-Green Building Initiative (GBI) ANSI Standard 01-2008: Green Building Assessment Protocol for Commercial Buildings
- ASHRAE Proposed ANSI Standard 191 - Standard for the Efficient Use of Water in Building, Site and Mechanical Systems

Comparisons of the provisions of these three ANSI standards with the requirements of the model 'green' codes are shown on the following four pages.

[219] American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.; www.ashrae.org

NATIONAL GREEN BUILDING STANDARDS, CODES, & GUIDELINES

	Applications	Guidelines, code or standard?	Code-adoptable language?	Minimum thresholds or points?	Status
USGBC LEED-NC et.al.	All except Single Family Residential	Guidelines	No	Prerequisite + points	LEED 2009 mandates 20% reduction from baseline; 2012 version in development
USGBC LEED-Homes	Single Family Residential (SFR)	Guidelines	No	Both	Active – to be updated
Green Globes – Green Bldg Initiative 01-200XP	Residential above 3 stories + all commercial	**ANSI Standard**	Yes	Points	Final standard ANSI-approved; published in April 2010
ASHRAE S189.1 – High Performance Buildings	Residential above 3 stories + all commercial	**ANSI Standard**	Yes	Minimum thresholds	Final standard ANSI-approved; published in January 2010; now in sustaining process
ASHRAE S191 – Water Efficiency	All except SFR	**ANSI Standard**	Yes	Minimum thresholds	Process began July 1, 2008; provisions being drafted
ICC 700 - NAHB Green Bldg Standard for Homes	Residential	**ANSI Standard**	Yes	Points	Final standard ANSI-approved; published in Jan 2009 as ICC-700
IAPMO Green Plumbing & Mechanical Code Supplement	Residential above 3 stories + all commercial	**Code**	Yes	Minimum thresholds	Completed and published in February 2010
ICC Green Construction Code	Residential above 3 stories + all commercial	**Code**	Yes	Minimum thresholds	Development underway; 2nd draft changes considered by code committee in May 2011
U.S. EPA WaterSense for New Homes	Residential	Guidelines	No	Minimum thresholds	Final specification issued in December 2009

NATIONAL GREEN BUILDING STANDARDS & CODES

Comparison of specific water use efficiency provisions – maximum water use

PLUMBING	Green Globes GBI 01-200XP	ASHRAE SS189.1	ASHRAE S191 (draft)	ICC-NAHB HOMES	IAPMO Green Plumbing & Mech Code Supplement	ICC Green Code (draft)
Residential toilets (per flush)	HET: 1.28g - 4.8L	HET: 1.28g - 4.8L	HET: 1.28g - 4.8L	HET: 1.28g - 4.8L	HET: 1.28g - 4.8L	HET: 1.28g - 4.8L
Commercial toilets (per flush)					1.6g - 6.0L	1.6g - 6.0L
Urinals (per flush)	HEU: 0.5g/1.9L	HEU: 0.5g/1.9L	HEU: 0.5g/1.9L	HEU: 0.5g/1.9L	HEU: 0.5g/1.9L	HEU: 0.5g/1.9L
Residential & commercial "private" lavatory faucets (per minute)	1.5gpm – 5.7Lpm	1.5gpm – 5.7Lpm	1.5gpm – 5.7Lpm	1.5gpm – 5.7Lpm	1.5gpm – 5.7Lpm	1.5gpm – 5.7Lpm
Commercial "public" lavatory faucets (per min.)	0.5gpm – 1.9 Lpm	0.5gpm – 1.9 Lpm	0.5gpm – 1.9 Lpm		0.5gpm – 1.9 Lpm	0.5gpm – 1.9 Lpm
Commercial metering faucets (per cycle)	0.25 gpc – 0.9 Lpc	0.25 gpc – 0.9 Lpc	0.20 gpc – 0.76 Lpc		0.25 gpc – 0.9 Lpc	0.25 gpc – 0.9 Lpc
Residential kitchen faucets (per minute)	2.2 gpm – 8.3 Lpm	2.2 gpm – 8.3 Lpm	2.2 gpm – 8.3 Lpm			2.2 gpm – 8.3 Lpm
Residential showerheads (per minute)	2.0 gpm – 7.6 Lpm	2.0 gpm – 7.6 Lpm	2.0 gpm – 7.6 Lpm	2.5 gpm – 9.5 Lpm	2.0 gpm – 7.6 Lpm	2.0 gpm – 7.6 Lpm
Residential showering com- partment – size increment		2600 sq. in – 1.7 sq.m.	3000 sq. in – 1.9 sq.m.		1800 sq. in – 1.2 sq.m.	
Commercial pre-rinse spray valve (per minute)	1.6 gpm – 6.0 Lpm	1.3 gpm – 4.9 Lpm	1.3 gpm – 4.9 Lpm		1.6 gpm – 6.0 Lpm	1.3 gpm – 4.9 Lpm

NATIONAL GREEN BUILDING STANDARDS & CODES

Comparison of specific water use efficiency provisions – maximum water use

Appliances, Equipment, Irrigation & Alternate Water	Green Globes GBI 01-200XP	ASHRAE SS189.1	ASHRAE S191 (draft)	ICC 700- (NAHB) HOMES	IAPMO Green Plumbing & Mech Code Supplement	ICC Green Code (draft)
Residential dishwasher (total water per full cycle)	Energy Star & 5.8 gal – 22L	Energy Star & 5.8 gal – 22L	Energy Star & 5.0 gal – 19L	Energy Star	Energy Star	Energy Star
Residential clothes washer (water factor)	Energy Star & 6.0 gal – 23L	Energy Star & 6.0 gal – 23L	Energy Star & 4.5 gal – 17L	Energy Star	Energy Star	Energy Star
Graywater treatment system	Encouraged through the treatment and use of alternate (non-potable) sources of water			Points available for use of alternate sources	Specific provisions for equipment installation & water treatment	
Rainwater harvesting	Encouraged through the treatment and use of alternate (non-potable) sources of water				Specific provisions for equipment installation & water treatment	
Landscape irrigation	Provisions are non-mandatory; no turf restrictions	ET-based; smart technology; restrictions on turf	ET-based; smart techno-logy; restric-tions on turf	Non-mandatory provisions; some turf restrictions	Only as related to treatment & use of water from alternate sources; no specific landscape provisions	
Water features (fountains, etc.)	Use alternate water sources (non-potable); recirculation required				Use alternate water sources (non-potable)	
Residential water softeners	Demand-initiated regeneration control required				Permitted where water hardness ≥ 8 grains/gallon (137 mg/L)	Demand-initiated regeneration required; max water use 5 gal (19L) per 1K grains of hardness removed; salt efficiency requirements
Water-powered pumps					Water-powered sump pumps prohibited	Prohibited

NATIONAL GREEN BUILDING STANDARDS & CODES

Comparison of specific water use efficiency provisions – maximum water use

Metering and Commercial Food Service	Green Globes GBI 01-200XP	ASHRAE SS189.1	ASHRAE S191 (draft)	ICC 700-(NAHB) HOMES	IAPMO Green Plumbing & Mech Code Supplement	ICC Green Code (draft)
Sub-metering tenant water use (usage per day)	No	Yes, where >1000g-3800L	Yes, where >1000g-3800L		Yes, where >500g – 1900L	All tenants
Sub-metering processes – industrial/ commercial (usage per day)	No	Yes, where >1000g-3800L	Yes, where >1000g-3800L		Yes, where >1000g-3800L	Yes, where >1000g-3800L
Sub-metering irrigation	No	Yes, <25,000 sq.ft. – 2300 sq.meters	Yes, <10,000 sq.ft. 930 sq.meters		Yes, <15,000 sq.ft. – 1400 sq.meters	Yes, all automatic systems
Building Meter Data Management System	Require remote data communication to central system, recording hourly consumption data				Connection to central building system not required	
Commercial food service – ice makers	Energy Star (air cooled)	Energy Star (air cooled)	Energy Star (air cooled)		Energy Star (air cooled)	Energy Star (air cooled)
Commercial food service – food steamers (per hour)	2.0 g – 7.6 L	2.0 g – 7.6 L	2.0 g – 7.6 L		2.0 g – 7.6 L	2.0 g – 7.6 L
Commercial food service – dishwashers	Energy Star	Energy Star	Energy Star		Energy Star	Energy Star OR meet specified thresholds
Commercial food service – combination ovens (per hour)		10 g – 38 L	10 g – 38 L		10 g – 38 L	
Commercial food service – dipper wells (per minute)						6.0 g – 22.7 Lpm

8.2.4 WaterSense

As early as 2003 and with encouragement from water efficiency advocates, the U.S. Environmental Protection Agency (USEPA) began investigating the feasibility of developing a voluntary product-labeling program directed at market enhancements for water efficient products. This effort came to fruition in mid-2006 when the USEPA officially rolled out the WaterSense program[220]. USEPA officials fashioned WaterSense along the same lines as the ENERGY STAR initiative, which certifies select products with an energy-efficiency mark. The ENERGY STAR logo has notable cachet among consumers and specifiers and is credited with helping sell 1.5 billion qualified products since the label was introduced in 1992.

There are *very significant differences* between the two programs, however, including: (1) WaterSense-labeled products must meet certain performance requirements above and beyond just water consumption[221] and (2) products applying for the voluntary WaterSense label must be independently tested by an approved laboratory[222] and found compliant with the appropriate performance specification.

Some of the current (tank-type toilets, urinals, showerheads, residential lavatory faucets) and proposed[223] WaterSense specifications may appear to relate only to residential applications. However, residential occupancies will frequently be found within the commercial and institutional sectors, including:

- Commercial mixed-use projects that include some residential occupancy,
- Transient lodging projects (hotels and motels), and
- Institutional projects with on-site residency, such as colleges and universities, fire stations, and similar government-operated operations.

While the existing WaterSense specifications are considered standards, they are not mandatory in California[224].

8.2.5 California Code

With the more recent proactive involvement of water efficiency interests in standards and codes (including both water utility and manufacturer interests), plumbing fixtures have evolved toward more efficient technologies and products. As a result, the California legislature has considered a number of initiatives directed at reducing urban water demand by adopting these efficiencies into California practice. On October 11, 2007, California Assembly Bill 715 (AB715) was signed into law by the Governor, setting a new standard for the state with regard to plumbing fixtures.

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[220] http://www.epa.gov/watersense/

[221] The performance requirements for WaterSense products are directed at assuring user satisfaction with the product's ability to perform the task(s) for which it is intended.

[222] Energy Star products were self-certified by the manufacturers as meeting the program specifications.

[223] Products that are being or will be considered for WaterSense specifications and labeling: flushometer valve toilets, residential water softeners, glassware washers, pre-rinse spray valves, irrigation controllers, moisture sensors, autoclaves, food disposers.

[224] Nationally, some states and municipal jurisdictions have mandated compliance with WaterSense for certain new construction projects, although such is not widespread at this time.

Among other things, AB715 provided that, effective January 1, 2014, toilets and urinals sold or installed in California could not exceed effective flush volumes of 1.28 and 0.5 gallons, respectively[225]. AB715 further called for the California Building Standards Commission (CBSC) to develop the specific language in the State codes that reflected these new requirements.

Following AB715, the CBSC began work on a set of State "green" codes that became mandatory beginning in 2011. These provisions were released in 2010 in the form of the California Green Building Standard Code[226] (CalGreen), which is adopted into Title 24 of the California Code of Regulations. Provisions within CalGreen affect all types of CII uses in one way or another, although much of the code has been "reserved" for future development. Chapter 5 of CalGreen covers Nonresidential Mandatory Measures, which are largely directed at plumbing and outdoor water use. Appendix A5 of CalGreen covers Nonresidential Voluntary Measures, which likewise focus mostly on plumbing and outdoor water use. However, voluntary measures in CalGreen may be adopted as mandatory by jurisdictions that desire to go beyond the minimum State mandates. The following table compares the provisions of AB715 with those of CalGreen and Senate Bill 407 (which was directed at replacing non-EPAct-compliant fixtures with EPAct-compliant fixtures).

[225] AB715 defines the effective flush volume of a dual flush toilet as the average flush volume of one full flush and two reduced flushes. The standard for dual flush toilets allows for a full flush maximum of 1.6 gallons and a reduced flush maximum of 1.1 gallons, although many dual flush toilets function satisfactorily on less that these amounts.
[226] http://www.bsc.ca.gov/CALGreen/default.htm

CII Toilet and Urinal Fixtures in the California Codes

Condition, Activity, or Event	AB 715 (2007)	SB 407 (2009)	CalGreen (2010)
Sale of toilet and urinal fixtures through retail or other outlets	All fixtures sold or installed after Jan 1, 2014 must be HETs or HEUs[3]	Not addressed	Not addressed
Existing[1] multi-family residential - Institutional			
Resale	Not addressed	As of Jan 1, 2019, requires written disclosure by Buyer to Seller of non-compliant fixtures in property	Not addressed
Renovation[2]	All fixtures installed after Jan 1, 2014 must be HETs or HEUs[3]	Renovated MFR must be 1.6 max (toilets) or 1.0 max (urinals) on or after Jan 1, 2014 to obtain bldg or occupancy permit	1.28 maximum[3] IF prescriptive path is chosen (per 4.303.1) – Jan 1, 2011
All other MFR	Not addressed	ALL MFR must be 1.6/1.0 max by Jan 1, 2019[6]	
Existing[1] Commercial-Industrial			
Resale	Not addressed	As of Jan 1, 2019, requires written disclosure by Buyer to Seller of non-compliant fixtures in property	Not addressed
Renovation[227]	All fixtures installed after Jan 1, 2014 must be HETs or HEUs[3]	Renovated Comm'l must be 1.6 max (toilets) or 1.0 max (urinals) on or after Jan 1, 2014 to obtain bldg or occupancy permit	1.28 max (toilets) and 0.5 max (urinals)[3] IF prescriptive path is chosen (per 5.303.2) – Jan 1, 2011

[227] SB407 applies only where building additions increase total building size by more than 10 percent OR for building alterations or improvements, where the total construction cost estimated in the building permit exceeds $150,000

All other Commercial	Not addressed	ALL Commercial must be 1.6 max on or after Jan 1, 2019[228]	

New multi-family residential - Institutional	All fixtures installed after Jan 1, 2014 must be HETs or HEUs[3]	Not addressed	1.28 max (toilets) and 0.5 max (urinals)[3] <u>IF</u> prescriptive path is chosen (per 4.303.1) – Jan 1, 2011
New Commercial - industrial			1.28 max (toilets)[3] and 0.5 max (urinals) <u>IF</u> prescriptive path is chosen (per 5.303.2) – Jan 1, 2011

8.2.6 Other Standards

The Energy Star Program, the Consortium for Energy Efficiency, and the U.S. Department of Energy have all promulgated other standards that affect the performance of water-using appliances and equipment, including clothes washers, dishwashers, steam cookers, and ice-makers, as well as the plumbing products mentioned previously. The various efficiency thresholds specified within these programs and mandates are displayed on the following pages.

[228] Places continuing responsibility on the owner of rental property to guarantee that the toilet "shall be operating at the manufacturer's rated water consumption at the time that the tenant takes possession."

Fixtures and Appliances	EPAct 1992, EPAct 2005, ‘‘Energy Independence and Security Act of 2007’’ *(or backlog NAECA updates)*		**WaterSense® or Energy Star®**		**Consortium for Energy Efficiency**	
	Current Standard	Proposed/Future Standard	**Current Specification**	**Proposed/Future Specification**	**Current Specification**	**Proposed/Future Specification**
Residential Toilets (Water Closets)	1.6 gpf[229]	1.28 gpf/ 4.8 Lpf proposed by efficiency advocates for tank-type only	Tank-type toilets only: WaterSense = 1.28 gpf (4.8L) with at least 350 gram waste removal + LADWP Supplementary Purchase Specification (SPS)	Effective Nov 2011, EPA announced revisions to product specifications for sampling, product marking, & flapper seals, see: http://www.epa.gov/WaterSense/docs/revised_het_spec_revisions_summmary_050611_final508.pdf	No specification	
Residential Lavatory (Bathroom) Faucets	2.2 gpm at 60 psi[230]	1.5 gpm/ 5.7 Lpm proposed by efficiency advocates	WaterSense = 1.5 gpm maximum & 0.8 gpm minimum at 20 psi		No specification	
Residential Kitchen Faucets				None proposed at this time	No specification	

229 EPAct 1992 standard for toilets applies to both commercial and residential models.
230 EPAct 1992 standard for faucets applies to both commercial and residential models.

Fixtures and Appliances	EPAct 1992, EPAct 2005, ''Energy Independence and Security Act of 2007'' *(or backlog NAECA updates)*		**WaterSense® or Energy Star®**		**Consortium for Energy Efficiency**	
	Current Standard	Proposed/Future Standard	**Current Specification**	**Proposed/Future Specification**	**Current Specification**	**Proposed/Future Specification**
Residential Showerheads	2.5 gpm at 80 psi		WaterSense = 2.0 gpm max with spray force & coverage requirements		No specification	
Residential Clothes Washers	MEF ≥ 1.26 ft^3/kWh/cycle WF ≤ 9.5 gal/cycle/ft^3 Note: MEF measures energy consumption of the total laundry cycle (wash + dry). The higher the number, the greater the energy efficiency	DOE to publish final rule by Dec 31, 2011, determining if standards will change effective 1/1/2015.	Energy Star (DOE) Effective Jan 1, 2011: MEF ≥ 2.0 WF ≤ 6.0 gal/cycle/ft^3 New: Energy Star Most Efficient (Tier 2 Energy Star) Effective May 5, 2011 to Dec 31, 2011: washers greater than 2.5 cubic feet, MEF 3.0 ft^3/kWh/cycle; WF 3.3 gal/cycle/ft^3 And for compact capacity washers less than 2.5 cubic feet, MEF 2.3 and WF 4.5 Note: Only EPA certified by independent body residential clothes		Effective Jan 1, 2011, Tier 1: MEF ≥ 2.0 ft^3/kWh/cycle; WF ≤ 6.0 gal/cycle/ft^3 Tier 2: MEF ≥ 2.2 ft^3/kWh/cycle; WF ≤ 4.5 gal/cycle/ft^3 Tier 3: MEF ≥ 2.4 ft^3/kWh/cycle; WF ≤ 4.0 gal/cycle/ft^3	

Fixtures and Appliances	EPAct 1992, EPAct 2005, ''Energy Independence and Security Act of 2007'' *(or backlog NAECA updates)*		**WaterSense® or Energy Star®**		**Consortium for Energy Efficiency**	
	Current Standard	Proposed/Future Standard	**Current Specification**	**Proposed/Future Specification**	**Current Specification**	**Proposed/Future Specification**
			washers (no combo washer-dryers) with capacity larger than 1.6 cubic feet are eligible for the Most Efficient Label			

Fixtures and Appliances	EPAct 1992, EPAct 2005, ''Energy Independence and Security Act of 2007'' *(or backlog NAECA updates)*		**WaterSense® or Energy Star®**		**Consortium for Energy Efficiency**	
	Current Standard	Proposed/Future Standard	**Current Specification**	**Proposed/Future Specification**	**Current Specification**	**Proposed/Future Specification**
Standard Size and Compact Residential Dishwashers [231]	*Standard models*: Energy Independence and Security Act of 2007 specified: effective 1/1/2010: Standard Size: 355 KWh/year (.62 EF + 1 watt standby) WF ≤ 6.5 gallons/cycle Compact Size: 260 kWh WF ≤ 4.5 gallons/cycle	Also specified by the Act: DOE shall publish final rule by 1/1/2015 determining if dishwasher standards will change effective 1/1/2018.	Energy Star (DOE) Effective July 1, 2009: Standard Size: 324 kWh/year WF ≤ 5.8 gallons/cycle Compact Size: 234 kWh/year WF ≤ 4.0 gallons/cycle kWH/yr is replacing EF since it includes	Energy Star Proposed effective Jan 1, 2013: Tier 1: Standard Size: 307 kWh/yr 5.0 gallons per cycleCompact Size: 222 kWh/yr 3.5 gallons per cycle Note: Tier 2 now being considered by EPA dates and metrics TBD	Effective Jan. 20, 2012: Tier 1: EF ≥ 0.75 cycles/kWh; and 295 max kWh/year; WF 4.25 gallons per cycle Tier 2: EF ≥ 0.75 cycles/kWh; 295 max kWh/year; WF 4.25 gallons per cycle *Compact models less than 8 place settings)*:	Could adjust Tiers after July 1, 2011 when new Energy Star becomes effective

[231] ***Standard models*:** capacity is greater than or equal to eight place settings and six serving pieces; **C*ompact models*:** capacity is less than eight place settings and six serving pieces

Fixtures and Appliances	EPAct 1992, EPAct 2005, ''Energy Independence and Security Act of 2007'' *(or backlog NAECA updates)*		**WaterSense® or Energy Star®**		**Consortium for Energy Efficiency**	
	Current Standard	Proposed/Future Standard	**Current Specification**	**Proposed/Future Specification**	**Current Specification**	**Proposed/Future Specification**
	EF is the number of cycles the machine can run for each kWh of electricity		the cycles the machine can run for each kWh, but also includes up to 8 kWh/yr of standby power (when the machine isn't cycling)		EF ≥ 1.0 cycles/kWh; 222 max kWh/year; 3.5 gallons per cycle	

Fixtures and Appliances	EPAct 1992, EPAct 2005 *(or backlog NAECA updates)*		WaterSense® or Energy Star®		Consortium for Energy Efficiency	
	Current Standard	**Proposed/ Future Standard**	**Current Specification**	**Proposed/Future Specification**	**Current Specification**	**Proposed /Future Specification**
Commercial Toilets (Water Closets)	1.6 gpf[232]/6.0 Lpf Except blow-out fixtures: 3.5-gpf/13 Lpf Note: Some states prohibit blow-out at 3.5 gpf	1.28 gpf/ 4.8 Lpf proposed by efficiency advocates for tank-type only	Tank-type toilets only: WaterSense = 1.28 gpf (4.8L) with at least 350 gram waste removal + LADWP Supplementary Purchase Specification (SPS)	Flushometer valve/ bowl combinations: WaterSense specification in development. No release date promised.	No specification	
Commercial Urinals	1.0 gpf	0.5 gpf/ 1.9 Lpf proposed by efficiency advocates	WaterSense = 0.5 gpf/1.9Lpf (flushing urinals only – non-water urinals not covered by WS)		No specification	
Commercial Faucets	Private faucets: 2.2 gpm at 60 psi[233] Public Restroom faucets: 0.5 gpm at 60 psi[5] Metering (auto shut off) faucets: 0.25 gallons per			WaterSense draft specification now under consideration	No specification	

[232] EPAct 1992 standard for toilets applies to both commercial and residential models.
[233] In addition to EPAct requirements, the American Society of Mechanical Engineers standard for public lavatory faucets is 0.5 gpm at 60 psi (ASME A112.18.1-2005). This maximum has been incorporated into the national Uniform Plumbing Code and the International Plumbing Code for all except private applications, private being defined as residential, hotel guest rooms, and health care patient rooms. All other applications subject to the 0.5 gpm/1.9 Lpm flow rate maximum.

Fixtures and Appliances	EPAct 1992, EPAct 2005 *(or backlog NAECA updates)*		WaterSense® or Energy Star®		Consortium for Energy Efficiency	
	Current Standard	Proposed/ Future Standard	Current Specification	Proposed/Future Specification	Current Specification	Proposed /Future Specification
	cycle[234] (no maximum flow rate)					
Commercial Clothes Washers (Family-sized)	MEF ≥ 1.26 ft^3/kWh; WF ≤ 9.5 gal/cycle/ft^3	Proposed Jan 1, 2013: Top loaders: 1.6 MEF and WF of 8.5 Front loaders: 2.0 MEF and 5.5 WF.	Energy Star: MEF ≥ 2.0ft^3/kWh/cycle; WF ≤ 6.0 gal/cycle/ft^3	Jan 8, 2013: Energy Star Proposed: 2.2 MEF and 4.5 W.F.	(Note: this spec covers only normal capacity family washers, NOT large capacity commercial washers) Tier 1: 2.0 MEF 6.0 gal/cycle/ft^3 Tier 2: 2.200 MEF 4.5 gal/cycle/ft^3 Tier 3: 2.40 MEF 4.0 gal/cycle/ft^3	Considering changes for 2013

[234] Metering faucets not subject to flow rate maximum

Fixtures and Appliances	EPAct 1992, EPAct 2005 *(or backlog NAECA updates)*		WaterSense® or Energy Star®		Consortium for Energy Efficiency	
	Current Standard	**Proposed/ Future Standard**	**Current Specification**	**Proposed/Future Specification**	**Current Specification**	**Proposed /Future Specification**
Commercial Dishwashers	No standard		Energy Star (EPA) using NSF/ANSI standards for water use and ASTM standards for energy use Effective **10/11/2007** *Under counter*: Hi Temp: 1.0 gal/rack; <= 0.90 kW; Lo Temp 1.70 gal/rack <= 0.5 kW *Stationary Single Tank Door*: Hi Temp: 0.95 gal/rack; <= 1.0 kW Lo Temp: 1.18 gal/rack; <= 0.6 kW *Single Tank Conveyor*: Hi Temp: 0.70 gal/rack; <= 2.0 kW; Lo Temp: 0.79 gal/rack; <= 1.6 kW *Multiple Tank Conveyor*: Hi Temp: 0.54 gal/rack; <= 2.6 kW Lo Temp: 0.54 gal/rack; <= 2.0 kW		No specification	

Fixtures and Appliances	EPAct 1992, EPAct 2005 *(or backlog NAECA updates)*		WaterSense® or Energy Star®		Consortium for Energy Efficiency	
	Current Standard	**Proposed/ Future Standard**	**Current Specification**	**Proposed/Future Specification**	**Current Specification**	**Proposed /Future Specification**
Automatic Commercial Ice Makers[235]	Effective 1/1/2010: Energy and condenser water efficiency standards vary by equipment type on a sliding scale depending upon harvest rate and type of cooling (see link to additional information at end of this table)		Energy Star (EPA) Energy and water efficiency standards vary by equipment type on a sliding scale depending upon harvest rate and type of cooling (see link to additional information at end of this table). Water cooled machines excluded from Energy Star		Energy and water (potable and condenser) standards are tiered and vary by equipment type on a sliding scale depending upon harvest rate and type of cooling (see link to additional information at end of this table)	

[235] Optional standards for other types of automatic ice makers are also authorized under EPAct 2005.

Fixtures and Appliances	EPAct 1992, EPAct 2005 *(or backlog NAECA updates)*		WaterSense® or Energy Star®		Consortium for Energy Efficiency	
	Current Standard	**Proposed/ Future Standard**	**Current Specification**	**Proposed/Future Specification**	**Current Specification**	**Proposed /Future Specification**
Commercial Pre-rinse Spray Valves (for food service appli-cations)	Flow rate ≤ 1.6 gpm (no pressure specified; no performance requirement)		No specification	Proposed Energy Star specification abandoned after standard established in EPAct 2005; WaterSense specification in development in conjunction with Energy Star	No specification (program guidance recommends 1.6 gpm at 60 psi and a cleanability requirement)	

Fixtures and Appliances	EPAct 1992, EPAct 2005 *(or backlog NAECA updates)*		WaterSense® or Energy Star®		Consortium for Energy Efficiency	
	Current Standard	**Proposed/ Future Standard**	**Current Specification**	**Proposed/Future Specification**	**Current Specification**	**Proposed /Future Specification**
Commercial Steam Cookers[236]	No standard		Energy Star (EPA) *Electric*: 50% cooking energy efficiency; idle rate 400–800 Watts *Gas*: 38% cooking energy efficiency; idle rate 6,250–12,500 British thermal units/hour *No specified water use factor		*Electric*: 50% cooking energy efficiency; idle rate 400–800 Watts *Gas*: 38% cooking energy efficiency; idle rate 6,250–12,500 British thermal units/hour Water Use Factor (for both electric and gas models): Tier 1A: ≤ 15 gal/hr Tier 1B: ≤ 4 gal/hr	

[236] Idle rate standards vary for 3-, 4-, 5-, and 6-pan commercial steam cooker models.

Information/materials on EPAct 2005/NAECA standards:

Schedule for development of appliance and commercial equipment efficiency standards:

http://www.eere.energy.gov/buildings/appliance_standards/2006_schedule_setting.html

Commercial Clothes Washers and Dishwashers (agenda/presentations at 4/27/06 DOE public meeting on rulemaking):

http://www.eere.energy.gov/buildings/appliance_standards/residential/home_appl_mtg.html

Automatic Commercial Ice Maker Standards:
http://www.eere.energy.gov/buildings/appliance_standards/pdfs/epact2005_appliance_stds.pdf (Page 18)

Pre-rinse Spray Valves

http://www.eere.energy.gov/buildings/appliance_standards/pdfs/epact2005_appliance_stds.pdf (Page 10)

Information/materials on WaterSense specifications:

Toilets

http://www.epa.gov/watersense/products/toilets.html

Urinals

http://www.epa.gov/watersense/products/urinals.html

Bathroom Lavatory Faucets

http://www.epa.gov/watersense/products/bathroom_sink_faucets.html

Information/materials on Energy Star specifications:

Residential Clothes Washers

http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers

Commercial Clothes Washers

http://www.energystar.gov/index.cfm?fuseaction=clotheswash.display_commercial_cw

Residential Dishwashers

http://www.energystar.gov/index.cfm?c=dishwash.pr_dishwashers

Commercial Dishwashers

http://www.energystar.gov/index.cfm?c=new_specs.comm_dishwashers

Automatic Commercial Ice Makers

http://www.energystar.gov/index.cfm?c=new_specs.ice_machines

Commercial Steam Cookers

http://www.energystar.gov/index.cfm?c=steamcookers.pr_steamcookers

Information/materials on CEE specifications:

Residential Clothes Washers

http://www.cee1.org/resid/seha/rwsh/rwsh-main.php3

Residential Dishwashers

http://www.cee1.org/resid/seha/dishw/dishw-main.php3

Commercial, Family-Sized Clothes Washers

http://www.cee1.org/com/cwsh/cwsh-main.php3

Commercial Ice-Makers

http://www.cee1.org/com/com-kit/files/ProgramGuidanceIceMachines.pdf

http://www.cee1.org/resrc/facts/com-ice-fx.pdf

Spec Table: http://www.cee1.org/com/com-kit/files/IceSpecification01Jul2011.pdf

Commercial Dishwashers

http://www.cee1.org/com/com-kit/files/ProgramGuidanceDishwashers.pdf

http://www.cee1.org/com/com-kit/files/DishwasherSpecification.pdf

Pre-rinse Spray Valves

http://www.cee1.org/com/com-kit/files/prv-guides.pdf

Commercial Steam Cookers

http://www.cee1.org/com/com-kit/files/ProgramGuidanceSteamers.pdf

http://www.cee1.org/com/com-kit/sc-hc-specs.pdf

Specification: http://www.cee1.org/com/com-kit/files/SteamerSpecification.pdf

9 Public Infrastructure Needs for Recycled Water

Commercial, industrial, and institutional (CII) water users can contribute to better management of the State's water by replacing potable or fresh water with recycled water or by using less water by following the BMPs cited in other sections of this report. This Section focuses on CII use of recycled water obtained from an external recycled water supplier, as defined in Box 9-1.One of the fundamental challenges to increasing CII use of recycled municipal water is infrastructure limitations. After a brief initial discussion on the history and status of municipal recycled water in the state, Section 10 focuses on public infrastructure needs for increasing CII recycled water use, as required by California Water Code Section 10608.43. It addresses some of the issues associated with on-site infrastructure, which is frequently a limiting factor in integrating municipal recycled water into a CII user's water supply. The section also includes a brief discussion of funding mechanisms and descriptions of successfully implemented projects.

> **Box 9-1.** Recycled Water Definition
>
> "Recycled water" is defined in the Water Code (see glossary) as wastewater treated to a quality suitable for beneficial use. The Water Code definition does not designate the source of the wastewater. In the context of this report, the discussion of recycled water is focused on treated wastewater of municipal origin and will usually be referred to as "municipal recycled water." Municipal wastewater is considered to be community wastewater containing a domestic wastewater component.

For this report, the term "Infrastructure" is separated into two components: "public infrastructure" and "on-site infrastructure". "Public infrastructure" refers to facilities serving the general community, including wastewater collection and treatment, and recycled water storage and distribution to customers. "On-site infrastructure" refers to facilities located on customer sites that might include additional water treatment, recycled water plumbing, and modifications of industrial processes (Figure 9-1). CII water users can also improve water management by using lower quality water appropriate for non-potable uses by identifying alternative water sources, such as low quality groundwater. CII facilities commonly reuse water within their facility, either by cycling water multiple times through an individual process, such as a cooling tower, or by cascading reuse by passing water from one process to another until its quality is no longer suitable for another use. In many instances, Industrial wastewater may also be treated and delivered to another site for reuse, such as food process discharge water being used for agricultural irrigation. Significant water savings can be achieved by this internal reuse or industrial water recycling. BMPs and case studies for cascading reuse or multi-cycle use are addressed in other sections. This section focuses only on municipal water recycling.

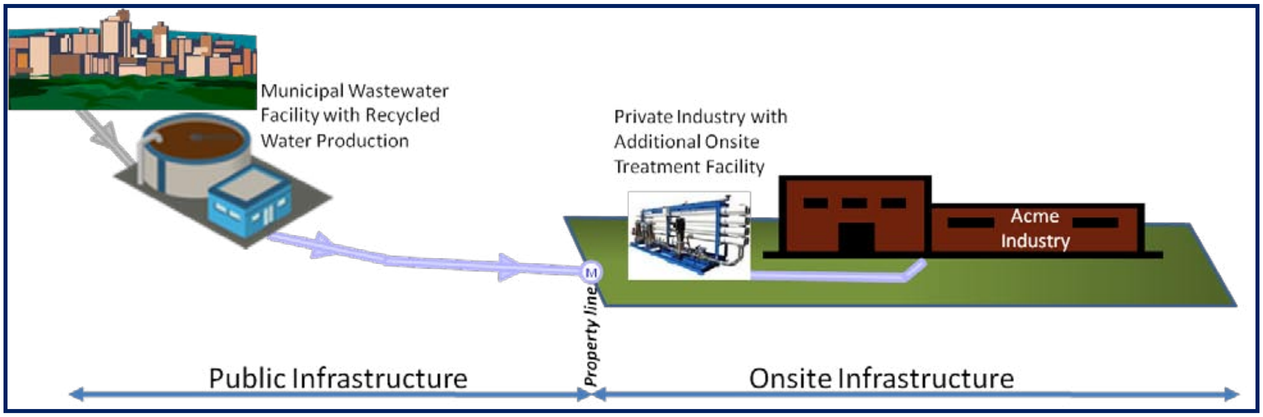


Figure 9-1: Public and Onsite Recycled Water Infrastructure. Delineation between Public Infrastructure – community-based wastewater collection, treatment and distribution system - and Onsite Infrastructure – customer-owned pipeline and or supplemental treatment system dedicated to treating water used at a commercial or industrial facility.

9.1 Municipal Recycled Water in California

Recycled water is used extensively in California to meet municipal, environmental, commercial, industrial, and institutional water supply needs. Recycled water projects are almost exclusively implemented on the local level and involve one or more agencies working cooperatively to address wastewater and recycled water issues. Because of the link between wastewater and water supply quality, quantity, and reliability, as well as jurisdictional issues and distribution systems, implementing these projects can involve extensive interagency collaboration. A brief, foundational discussion of recycled water in California is included below.

9.1.1 History

Recycled water has been used beneficially in California for over 100 years. In the earliest applications, farms located near urban areas in this drought-prone state used effluent from municipal wastewater treatment plants. In some cases, farmers even gave cities easements for sewer mains in exchange for the right to pump untreated wastewater to irrigate their crops. By 1910, 35 sites were using recycled water for agriculture purposes. San Francisco's Golden Gate Park began using raw sewage for irrigation water, but in 1932 it had to add a septic tank because of complaints from nearby residents. This system became the first documented California facility dedicated to treating recycled water. The McQueen Treatment Plant operated until 1978. In 1952, 107 California communities were using recycled water for agricultural and landscape irrigation. Following a national initiative to upgrade and improve the level of wastewater treatment in the 1970s, the diversity of recycled water uses increased, and they now include landscape, agricultural, and golf course irrigation; commercial and industrial applications; environmental enhancement; groundwater recharge; and reservoir augmentation. Statewide surveys conducted since 1970 have quantified the annual volume of recycled water use and have shown a steady increase in the amount and types of uses for recycled water in California (Figure 9-2).

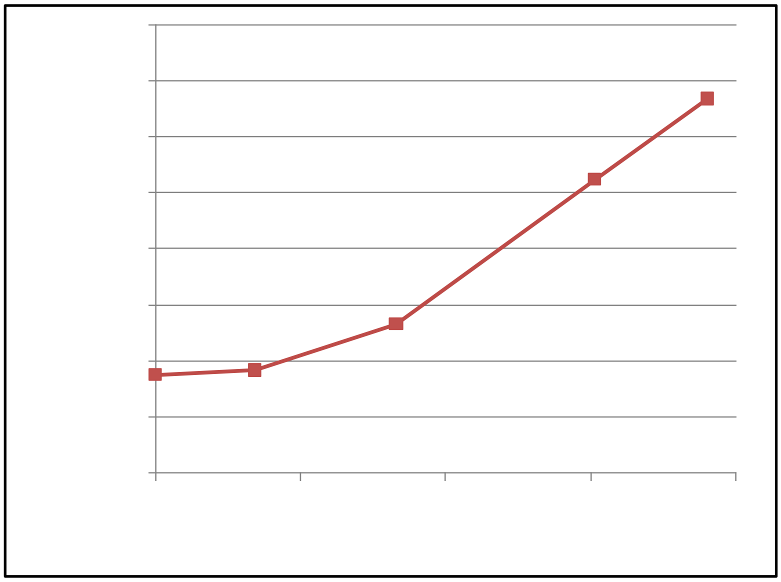


Figure 9-2: Municipal Recycled Water in California Since 1970. Recycled water beneficially reused in California since 1970, based on statewide surveys.

9.1.2 Potable and Non-potable Recycled Water Applications

Treated municipal wastewater is used as potable and non-potable supply. Currently, municipal recycled water is used directly in CII applications in California for non-potable purposes, such as process or landscaping applications. In these applications, recycled water is delivered from the recycled water treatment facility to water users via distribution pipeline systems dedicated to recycled or nonpotable water. Eighty-one percent of recycled water use in California is for nonpotable purposes delivered in these “dual distribution” (recycled water, separate from potable water) systems.

CII users benefit indirectly when a water supplier is able to augment its overall potable water supplies by implementing potable recycled water projects, such as groundwater recharge with recycled water. Potable recycled water projects are classified as either indirect potable or direct potable reuse. Indirect potable reuse projects incorporate recycled water into a raw water supply such as a surface storage reservoir or a groundwater aquifer. The recycled water mixes with the native water and often benefits from additional natural systems treatment. Direct potable reuse projects incorporate highly treated recycled water directly into potable water treatment plants or water distribution systems. Currently indirect potable reuse through groundwater recharge is the only form of potable reuse that has been permitted in California. Table 10-1 summarizes the indirect potable water use projects active in California in 2011. Some of the injection projects provide a dual benefit of protecting the groundwater basin from seawater intrusion by creating a hydraulic barrier, while also augmenting the groundwater supply available for use. Several other indirect potable reuse projects are in pilot phase testing, including reservoir augmentation, and they are expected to be online within a few years.

Table 9-1
INDIRECT POTABLE REUSE PROJECTS ACTIVE IN 2011

PROJECT	TREATMENT[1]	GROUND-WATER RECHARGE METHOD	RECYCLED WATER VOLUME (TAFY/%)[2]	POPULATION SERVED (millions)[3]	INITIAL YEAR OF OPERATION
Montebello	Tertiary	Percolation	50/35	4	1962
West Coast	Advanced	Injection	15/ 50-100		1994
Dominguez Gap	Advanced	Injection			2006
Alamitos	Advanced	Injection			2005
Orange County/ Talbert	Advanced	Injection	72(104)[4]/50-100	2.4	1976
Orange County/ Anaheim	Advanced	Percolation and Injection			2008
Chino Basin	Tertiary	Percolation	5/8-13	0.8	2005

1. **NOTES:**Advanced treatment is reverse osmosis and advanced oxidation (ultraviolet plus peroxide).
2. TAFY=quantity of recycled water injected or percolated to groundwater each year in thousands of acre-feet. The average concentration in percent by volume of recycled water in groundwater is also shown.
3. 3. Population served by distribution system connected to the groundwater recharge project.4. The project is being expanded from 72 to 104 TAFY in 2011.

9.1.3 Current Statewide Recycling

The State Water Resources Control Board (SWRCB) with assistance from the DWR conducted a survey of agencies involved with the beneficial treatment, conveyance, or reuse of domestic wastewater as recycled water. The survey results established that a total of 669,000 acre feet of municipal wastewater were treated and delivered for use in California in 2009.

Recycled water use was classified according to eleven beneficial uses, as shown in Figure 9-3. The categories of CII uses are Commercial, Industrial, Golf Course Irrigation, and most of Landscape Irrigation. A few minor CII uses, such as toilet flushing, are in the “Other” category. The commercial (6,400 AF) and industrial (47,100 AF) beneficial uses account for eight percent of the overall municipal recycled water use in 2009. A small but unknown quantity of Landscape Irrigation occurs in residential settings. In total, CII uses represent about 30 percent of total recycled water use. Institutional uses were not categorized separately from the other beneficial uses, although the recycled water use at prisons, colleges, and military bases included in the survey include 10,200 AF of golf course, landscape, and agricultural irrigation.

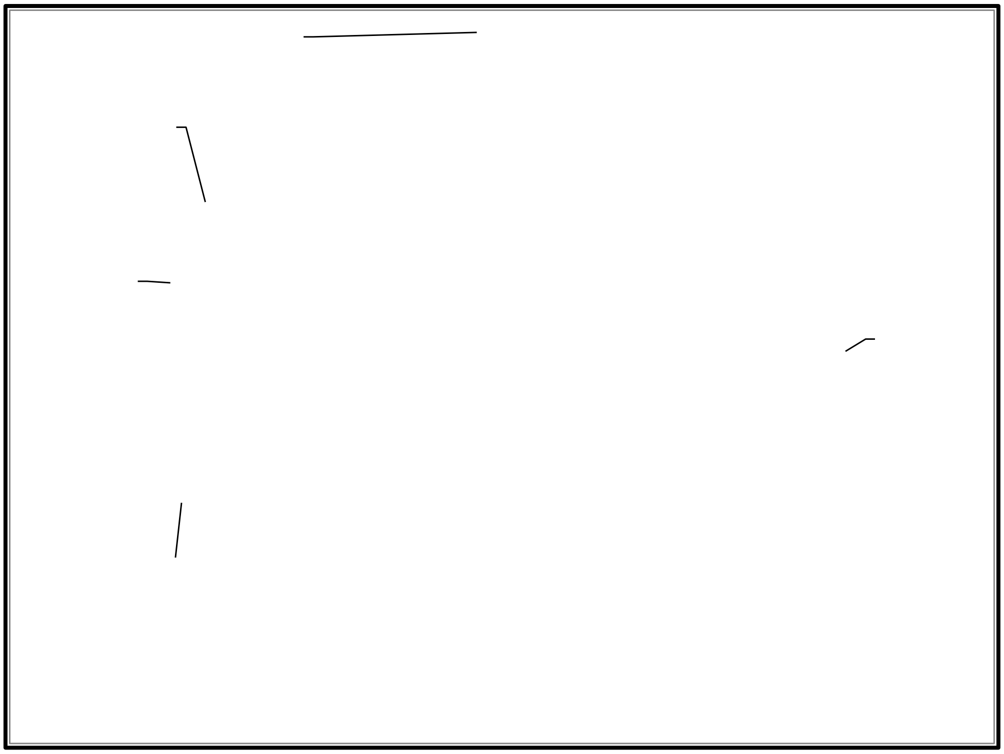


Figure 9-3: Recycled Water Beneficial Use Distribution in 2009. 2009 Recycled Municipal Wastewater Survey, showing beneficial use categories, volume of water in acre-feet beneficially used in 2009, and the overall percentage of the category based on the annual amount of water beneficially used in 2009.

9.1.4 Title 22 Levels of Treatment

The California Department of Public Health (CDPH) prescribes the levels of treatment that are required for recycled water to protect public health. In general, the levels of treatment are based on the levels of human exposure and the types of exposure that provide pathways to infection. The required levels of treatment are specified in Title 22 of the California Code of Regulations (Division 4, Chapter 3, §60301 et seq.). The Title 22 regulations also specify monitoring and reporting requirements and on-site use area requirements.

Box 9-2. Wastewater Treatment Levels

Primary Treatment removes 70 to 85 percent of the organic and inorganic solids that either settle out or float to the top.

Secondary Treatment mixes the remaining suspended waste solids with microorganisms and air. The micro-organisms convert the waste solids to biomass that settles out.

Tertiary Treatment filters out most of the remaining solids through a granular media (sand or anthracite coal) or a membrane, with the final product water being disinfected with chlorine or ultraviolet light to kill off bacteria, viruses, and other microorganisms.

Advanced Treatment is any water treatment technologies beyond conventional coagulation, filtration and disinfection. These may include reverse osmosis, micro- or nanofiltration, ozonation, or advanced oxidation.

(Los Angeles County, 2005; AWWARF, 2006;

Municipal wastewater treatment generally can have four levels, as commonly described in Box 9-2. The levels of treatment are mostly governed by Title 22 requirements to protect public health. However, as described later in this Section, water quality can be critical to certain CII applications and the type and level of treatment may be determined based on needs aside from public health protection.

One of the key components of incorporating recycled water in CII applications is aligning potential uses to the level of treated recycled water that is or is potentially available. Determining recycled water availability requires coordination with both the local water and wastewater agencies, because each jurisdiction has its own roles, authorities, and service areas with respect to recycled water generation and distribution.

Table 9-2 summarizes the CII applications that are allowed for levels of recycled water treatment specified in Title 22. While Title 22 lists specific allowed uses, other uses are permitted after a case-by-case evaluation and approval by CDPH. For example, additional non-potable recycled water applications include geothermal power production and carpet-dying. In general, the linkage between level of recycled water treatment and potential uses specified in Title 22 is strongly influenced by the potential for direct human contact and ingestion, with higher levels of treatment (tertiary or advanced) required for open public access and worker contact issues.

Indirect potable reuse through groundwater recharge has occurred in California since 1962. Title 22 does not specify specific treatment, design, or monitoring requirements for groundwater recharge. The regulations provide that CDPH will make recommendations to the RWQCBs for each project on a case-by-case basis. The recommendations are reflected in requirements in water recycling permits issued by the RWQCBs. To provide a more systematic approach to regulating groundwater recharge, CDPH drafted regulations in the 1980s. The draft regulations were based in part on recommendations by the Scientific Advisory Panel on Groundwater Recharge and an earlier scientific panel. These draft regulations have evolved as new research and data from existing projects have become available. In general, the draft regulations have become more flexible and are tailored for each new project in the form of recommendations for RWQCB permits.

CDPH has an independent authority to protect sources of drinking water and to regulate public drinking water systems. In its role of protecting drinking water sources, CDPH may specify requirements that would be included in the water recycling permits issued by the RWQCBs. In regulating public water systems, potable water suppliers obtain permits for operating water treatment plants or drinking water wells. For groundwater recharge projects using recycled water, these CDPH permits have not been a focus. However, in the future, for indirect potable reuse involving surface water augmentation or direct potable reuse, CDPH permits may play a more significant role.

Table 9-2

POTENTIAL CII APPLICATIONS FOR RECYCLED WATER, BASED ON TITLE 22 REQUIREMENTS[1]

POTENTIAL COMMERCIAL (non-agricultural), INDUSTRIAL, AND INSTITUTIONAL USES	MINIMUM TREATMENT LEVEL[2]		
	Disinfected Secondary-23[3,4]	**Disinfected Secondary-2.2[3,5]**	**Tertiary[6]**
Landscape and Buildings			
Cemetery landscaping	X		
Decorative fountains			X
Drain trap priming			X
Fire protection, structural			X
Fire protection, non-structural	X		
Golf courses, restricted access	X		
Golf courses, unrestricted access			X
Landscape impoundments	X		
Landscaping, freeway	X		
Landscaping, restricted access	X		
Landscaping, unrestricted access			X
Toilet and urinal flushing			X
Commercial and Industrial			
Aquaculture		X	
Artificial snow making			X
Backfill consolidation around nonpotable piping	X		
Backfill consolidation around potable piping			X
Car washes			X
Cleaning roads, sidewalks and outdoor work areas	X		
Concrete mixing	X		
Cooling and air conditioning, mist generation			X
Cooling and air conditioning, no mist generation	X		
Dust control on roads and streets	X		
Industrial boiler feed	X		
Industrial process water, no worker contact	X		
Industrial process water, worker contact			X
Laundries			X
Nurseries irrigation	X		
Sod farms	X		
Soil compaction	X		

NOTES:
1. Title 22 of the California Code of Regulations (Division 4, Chapter 3, §60301 et seq.)
2. Undisinfected secondary water is primarily used for agricultural applications and sanitary sewer flushing. Advanced treated water is used primarily for potable groundwater recharge applications. Neither application is presented in this table.
3. Title 22 identifies two levels of secondary treatment based on total coliform testing and differentiates recycled water use for each.
4. §60301.225.
5. §60301.220.
6. §60301.230.

1

In 2010 Senate Bill No. 918 (SB 918) was enacted. One of its primary provisions was to add Chapter 7.3 to Division 7 of the California Water Code, addressing the regulation of indirect and direct potable reuse. The following provisions were enacted:

- On or before December 31, 2013, CDPH shall adopt uniform water recycling criteria for indirect potable reuse for groundwater recharge.
- CDPH shall convene and administer an expert panel for the purposes of advising CDPH on public health issues and scientific and technical matters regarding development of uniform water recycling criteria for indirect potable reuse through surface water augmentation and investigation of the feasibility of developing uniform water recycling criteria for direct potable reuse.
- On or before December 31, 2016, CDPH shall develop and adopt uniform water recycling criteria for surface water augmentation, provided that CDPH submit the proposed criteria to the expert panel and the expert panel adopts a finding that the proposed criteria would adequately protect public health.
- CDPH shall investigate and report to the Legislature by December 31, 2016, on the feasibility of developing uniform water recycling criteria for direct potable reuse and shall complete a public review draft of its report by June 30, 2016.
- CDPH, in consultation with SWRCB, shall report to the Legislature as part of the annual budget process, in each year from 2011 to 2016, inclusive, on the progress towards developing and adopting uniform water recycling criteria for surface water augmentation and its investigation of the feasibility of developing uniform water recycling criteria for direct potable reuse.
- CDPH may appoint an advisory group, task force, or other group, comprised of representatives of water and wastewater agencies, local public health officers, environmental organizations, environmental justice organizations, public health nongovernmental organizations, and the business community, to advise the department regarding the development of uniform water recycling criteria for direct potable reuse.
- SWRCB shall enter into an agreement with CDPH to assist in implementing these provisions.

9.1.5 Regulatory Agencies and their Roles in Statewide Recycling

The current framework for regulating recycled water has been in place since the 1970s. Primary authority for overseeing recycled water is divided between the SWRCB, including the nine RWQCBs, and CDPH. A memorandum of agreement between the SWRCB and CDPH documents this arrangement and clarifies the roles of the agencies.

Four other state agencies are directly involved with recycled water issues in California and implement various sections of state law: DWR, California Public Utilities Commission, California Department of Housing and Community Development (HCD), and California Building Standards Commission (CBSC). Statutes governing recycled water are currently contained within the Water, Health and Safety, and Public Utilities codes and regulations are in various subdivisions (titles) of the California Code of Regulations (CCR). State agency roles and responsibilities are summarized in Table 9-3.

Table 9-3
REGULATORY AGENCY ROLES AND RESPONSIBILITIES FOR THE REGULATION AND USE OF RECYCLED WATER

AGENCY	ROLE	RESPONSIBILITY	CALIFORNIA CCR
Department of Public Health	Protects public health	• Adopts uniform recycled water criteria for non-potable and potable recycled water projects[1] • Provides recommendations for recycled water project permits • Reviews and makes recommendations on sites proposed for recycled water use • Oversees cross-connection prevention[2] • Oversees protection of drinking water sources • Regulates public drinking water systems	Titles 17 and 22
State Water Resources Control Board	Protects Water quality and water rights	• Establishes general policies governing recycled water project permitting • Oversees RWQCBs • Provides financial assistance to local agencies for recycled water projects • Allocates surface water rights	Title 23
Regional Water Quality Control Boards (nine)	Protects water quality	• Issues and enforces permits for recycled water projects, incorporating Title 22 requirements and CDPH recommendations • Protects surface and ground water quality from recycled water impacts	Title 23
Department of Water Resources	Manages statewide water supply	• Evaluates the use of and plans for potential future uses of recycled water through the preparation of the California Water Plan • Provides financial assistance to local agencies for recycled water projects • Adopts standards for indoor plumbing for recycled water	Title 24 (California Plumbing Code, Chapter 16A, Part II)
Public Utilities Commission	Oversees rates and revenues of investor-owned utilities	• Approves rates and terms of service for the use of recycled water by	Title 20

		investor-owned utilities	
Department of Housing and Community Development	Oversees building standards for dwellings, including institutions and temporary lodgings	• Adopts standards for graywater systems in residential structures • Adopts standards for nonpotable water systems within	Title 24 (California Plumbing Code, Chapter 16A, Part I; Chapter 6)
California Building Standards Commission	Oversees the adoption of standards for buildings	• Will adopt standards for graywater systems in nonresidential structures in 2011 cycle of California Building Standards Code • Oversees the adoption of California Plumbing Code, including provisions added by other state agencies	Title 24 (California Building Standards)
Local Building Officials	Oversee building design, including plumbing	• Enforce building standards, including California Plumbing Code	Title 24
County environmental health departments	Protect drinking water systems	• Enforce cross-connection control • Review and make recommendations on sites proposed for recycled water use	Titles 17 and 22

NOTES:
1. As of November 2011, CDPH has adopted regulations in Title 22 for non-potable use of recycled water, but not for potable reuse projects. SB 918 requires CDPH to adopt uniform water recycling criteria for indirect potable reuse projects involving groundwater recharge and surface water augmentation.
2. May delegate some responsibilities for review of new sites and cross-connection control to the local County Health Departments with the permission of the local recycled water provider

Local city and county officials also have a regulatory role affecting recycled water projects. In some cases, CDPH can delegate responsibilities to local officials if local recycled water project sponsors agree with the delegation.

Nine RWQCBs, several CDPH district offices, 58 counties, and numerous cities have a role in regulation water recycling. Statewide, many officials have a regulatory role governing some aspect of water recycling projects. In some cases, maintaining consistent application of laws and regulations has been a challenge.

9.1.5.1 Recycled Water Permits

Recycled water permits may be issued by either individual RWQCBs or the SWRCB to producers of recycled water, purveyors who supply their customers with recycled water produced by others, or individual users of recycled water. With a minor exception, recycled water permits are issued by RWQCBs in the form of water reclamation requirements, waste discharge requirements, or master recycling permits. Master recycling permits combine provisions from both water reclamation requirements and waste discharge requirements, and the producer with a master permit is required to adopt a use ordinance and enforce this ordinance. Regardless of the form of the permit, the requirements applicable to recycled water would be the same and incorporate applicable provisions of Title 22 regulations and recommendations of CDPH. In lieu of writing permits for each project, the SWRCB also has a statewide general permit for landscape irrigation with tertiary treated recycled water. The variety of permitting approaches provides flexibility to adapt permits to the roles and authorities of agencies involved in recycled water production or distribution.

As noted in section 9.1.4, CDPH oversees protection of drinking water sources and issues permits to water suppliers for public drinking water systems. To date, the drinking water permits have not played a significant role in regulating water recycling projects.

9.1.5.2 Recycled Water Policies

Recycled water law in the state is based on the California Constitution (Article X, Chapter 2) which states that ". . . waste or unreasonable use or unreasonable method of use of water be prevented . . .".

Issues of concern for permitting recycled and for protecting water quality include salinity management, regulation of incidental runoff, and monitoring and regulation of constituents of emerging concern. To address these issues, the SWRCB in 2009 adopted a Recycled Water Policy. Some key elements of the policy were:

1. Manage salinity for each basin/subbasin through involvement and implementation salt and nutrient management plans.
2. Regulate incidental runoff through waste discharge requirements, which may include NPDES permits or stormwater permits with specific permit provisions.
3. Prioritize approval of groundwater recharge projects utilizing recycled water treated by reverse osmosis.
4. Convene an expert technical panel to provide recommendations on regulation of constituents of emerging concern for recycled water policy.

9.2 Municipal Recycled Water Infrastructure

The infrastructure for use of municipal recycled water begins with the wastewater collection system and ends with the plumbing on the recycled water user's site. Many components of this infrastructure and factors are needed to make a project feasible for successful use of recycled water by CII customers. An overview of these components is presented below. Section 9.3 contains a greater focus on issues pertinent to CII recycled water use.

9.2.1 Wastewater Collection and Treatment and Recycled Water Distribution

Water recycling projects are generally infrastructure-intensive to construct and operate, requiring capital investment, project sitting, construction, maintenance, operation, and other significant challenges for the agency and customer building and operating the project. Key project-specific variables affect infrastructure requirements for future water recycling projects in California as described below. This section addresses only non-potable recycled water treatment and distribution because most CII recycled water applications are non-potable.

9.2.1.1 Source Control

The quality of recycled water is affected by the quality of the source of potable water supply and the pollutants added to the water during use before the wastewater is discharged into wastewater collection systems. Conventional secondary and tertiary treatment are very effective in removing organic matter and pathogens. However, these levels of treatment are not designed to remove many chemicals. While many chemicals are not harmful to the environment when discharged into a river, they may be detrimental to certain uses of recycled water. For example, boron can be harmful to landscape plants. Source control or industrial pretreatment programs are in place to require commercial and industrial water users to reduce or eliminate certain chemicals before releasing their wastewater into sewers. Source control can be an important factor for recycled water projects because it may improve the quality to be acceptable to CII users without the need for expensive advanced wastewater treatment. Control of wastewater quality starts with the collection, pretreatment, and source control of sewage.

Other source control issues include:

- Inflow and infiltration. Sewage quality can be deteriorated through infiltration into the sewer system. For example, when sewers run through areas with brackish groundwater, salt concentration of the sewage can increase. Proper construction and maintenance of the sewers can reduce the impacts of infiltration.
- Source water. Higher salinity water supply sources can contribute to higher salinity in sewage that passes through to recycled water. For example, this could be true in system with both high TDS groundwater and good quality surface water sources. Sewage salinity would increase when higher TDS groundwater is used during seasonal supply changes or when groundwater is used during drought conditions when surface water is not available. This salinity increase could result in additional treatment to achieve recycled water at a target quality and also increase the waste byproducts of the recycling process.
- Water softeners. Home-based water softeners may introduce additional salts into the municipal waste stream. AB 1366 (2009, CWC §13148) enables local jurisdictions to regulate home self-regenerating water softener use to reduce the salinity of inflow to wastewater treatment facilities and water recycling facilities.

9.2.1.2 Treatment Approaches

The type and level of wastewater treatment required and selected for a water recycling project is one of the most important variables in determining the ultimate infrastructure cost for the project. According to the RWTF Water Recycling 2030 Report,

> "The degree and type of wastewater treatment that is provided to make recycled water suitable for use depends on the types of use, the potential exposure of humans to recycled water and the public health implication, and the water quality required beyond health considerations. The basic levels of treatment include primary, secondary, and tertiary. Not all wastewater receives all three levels of treatment. Secondary treatment is commonly the minimum level of treatment for discharge to surface waters and for many uses of recycled water. Tertiary treatment is sometimes required for discharge to surface

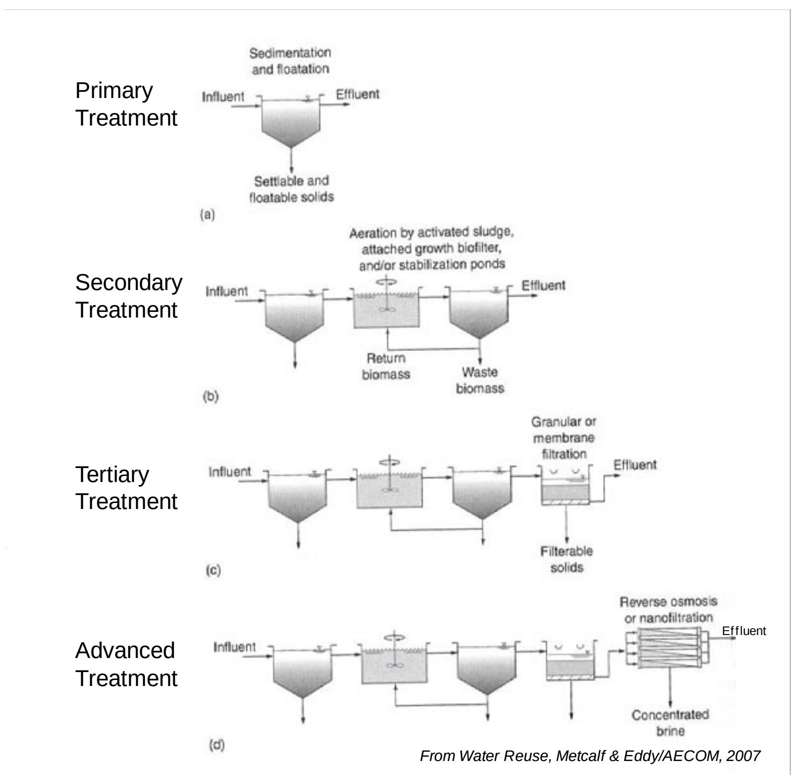
water to protect fisheries or protect use of the waters. Tertiary treatment is often required for recycled water where there is a high degree of human contact. Disinfection is usually required for either discharge or recycled water use to kill viruses and bacteria that can cause illness."

The CDHS specifies the levels of treatment for recycled water and publishes the standards in Title 22 of the California Code of Regulations. Beyond the treatment required for health protection, certain uses have specific water quality needs. High sodium or boron in water can be harmful to crops. Water hardness can cause scaling in industrial boilers. Nitrogen and phosphorus can stimulate algal growth in ponds or cooling towers. Sometimes specialized forms of tertiary treatment are needed to remove specific chemicals that would make recycled water unusable."

The recycled water treatment process consists of a series of steps or stages. The steps may include:

- Primary sedimentation
- Activated sludge secondary treatment
- Secondary sedimentation, potentially including nitrification and denitrification
- Chemical coagulation with alum and polymer
- Dual media filtration
- Advanced treatment processes, such as reverse osmosis (RO), etc.
- Disinfection using chlorination or sodium hypochlorite

Figure 9-4 illustrates examples of these steps combined in a treatment process.



From Water Reuse, Metcalf & Eddy/AECOM, 2007

Figure 9-4: Recycled Water Treatment Process. Schematic of possible treatment steps to achieve different levels of treatment and potential recycled water use.

With the exception of a few ocean discharges, all municipal wastewater in the United States must receive a minimum of secondary treatment. To avoid polluting sensitive rivers, bays, or estuaries, tertiary treatment by dual media filtration (or equivalent) is frequently required. To the extent that treatment is required to meet pollution control levels to protect receiving waters, the cost of treatment is typically borne by the wastewater agency and sewer users. In many cases, the treatment already in place to satisfy pollution control requirements is satisfactory for many CII recycled water users. However, if specialized water quality needs of CII customers require additional recycled water treatment, the cost of the additional treatment would be allocated to a water supply function.

Reducing the salinity of the treated wastewater flow entering the recycled water distribution system in some cases is a key aspect of producing recycled water. Reverse osmosis (RO) commonly is used to remove salinity. The RO process produces a concentrated salt solution called brine. Disposal of brine can be costly and environmentally challenging.

The Santa Ana River Interceptor (SARI) system provides an example of a regional solution to the brine disposal challenge. SARI is a pipeline that conveys saline waters from many brine producers in the upper Santa Ana River region to the Orange County Sanitation District for treatment and disposal into the Pacific Ocean. It segregates high-salt wastewater from domestic wastewater, thus protecting the quality of domestic wastewater for reuse.

9.2.1.3 Distribution System

The non-potable recycled water distribution system typically includes a number of interrelated elements:

- Delivery System - A network of "purple pipes" (although large diameter pipes installed beneath streets are not always purple, purple is the color reserved for recycled water distribution pipes) sized to meet peak recycled water distribution demands. The flow capacity of the distribution pipes generally decreases as the distance from the treatment plant or storage facility increases and water deliveries are made. Except in systems in which recycled water is treated and approved for direct potable use, the recycled water delivery system must always be segregated from the potable water delivery system.

- Pumping – Conveyance of recycled water from the treatment facility to its ultimate point of use often requires pumping. Wastewater collection systems are typically designed to use gravity flow to move wastewater through sewer mains to a lower point for treatment. Consequently, the finished recycled water product must sometimes be pumped back up to a higher elevation to maximize opportunities for use. Again, recycled water pumping systems must be separated from potable water pumping systems.

- Storage – Recycled water storage assists in increasing the efficiency of the recycled water distribution system in three ways:

    - Recycled water produced during a time of day or time of year when demand is low can be retained for use when demand is high, which provides for more complete utilization of this resource.

    - Storage reduces the capacity and size (and, therefore, the cost) of treatment, pumping, and distribution system pipe needed to meet peak irrigation demands

    - Allows for recycled water to be pumped to storage during lower cost non-peak energy demand periods thus reducing operational cost and allowing limited energy resources to be used for other purposes.

- Backflow and cross connection prevention: All recycled water delivery systems must include safeguards to prevent backflow, or the reverse flow of recycled water back into the public drinking water system. Additionally, a program must be in place to detect cross connections, or the inadvertent connection of the recycled water “purple pipe” to a potable water delivery system.

- Metering – All recycled water use must be metered and tracked separately from the potable water delivery system, a strategy that can also be helpful in identifying cross connections.

- Supplemental or backup water supply –The ability to add potable or non-potable water into the recycled water system either to meet peak water demands in the recycled water system or to provide a reliable backup supply to recycled water users in case the recycled water supply is interrupted for any reason, such as a wastewater treatment malfunction is commonly incorporated into recycled water systems.

9.2.2 On-Site Infrastructure

If an existing water user is going to convert part or all of its use to recycled water, its use site must undergo a use site retrofit and be designed to meet CDPH requirements before receiving that water. In new developments where recycled water delivery is planned, use sites can be designed from the beginning with separated potable and recycled water plumbing. Examples of use site design criteria include use of purple pipes and appurtenances, design to prevent overspray, and design of separate potable water and recycled water systems with appropriate air gaps or other acceptable backflow prevention devices to avoid cross-connections. Other use site issues may include the need for changes in on-site treatment process and other operating criteria to accommodate the differences in water quality. A cross-connection test is required before the use site is approved for recycled water use. Use site plans must be reviewed and approved by CDPH or the local county health department. All of this costs money for both users and suppliers of recycled water.

9.2.2.1 Discharge

(Note to reviewer - information to be added later)

9.3 Recycled Water for CII Applications

CII facilities are currently successfully integrating recycled water into many aspects of their process, as indicated in earlier sections of this report and in Table 9-4. Currently, municipal recycled water is being used for (the applicable Common Devices, Processes, and Practices Applicable to the Commercial, Institutional, and Industrial Sectors, identified in Section VII.C, are shown in parentheses):

- landscaping (5. Commercial Landscaping)
- process water
- boiler/cooling tower applications (3. Building Systems – Thermodynamic Processes)
- dual plumbing (6. General Building Sanitary and Safety Applications)

In 2009, commercial and industrial applications represented 8 percent of the total recycled water use in California. These applications have the potential to be expanded. This section addresses the issues or challenges associated with expanding the CII use of municipal recycled water and factors to consider when implementing the applications.

Resources

EBMUD – Watersmart Guidebook A Water-Use Efficiency Plan-Review Guide for New Businesses (EBMID, 2008

LA County – Recycled Water Urban Irrigation User's Manual (2005)

Table 9-4

CII SECTOR RECYCLED WATER APPLICATIONS[1]

Note to reviewers: this table is a skeleton for linking the Title 22 table to actual uses. It can be expanded to include other uses, such as quenching, which have been approved but are not listed in Title 22 and are not addressed in other CII TF report sections. The right hand column in the final version would have references to specific case studies in the appendix. Currently that column holds comments I have from reviewing the existing sections. Is this helpful? As an alternative, we could go with a single table similar to what's on EBMUDs website

http://www.ebmud.com/sites/default/files/pdfs/Recycled_Water_Uses_Allowed_in_California-2009.pdf

CII SECTOR	CII TASK FORCE REPORT SECTION	APPLICATION[2]						
		Cooling Tower Make up	**Dual Plumbing**	**Landscaping**	**Process Water**	**Boiler Feed**		**CASE STUDIES (now this holds comment)**
Commercial and Institutional Sector Uses								
Offices	VII.A.6.__.	●	○					Dual plumbing not mentioned
Prisons	VII.A.7.__.							Mentioned RW in a table, but no discussion
Schools and Educational Facilities	VII.A.9.__.	○						Landscape or playing field irrigation?
Industrial Sector Uses								
Food and Beverage	VII.B.2.b.__.							Section mentioned RW, but use not specified.
Microelectronics	VII.B.2.c.__.							Solar (manufacturing or operation?)
Petroleum refining and chemicals	VII.B.2.d.__.	●				●		all other uses except potable use. Additional treatment may be needed and its availability may be limited. (Refers to recycled section for details)
Pharmaceutical	VII.B.2.e.__.	○				○		all other uses except potable use. Additional treatment may be needed and its availability may be limited. (Refers to recycled section for details) Outdoor landscaping use was referred to

								earlier as the only non-potable water pharmaceutical use.
Power Plants	VII.B.2.f.__.	●						Section not complete, but it should be in there . . .

NOTES:

1. Refer to Table 10-2 for a summary of recycled water applications approved under Title 22 of the California Code of Regulations (Division 4, Chapter 3, §60301 et seq.), based on required treatment levels.
2. Filled circles are commonly applied applications of recycled water. Open circles are less commonly applied, but are approved. Small dots are applications which currently have limited application.

9.3.1Water Quality Issues

Water quality is a key issue with almost every CII application of municipal recycled water use. It applies both to the quality of municipal recycled water currently available and to the needs of the proposed application. For example, proposed power plants are required by the California Energy Commission to consider recycled water for cooling tower use when the plant's application for certification is submitted. High concentrations of some dissolved minerals can affect how many times water can be cycled through the cooling towers and then the concentration of the discharge. These concentrations affect both the plant operation and waste disposal – both of which are costly to power plant operation. Table 9-5 summarizes key water quality issues and the BMP within this report where they are addressed.

Table 9-5
KEY WATER QUALITY ISSUES FOR CII RECYCLED WATER APPLICATIONS

Note to reviewers: this table is conceptual right now. Is it helpful?

APPLICATION	KEY WATER QUALITY ISSUES	BMP
Dual Plumbing	Color	Tertiary treatment processes
Landscaping	Boron, salt	Source control, irrigation management
Process Water	Salt	Source control, reverse osmosis
Boilers Feed	Salt	Reverse osmosis
Cooling Tower Make up	Salt	Source control, on-site water conditioning

Supplemental treatment may be necessary to address water quality issues. In some cases, the water supplier provides additional treatment. For example, both the Long Beach Water Department and West Basin Municipal Water District operate recycled water plants that take wastewater effluent treated by other entities (and that meet Title 22 requirements for some reuses) and treat the water to higher standards. The more highly-treated recycled water is then distributed separately from its original inflow water.

In some cases, additional treatment is provided on-site by either the CII user or the recycled water supplier.

9.3.2 Supply Issues

Supply issues are those related to getting the recycled water to the end user. Refer to Section 9.2.1 and Figure 9-1 for a description and schematic representation of public and on-site infrastructure.

9.3.2.1 Public Infrastructure

Development of a public infrastructure system is a substantial undertaking for a supplier. In most cases cooperation between water purveyors and wastewater agencies is required for the planning, design, and operation of recycled water systems. Recycled water systems often cross jurisdictional boundaries between water suppliers, cities, and wastewater agencies. Interagency agreements are often required to implement municipal recycled water projects. In some cases, supplemental agreements between local wastewater and water agencies are needed because some wastewater suppliers are not permitted to deliver treated water or may prefer that potable water suppliers take on the function of recycled water supply and/or distribution. Under current practices, a separate “purple pipe” infrastructure is required, which involves coordinating locations with existing infrastructure, monitoring cross-connection issues, and maintaining the system. It also involves conducting a customer survey to determine the financial viability of the system and whether the supplier is able to operate and maintain it.

Public infrastructure may also include planning and constructing a regional brine disposal system, such as the Santa Ana Regional Interceptor (SARI) system.

9.3.2.2 On-site Infrastructure

If the municipal recycled water available to a CII user does not meet the water quality standards it needs to incorporate recycled water into its water supply, then the CII user may:

- Install additional on-site treatment facilities
- Address differences in wastewater disposal issues – either to the existing wastewater provider or identifying on-site wastewater disposal options
- Modify the on-site process to accommodate different water quality

In addition, the CII user is responsible for installing the conveyance facilities (pipeline, valves, and pumps) necessary to move the water from the public infrastructure installed to the property line to the point of use. The CII user must also operate and maintain any on-site infrastructure and train its employees to work with recycled water. On-site treatment plants require maintenance and potentially periodic component replacement, as well as additional energy and chemical costs. Backflow and cross connection monitoring and maintenance are also required by CDPH.

In most cases the price of recycled water is set at a discount from potable rates to encourage recycled water use and to offset on-site costs borne by CII customers. In some cases, the price savings a water supplier often provides to the CII user to receive recycled water instead of potable water does not offset the additional costs incurred by receiving it. Water utilities have provided various mechanisms to assist the financing of on-site costs.

9.3.2.3 Supply Interruption, Backup Requirements

Most non-landscape CII municipal recycled water applications require a dependable water supply. If, for some reason, recycled water is not provided, then operations may need to be suspended. If supply reliability is a key issue for the CII user, then it may need to identify a back-up water supply or require assurances from the recycled water supplier that supplies will not be interrupted. This can be a challenge for large water users and can also increase the costs for developing recycled water supplies. Many recycled water suppliers ensure a reliable supply by designing the ability to add potable or suitable non-potable water into recycled water systems during any shortfall or interruption in recycled water supply.

9.3.2.4 Seasonal Demand

Seasonal demand for recycled water is mainly a challenge for recycled water suppliers. Currently, landscape irrigation is the most common CII application of municipal recycled water. However, the demand for landscape irrigation is primarily a spring-summer-fall demand because winter rains reduce or remove the need for supplemental year-round irrigation in California. Landscape irrigators are important recycled water customers because they are often high-volume users and are somewhat flexible in delivered water quality. Some water suppliers have addressed this by ceasing winter production of recycled water (which reduces revenue), developing winter storage, or supplementing peak demands with other supply such as non-potable groundwater.

9.3.3 Emerging Technologies (or Alternate Distribution Options?)

Because of the inherently high costs of dedicated recycled water distribution systems, complexities in installing new infrastructure in areas with limited access, and the tendency for wastewater treatment facilities to be located downstream and at a distance from potential recycled water users, extensive work is being done to look at alternative methods for distributing recycled water. These include:

- Satellite Plants – A smaller wastewater treatment facility is located on a regional wastewater collection trunk line. It takes some of the raw sewage off of the trunk line, treats it to the recycled water standards for its local customers, and returns treatment residuals to the trunk line. In this way, treatment facilities can be located more centrally to the market for recycled water.
- Potable System Distribution – If recycled water could be treated to a level that is acceptable for drinking, the recycled water could be distributed in the same pipeline system as potable water, eliminating the need for a separate purple pipe distribution system. The added costs of recycled water treatment to potable standards might be more than offset by the elimination of a recycled water distribution system. Direct potable reuse is not currently authorized in California. However, SB 918, as described in section 9.1.4, provides that this concept of direct potable reuse be studied further and that an expert panel make recommendations on it.

9.4 Public Infrastructure Needs for Increasing CII Recycled Water Use

The components of public infrastructure for specific municipal recycled water systems are described in Section 9.2.1. The needs for a local or regional system are specific to the unique characteristics of the area: the quality of wastewater, the locations and types of wastewater treatment in place to serve pollution control needs, the added treatment that might be needed to meet recycled water customer needs, the types of recycled water users and their needs, and the proximity of recycled water users to the sources of recycled water. These needs are determined through a systematic planning process to investigate all issues and assess the potential market for recycled water and public acceptance of a project.

Because of the comprehensive local planning still required to identify public infrastructure needs, identifying aggregate needs at a statewide level is not currently possible. Nevertheless, the overall pace of increasing the infrastructure is lower than anticipated. Despite the gains in California's use of recycled water since the early 1990s, California is not on target to attain the various projections of 2030 recycled water use potential: 1.85 to 2.25 MAF (based on the RWTF of 2003) and 2.5 MAF (based on the SWRCB Recycled Water Policy). If the pace of adding recycled water use that was set between 1990 and 2009 is maintained for the period between 2011 and 2030, the state will only be recycling about 1.1 MAF by 2030. Strong focus and direction are needed to make better progress to achieving a goal of at least 2 MAF by 2030. Water recycling goals will not be met with only non-potable reuse, and additional potable reuse will be required. This section addresses the requirement that the CII Task Force was directed by Water Code section 10608.43(c): to evaluate "public infrastructure necessary for delivery of recycled water to the commercial, industrial, and institutional sectors." It includes recommendations that may assist in improving the progress toward increasing CII recycled water use. Section 11, meanwhile, includes ten current barriers to water recycling and identifies solutions to overcome each of the barriers.

9.4.1 Current Recycled Water Implementation

Recycled water currently is produced and distributed on a local level. This local component allows suppliers to maintain control of their systems and meet the needs of their customers. It also enables water suppliers with water source challenges to increase local supplies and reduce dependency on imported water.

Maintaining local and regional control of recycled water works well. However, the State of California sees an overall benefit to expanding recycled water use because doing so supports the overall objective of water supply reliability and sustainability.

Experience has shown that the success of a local municipal recycled water project depends on good planning and local interagency cooperation.

Recommendation 9.4.1.1 Encourage More Planning

Section XI contains recommendations for overcoming current barriers to water recycling, however, obsticals to good water recycling planning have been identified as well. The Task Force encourages local planning efforts to maximize the potential implementation of recycled water use and recommendations to accomplish this goal have been identified below.

Implementers: Local and regional water suppliers and wastewater management agencies

Recommendation 9.4.1.2 Follow Good Planning Practices

The Task Force also recommends that good planning practices be followed to ensure that projects are cost-effective and successful. There are several good sources for guidance on planning and local efforts should consider the following as potential resources:

- U.S. EPA guidance manual (obtain proper citations)
- CUWA draft handbook
- Metcalf & Eddy text
- Asano, Technomics book
- WEF manual of practice

Implementers: Local and regional water suppliers and wastewater management agencies 9.4.2 Justification for Additional Recycled Water Funding

Sufficient state-wide infrastructure is a fundamental requirement for water recycling to support meeting State water resource supply expectations. Infrastructure trends have been governed by shifts in the purpose of reuse as it evolved from wastewater disposal to a water supply. Currently, local water and wastewater agencies are postponing or shelving planned projects because of fiscal challenges. If additional projects are not implemented, increased recycled water use will not occur.

Augmenting current statewide recycled water funding, even in light of current statewide budget issues is a long-term benefit to the state for the following reasons:

- California is expected to experience continued population growth and recurring periods of drought, so it is imperative that existing water supply is used as efficiently as practical.
- Establishing and fully utilizing recycled water supplies reduce dependence on imported water and provide local water sources.
- Potentially reducing the amount of water diverted south through the Delta, by supporting local development of recycled water supplies, may have an environmental benefit to the Delta.
- Global warming will continue to strain statewide water management issues. Development of local water resources will provide the state's communities with better self reliance.
- Using recycled water may reduce greenhouse gas emissions because less energy is needed to treat and reuse water than to convey fresh water long distances.

9.4.3 Known Issues

Section 11 addresses many barriers to increasing recycled water use in California. Two infrastructure needs were identified:

- Local Delivery Infrastructure Needs – Some recycled water purveyors have been able to construct and implement recycled water facilities. However, establishing customer bases and delivering recycled water to identified customers has been problematic. Additional funding would support installation of additional conveyance and could also be used to support appropriate onsite infrastructure improvements.

- Brine Disposal Needs – Brine disposal continues to be a significant obstacle to expanding recycled water development, particularly in inland communities. Southern California has successfully developed portions of the Santa Ana Regional Interceptor, a brine export line. Expansion of the infrastructure would enable completion and expansion of the system and provide opportunities for additional recycled water supply.

9.4.4 Specific Public Infrastructure Needs

A statewide master plan for municipal recycled water could assemble in one place the results of many local and regional planning activities. This plan would provide a basis for targeting state and local efforts most effectively.

Recommendation 9.4.4.1 Develop State Master Plan and Targeted Funding

Statewide investment in supporting additional recycled water project implementation should focus on the following steps. Step 1 would begin immediately. Steps 2 and 3 would begin as soon as possible to support additional project development as Step 1 is implemented.

1. Develop a Statewide Recycled Water Master Plan. Working with local and regional stakeholders, review the recently completed 2009 Municipal Recycled Water Survey and identify customer bases and geographic areas where the greatest additional benefit can be realized by increasing recycled water use. Working with the stakeholders, identify specific projects and actions that can be implemented to realize the statewide recycled water use potential of at least 2 MAF of recycled water use by 2030. Evaluate whether the current approach to funding recycled water projects (state grant and low-interest loan funding through DWR and SWRCB) is the most cost effective approach to implementing the master plan.
2. Provide additional funding to existing recycled water suppliers who have excess treatment capacity to install additional infrastructure or provide grants for local on-site infrastructure improvements to enable developing the additional customer base for recycled water.
3. Provide additional funding to brine management projectsthat would enable increased use of municipal recycled water.

Implementers: DWR, SWRCB, regional and local water suppliers

9.5 Funding/Cost

While identifying specific infrastructure necessary for delivery of recycled water to CII sectors is not possible, the overall costs for this infrastructure can be estimated based on historic data and experience. The Recycled Water Task Force provided an estimate in 2003 of state-wide capital investment needed to increase all municipal recycling from 0.5 to 2.0 MAF (1.5 MAF increase) by 2030. The total capital investment was estimated to be between $9.2 and$11 billion (in 2003 dollars) (note to reviewer – this needs to be converted to 2011 dollars). This represents an initial capital investment of about $6,600 per acre-foot per year of project capacity. Amortized over the life of the project, the unit cost is about $425 per AF. Operations and maintenance costs, meanwhile, were expected to average $300 per AF (2003 dollars). The RWTF report noted that there was a wide range of costs for municipal recycled water projects, from essentially no extra cost to over $2,000 per AF for capital and operational costs combined.

Because of the expected high cost of the recycled water projects, additional funding assistance for the local and regional agencies implementing and operating the water recycling projects was the recommendation of RWTF. This recommendation has been implemented through grants and loans administered both by the State Water Board and the Department of Water Resources.

A more recent estimate for selected projects in the San Diego area was provided in a September 15, 2010, report to the San Diego County Water Authority Board of Directors. A range of those unit costs in dollars per acre foot after cost credits that includes annual capital cost and annual operating costs are displayed below. The proposed potable projects include unusually costly conveyance systems necessary to reach the blending point.

Type of projects and number	**Range of Unit Cost ($/AF)**
Existing non-potable projects (4)	$1,259 - $1,662
Proposed non-potable projects (5)	$1,000 - $2,437
Proposed potable projects (2)	$1,400 - $1,814

9.6 Successful Partnerships (case studies)

Note to reviewer: information to be added later

9.7 References

California Department of Water Resources. 2009. California Water Plan Update 2009. 4 v. Sacramento (CA) California Department of Water Resources. http://www.waterplan.water.ca.gov/cwpu2009/index.cfm

Recycled Water Task Force. 2003. Water Recycling 2030 Recommendations of the California Recycled Water Task Force. http://www.water.ca.gov/pubs/use/water_recycling_2030/recycled_water_tf_report_2003.pdf

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10 Evaluation of Institutional and Economic Barriers to Recycled Water Use

Increasing the amount of recycled water used in California supports the State's water supply resources and provides environmental benefit. However, barriers potentially hinder the continued expansion of recycled water use in California. This Section builds upon the background information provided in Section 9 and identifies barriers and solutions to increasing CII recycled water use in California, in accordance with Water Code Section 10608.43(d).

The CII Task Force (CIITF) developed a list of 10 current barriers to integrating municipal recycled water into CII applications. CIITF ranked the barriers based on their potential to limit increasing local and regional recycled water use and identified possible solutions. The CIITF also evaluated obstacles and recommendations of the RWTF (DWR, 2003), and it reviewed and assessed the current level of implementation of the recommendations. Last, the Task Force evaluated obstacles not addressed by the RWTF, drawing upon professional experience and knowledge. The barriers reflect a range of different factors related to CII customers, recycled water producers and distributors, State policymakers and regulators, and others.

The institutional and economic barriers to increasing the use of municipal recycled water in CII applications identified by the CIITF are listed below and ranked according to their overall level of importance in limiting State-wide use of recycled water of municipal origin by the CII sector.

1. Infrastructure Cost and Feasibility
2. Regulatory Impediments
3. Awareness and Education of Recycled Water Quality
4. Public/Customer Acceptance
5. Cost for CII Users
6. Source Water Quality
7. Recycled Water Supply Reliability
8. Terminology Used in Describing Process
9. Data for Tracking Use
10. Institutional Coordination among Agencies

Summaries of each of these barriers, along with potential solutions, may be found below. Water agencies, recycled water users, State regulatory agencies, and organizations expected to have the greatest involvement in implementing each solution are identified with the understanding that other stakeholders and organizations may be involved during the implementation process. In some cases, the CIITF recommends State funding or changes in State law, which would require action by the Legislature. The section also includes examples of case study experience, including a discussion of the barriers and solutions, and the Appendix includes more information on each of the case studies cited.

Background

As noted in Section 9, water recycling in California has overcome barriers to achieve its current level of success. The 2003 RWTF report identified issues and made recommendations for addressing barriers. The 2009 SWPU provided a status report on implementation of the RWFT recommendations as well as making four additional new recommendations.

The RWTF identified and adopted 26 issues with respective recommendations to address obstacles, impediments, and opportunities that would allow Californians to increase their use of recycled water. Additionally, the RWTF adopted 14 of the issues as key and deserving of more immediate attention. Those issues included:

- Funding for water recycling projects
- Community value-based decision-making model for project planning
- Leadership support for water recycling
- Educational curriculum
- State-sponsored media campaign
- Uniform Plumbing Code Appendix J
- CDHS guidance on cross-connection control
- Health and safety regulation
- Incidental runoff
- Uniform interpretation of State standards
- Water softeners
- Uniform analytical method for economic analyses
- Research funding
- University academic program for water recycling

While other issues were deemed to be important, the RWTF recommended these 14 as the focus of statewide efforts to increase the use of recycled water.

The 2009 State Water Plan Update (SWPU) provided information on progress made in implementing a number of the RWTF's recommendations including:

- AB 334 (2003 statutes, chapter 172) allowing local water agencies more authority to address wastewater salinity levels from residential water softeners
- Symbol code changes to notify the public not to drink recycled water
- Additional support by State agencies for recycled water
- Development of a fifth grade water recycling educational curriculum

- Additional federal funding for water recycling through the U.S. Bureau of Reclamation
- SWRCB direction on regulation and enforcement of incidental recycled water runoff
- SWRCB funding for water recycling research

Subsequently, Appendix J of the Uniform Plumbing Code (UPC) has been amended as recommended.

The 2009 State Water Plan also included four recommendations to increase recycled water use.

1. State and local agencies and stakeholders should implement, as appropriate, the RWTF recommendations. The recommendations can be used as a toolbox for communities to improve their planning of recycled water projects.
2. The SWRCB should establish a centralized data repository of recycling facilities and programs that contains basis information such as type of treatment, volume of water recycled, uses of recycled water, and costs of operation. Additionally, a systematic reporting process should be established to ensure maintenance and integrity of the data for future reference.
3. State agencies should develop a uniform interpretation of State standards for inclusion in regulatory programs and integrated water management plans (IRWMs), and they should clarify regulations pertaining to water recycling, including permitting procedures, health regulations, and the impact on water quality.
4. The State should expedite the availability of funding regional Salt Management Plans necessary to increase the potential of recycled water.

These previous recommendations served as a foundation as the CIITF developed the following list of barriers and solutions.

10.1 INFRASTRUCTURE COST AND FEASIBILITY

Cost and feasibility of water recycling infrastructure to deliver recycled water to the CII use site and then use recycled water at CII sites are the primary limitations on recycled water use in CII applications.

Conveyance of recycled water through parallel distribution systems to end users (purple pipes), while a necessary and appropriate component of the State's strategy to achieve the goal of increasing water recycling, is cost-prohibitive for many communities. Compounding the cost of installing a separate water distribution system is the complex piping and other facilities already buried in streets, especially in dense urban areas. Furthermore, traffic disruptions during construction result in inconvenience and additional costs.

As noted in Section 10, indirect and direct potable reuse can provide opportunities to use municipal recycled water without the need for complex dual distribution systems. The trade-offs may be the need for advanced wastewater treatment or construction of long transmission pipelines to convey recycled water to groundwater or surface water sites, or to suitable locations for connecting directly into potable distribution systems. Indirect potable reuse through groundwater recharge has a long and successful history in California and its continued expansion is expected. Advanced treatment technologies with proven performance and reliability that have been used for groundwater injection projects provide the foundation for other indirect and direct potable reuse projects. A legislatively mandated path to the further evaluation of indirect potable reuse through surface water augmentation and a report to the legislature investigating the feasibility of developing regulatory criteria for direct potable reuse were included in Senate Bill 918 which was enacted in 2010.

Solution 10.1.1 – Conduct Local and Regional Water Recycling Planning Analyzing All Options

Agencies often plan water recycling projects with preconceived limitations that may preclude opportunities for exploring recycled water markets outside of certain jurisdictional boundaries, taking advantage of certain sources of recycled water, or exploring potable reuse. Guidance on good planning concepts can be found in the following resources: Metcalf and Eddy text, CUWA draft guidelines, Water Environment Federation Manual of Practice, U.S. EPA Guidelines.

Implementers: Water supply and wastewater agencies.

Example – recycled water planning

The development analysis from the City of Riverside's Potable Reuse Project provides a helpful insight into the considerations involved in determining which type of recycled water project is best for a community, potable or non-potable. Riverside developed two options:

- Purple Pipe: 10,000 AFY could be served to 740 customers through 172 miles of distribution pipeline at a capital cost of $550 million. The cost of this project is equivalent to $42/month for each customer, which is greater than the current average user cost of $35/month.
- Indirect Potable Reuse: The City's water supply could be increased by 10,000 AFY at a capital cost of $95 million by adding 6 miles of pipe to convey recycled water to groundwater recharge basins. The City can use existing infrastructure to remove groundwater and distribute it to customers. The cost of this project is equivalent to $9/month for each customer.

As a result of the analysis, the City considered the purple pipe option infeasible because of cost and community disruption reasons. Instead, it is implementing the indirect potable reuse option based on its low cost.

Solution 10.1.2 – Seek or Provide Funding Sources to Facilitate Local Projects

Local agencies can take advantage of various regional, State, and federal funding sources to make water recycling projects financially feasible. In addition, regional agencies could develop financial incentives that would facilitate local projects that have regional benefit. The following examples show how water agencies have helped overcome infrastructure cost barriers,

Implementers: Regional, State, and federal agencies, State Legislature, U.S. Congress.

Examples:

1. Efforts by the City of Santa Clara to provide recycled water to Air Products, a provider of industrial gases, demonstrate how distribution system problems can be overcome. City staff realized that a new 1,300-foot pipeline would be needed to

reach the Air Product facility fence line. The City applied for and received stimulus funds through the Bureau of Reclamation's Title 16 Program.

2. The Central Contra Costa Sanitary District could provide up to 22,500 AFY to local refineries in Martinez, CA if adequate funding were available. Recycled water would be used to replace water from the Delta that is currently used for cooling towers and boiler feed. Producing and delivering recycled water would require new tertiary treatment and distribution facilities at an estimated cost of $100 million. CCSD is seeking federal funding assistance through the Water Resources Development Act (WRDA).

3. The Metropolitan Water District of Southern California (Metropolitan) Local Resources Program provides incentive funding in the amount of $250/AF for delivered recycled water to its member water suppliers. Metropolitan also provided incentives for institutional on-site retrofits during 2009-2010, which were used to expedite the connection of customers to the local recycled water system. While Metropolitan continues to offer $250 per acre foot for projects that are not cost effective, the on-site retrofit incentives are no longer offered

Solution 10.1.3 – Evaluate the need for on-site retrofit and other accommodations for the use of recycled water and the associated costs

To convert an existing site from the use of potable to recycled water results in costs that, if borne by the customer, may make recycled water use infeasible. The costs can range widely, from very little to hundreds of thousands of dollars per site. The cost analysis from the customer perspective would be similar to the procedure described in Section 6. Proponents of recycled water projects should plan for on-site facilities and develop strategies for paying for them.

Implementers: Water supply and wastewater agencies, CII water users.

Example: The BP Carson Refinery (BP Carson) is located on 630 acres in Los Angeles County near the Long Beach and Los Angeles Harbors. It is one of the largest refineries in California and is a major producer of clean fuels. It processes a variety of different crudes from all over the world and supplies 25 percent of the Los Angeles gasoline demand and 15 percent of the jet fuel to Los Angeles International Airport.

In this case, much of the cost stems from requirements to protect the public health and ensure the safety of public water supplies. The refinery uses recycled water provided by West Basin Municipal Water District. Since a mixture of potable and recycled water is used at the facility, the system requires the use of air gaps to prevent backflow if the potable system goes down for any reason. The air gaps are required by the Health Department, and simple check valves or block valves are not sufficient. Installing multiple air gaps throughout the facility and meeting other mandatory regulations is costly but necessary to enable the use of recycled water.

These costs include air gaps, instrumentation and controls systems, and storage tanks that ensure an uninterrupted supply and that backflow does not occur if a pressure outage or reduction occurs in the city water supply line.

Solution 10.1.4 - Fund Development of Indirect and Direct Potable Reuse Regulations

Indirect potable reuse through groundwater recharge currently augments the groundwater supply available to potable customers, including CII customers, thereby providing a more reliable and potentially cheaper water supply. The potential exists for expanding indirect potable reuse through surface water augmentation and, eventually, direct potable reuse. The Legislature, through SB 918 (2010 Statutes, Chapter 700), prescribes a pathway to address the public health issues of indirect and direct potable reuse and adopt regulations as appropriate. However, the ability of the California Department of Public Health to conduct advisory panels and draft appropriate regulations is uncertain without increased funding.

Responsible implementers: Legislature.

Examples:

Three current projects are on the forefront of advancing the use of recycled water in California.

1. The West Basin Municipal Water District Edward C. Little Water Recycling Facility injects recycled water as a seawater intrusion barrier. The water migrates slowly from the point of injection to the points of extraction, where it is eventually pumped and treated by retail agencies and distributed to retail customers.
2. The Orange County Water District Groundwater Replenishment System has also injected recycled water as a seawater intrusion barrier. In 2007 it launched the Groundwater Replenishment System that now produces 70 million gallons per day (MGD) of advance treated recycled water to augment drinking water supplies through surface spreading in recharge basins. In 2011, efforts began to expand the system to increase flow to 100 MGD and add drinking water aquifer injection wells.
3. The City of San Diego Water Purification Demonstration Project will examine the safety of augmenting a surface water reservoir with highly treated recycled water. The demonstration phase involves a 1 MGD treatment facility. The eventual goal is to produce 16 MGD. It is anticipated that the demonstration project will continue through early 2013. Upon completion of the demonstration phase, the proposed full scale project will be presented to the City Council and Mayor for approval

Solution 10.1.5- Provide Greater State Funding for Recycled Water Projects Commensurate With Benefit to State

Because of the complex institutional structure for water supply and delivery in California, retail water suppliers use a variety of approaches to assess the true costs for developing new water supplies. Major new water development projects are often sponsored by regional, State, or federal agencies; water recycling projects, on the other hand, are typically sponsored by local water suppliers. The cost comparison conducted by local water suppliers may involve comparing the capital and operational costs of a new water recycling project to the price charged by wholesale water suppliers; it may be compared to the marginal cost of developing alternative water supplies; or it may be considered as part of a diversified water supply portfolio in an effort to improve supply reliability. In addition, the price charged to the customer is typically an average cost of many existing water sources including new and existing water supplies from a local perspective, many new non-potable recycled water projects are more costly than the existing supply costs or the wholesale cost of water, so they may be rejected. From a supply perspective, recycled water may be similar in cost to or higher than other marginal water supplies depending on local circumstances.

State and federal funding subsidies can be a mechanism for promoting recycled water projects, particularly in areas where their value is great to society but the cost to local water users is too great. The value to society typically comes in the form of environmental benefits in waterways such as the Delta and rivers resulting from the use of recycled water instead of fresh water. The environmental benefits can also include reduced energy use. These benefits may accrue State-wide and warrant State financial assistance.

State and federal financial assistance in the form of low interest loans and grants to local agencies have been provided for many years. In fact, the State Water Board has provided over $760 million since 1978 for water recycling projects built for water supply purposes. In addition to State Water Board funding, the Department of Water Resources provides Proposition 84 Integrated Regional Water Management grants for water recycling. Nevertheless, the currently available funding is inadequate, especially in the form of grants.

Potential responsible implementers: Legislature

Solution 10.1.3 – Provide incentives for installation of customer-side (on-site) infrastructure

As described above, on-site costs at customer sites can be considerable. Recycled water suppliers should consider providing technical and financial assistance to reduce the cost to the customer or help the customer spread the costs over several years. The California Public Utilities Commission (CPUC) regulates water rates and other management of investor-owned water utilities. The CPUC should support rate structures and utility subsidies to provide an incentive to CII customers to use recycled water.

The State could also provide incentives or grants for developing on-site water recycling facilities. On-site “package plants,” for example, collect waste water and other wastewater flows, then treat and reuse the recycled water at customer’s location. Another example is distributed wastewater treatment systems similar to those successfully used at the Port of Portland, Oregon and the New York Solaire apartment complex. (See, “Valuing Decentralized Wastewater Technologies”,” prepared by the Rocky Mountain Institute for the U.S. Environmental Protection Agency, November, 2004 for additional information.)

Implementers: Water supply agencies, CPUC.

10.2 REGULATORY IMPEDIMENTS

The Task Force affirms the need for strong public health and environmental protection. Statutory and regulatory requirements and the interpretation of those requirements by the State Water Resources Control Board (SWRCB), the nine Regional Water Quality Control Boards (RWQCB), the California Department of Public Health (CDPH), and local health and local building officials have a significant impact on the costs associated with the production, delivery, and use of recycled water. With some exceptions, these costs serve to protect public health, water quality, and the environment, and they help to ensure public confidence in recycled water. As can be expected, however, regulatory bodies throughout the State interpret the requirements differently. Complex and inconsistently implemented regulations may discourage recycling by creating regulatory uncertainty or confusion as well as an unnecessary cost burden. This section is intended to provide recommendations on some key areas where the regulatory agencies can offer additional guidance and consistency and to identify areas where statutory or regulatory clarification may be needed. Where appropriate, the report offers recommendations to build on existing successful efforts by the State regulatory agencies in improving regulatory oversight and permitting.

Three major regulatory and statutory issue areas have been identified:

1. Re-codification and update to the recycled water statutes
2. Need to fund updates to recycled water regulations
3. Consistent implementation of regulations and policies by the various regulatory agencies.

Solution 10.2.1 – Revise Water Recycling Statutes

Currently, the recycled water statutes appear in various sections of the Water Code and Health and Safety Code. The recycled water community would like recycled water to have an equal level of credibility with other water supplies. Re-codification of the laws to consolidate and simplify recycled water statutes into a section of the code dedicated to "water recycling" would help recycled water purveyors, users and regulators better locate, understand, and use the appropriate sections of the code.

Other concerns about the statutes have been expressed and statutory changes have been proposed. The Task Force does not specifically endorse or reject any of these changes, but it does support further analysis. The proposed changes are:

- Amend statutes to provide for a simplified and consistently implemented permitting approach to govern most recycled water projects. Currently there are four different types of permits issued for recycled water projects.
- Have the CDHP regulate the use of "advanced treated" recycled water to be used for potable reuse, and have the RWQCBs regulate other uses of recycled water. "Advanced treated purified water" would constitute a level of treatment higher than tertiary treatment as defined in Title 22 of the current State regulations and would

include treatment equivalent to reverse osmosis and advanced oxidation treatment processes.

- Change the definition of "waste" in Section 13050(d) of the Water Code and other sections of statute. Recycled water should continue to be regulated to protect public health, and it should be recognized and regulated in the appropriate statute(s) as a valuable resource, not as a waste product.
- Update the statutes to address constituents of emerging concern if an update to the State Board's Recycled Water Policy cannot adequate address the issues.

Implementers: SWRCB, CDPH, and Legislature.

Solution 10.2.2 - Provide Consistent Implementation of the SWRCB's Recycled Water Policy and Revise Policy as Appropriate

a. The SWRCB's Recycled Water Policy provides for the development of stakeholder-driven regional or sub-regional salt and nutrient management plans to replace regulation of salts and nutrients solely on individual recycled water projects and to consider all relevant sources of salt and nutrients. Regulatory requirements to develop criteria for monitoring of constituents of emerging concerns and stakeholder development of salt and nutrients management plans should be developed by Regional Water Boards consistent with State Water Board and CDPH efforts. Several successful efforts provide good examples to follow.

Implementers: RWQCB's, SWRCB, Stakeholders

Examples: Four RWQCB's provide good examples of proactively working with stakeholders on implementing salt and nutrient management plans. These efforts range from Regional Boards that have had long-term successes to those that are in the early phases.

- Region 8 was an early adopter of the stakeholder driven salt and nutrient management planning approach. It supported a maximum beneficial use approach that was incorporated into the basin plan, and it provided a positive example for the SWRCB's Recycled Water Policy approach to addressing salt and nutrients. This stakeholder group has since expanded its efforts to include constituents of emerging concerns.

- Following adoption of the Recycled Water Policy, Region 9 staff worked with stakeholders to develop and approve guidelines for the development of salt and nutrient management for the numerous small basins in the region. These guidelines allow stakeholders to focus their efforts on the highest priority basins and provide regulatory certainty for any agency/stakeholder that participates. DWR, in its IRWM Plan/Proposition 84 Planning grant, has provided funding to assist in developing these plans.

- In July 2008, the Central Valley Salinity Coalition (CVSC) was formed. It represents stakeholder groups working with the Region 5 in the CV-SALTS effort, and its purpose is to organize, facilitate, and fund efforts needed to fulfill the goals of CV-SALTS. CVSC coordinates the meetings of the CV-SALTS committees, maintains an independent web site, and manages the projects originating from this effort.

- In November 2010, Region 4 staff held an initial workshop to introduce the salt and nutrient plan concept to stakeholders. Since that time, five major basin groups have been formed to develop the plans: Central and West Basin, San Gabriel and Raymond Basins, San Fernando Basin, Pleasant Valley, Oxnard and Las Posas Basins, and Lower and Upper Santa Clara Basins. Each basin group has an assigned Regional Board staff person with local agencies taking the lead as stakeholders. One basin group (Santa Clara) is receiving IRWM funding for its plan. The Regional Board is providing guidance and updates for the plans through their website, an email distribution list, and stakeholder meetings.

b. An expert panel on monitoring constituents of emerging concern made recommendations to the SWRCB in a report dated June 25, 2010. The SWRCB and CDPH should evaluate the recommendations, propose changes as appropriate to the SWRCB's Recycled Water Policy, and incorporate the recommendations into the groundwater recharge criteria being developed by CDPH. The policy update should also address the additional work needed to expand laboratory methods and to monitor for future emerging constituents.

Implementers: SWRCB in cooperation with CDPH, the Expert Panel, and other potential monitoring entities (USGS under GAMA)

c. MS4 permits issued by RWQCBs are a mechanism that can be used for regulating recycled water runoff consistent with other landscape over-irrigation runoff. MS4 permits can put recycled water on par with other potable water supplies. Currently the SWRCB's Recycled Water Policy allows for the use of both MS4 and NPDES permits to regulate runoff for recycled water landscape irrigation sites. The State Board should work with stakeholders to evaluate whether MS4 permits should be the favored approach where those permits are available.

Implementer: SWRCB.

Solution 10.2.3 – Ensure Consistent Implementation of Use Site Oversight throughout the State.

The oversight of sites where recycled water is proposed or used is currently provided by two State agencies: the RWQCBs and CDPH. CDPH reviews proposed use sites for compliance with Title 22, Health and Safety Code and Water Code requirements, and it makes recommendations to the project proponent either through the Regional Board or in a manner consistent with Regional Board master permit requirements. This task can be delegated to county health departments as a fee-for-service with the permission of the project proponent, as long as the County follows CDPH regulatory guidance. Once recycled water use begins, the regulatory responsibility shifts to the RWQCBs through enforcement of permits. The Regional Board permits incorporate applicable provisions of Title 22 regulations as well as case-by-case recommendations from CDPH.

To the extent possible, CDPH recommendations to the Regional Boards should be consistent throughout the State based on the need for public health protection. They should not vary based on availability of local staff resources. CDPH and the RWQCBs need sufficient resources to ensure adequate public health protection. In addition, consideration should be given to delegating increased review, approval, and site oversight responsibilities to the recycled water purveyors when the purveyor can demonstrate the necessary ability.

Implementers: CDPH, RWQCBs, local County health departments, and recycled water purveyors.

Solution 10.2.4 - Revise Water Recycling Regulations and California Plumbing Code

Specific changes are needed to the water recycling regulations in Title 22 and Title 17 of the California Code of Regulations to eliminate unnecessary restrictions and inconsistencies, as well as to align recycling regulations with the California Plumbing Code (CPC). CDPH currently has areas of Title 22 and Title 17 out for review and update, but it does not have the resources needed to complete the updates. The regulations and the CPC need to be clear on the oversight needed for dual plumbed facilities. Appendix X includes descriptions of some of the possible changes to Title 22 and Title 17

Implementers: CDPH, DWR, California Building Standards Commission.

Solution 10.2.5 –Ensure that the Ocean Plan Update Adequately Addresses Brine Disposal from Recycled Water and Groundwater Facilities

Salt removal and disposal from recycled water and groundwater facilities are important parts of implementing the SWRCB's Recycled Water Policy. In short, properly disposing of brine via ocean discharge is critical to implementing the Policy. Because brine disposal from recycled water and groundwater facilities is not specifically addressed in the Ocean Plan, recent RWQCBs permits have taken a strict interpretation of the regulations by not allowing blending of brine water to meet the ocean plan standards for turbidity, based on guidance from the United States Environmental Protection Administration (USEPA.) As of the Fall of 2011, SWRCB has been in the process of revising its Water Quality Control Plan For Ocean Waters Of California (Ocean Plan) to address disposal of brine, including brine produced by reverse osmosis systems at recycled water and groundwater treatment facilities. Ocean Plan review provides the SWRCB with an opportunity to develop a policy that recognizes the importance of advanced treatment in achieving the State's water recycling goals while at the same time protecting beneficial uses in the ocean.

Potential Implementers: SWRCB and USEPA

10.3 AWARNESS AND EDUCATION OF RECYCLED WATER QUALITY

Some CII users and recycled water suppliers are not aware of how recycled water can be managed and used in particular CII settings. As a result, some of these CII users resist using it. Potential CII users and suppliers need to develop a technical understanding of how recycled water can be properly and successfully used in unique water use situations.

Solution 10.3.1 – Educate Potential Recycled Water Users and Suppliers

An effort should be launched to educate CII users about recycled water use opportunities using technical information and examples. Additionally, those users should be made aware of opportunities to participate in implementing the solutions recommended in this report. Recycled water producers, State and local agencies, industry trade associations, the WateReuse California, Association of California Water Agencies (ACWA), and environmental advocacy groups should provide information about successful uses of recycled water through workshops, at trade shows, in trade publications, at public forums and other venues. Finally, BMPs that address water quality issues such as on-site treatment and blending with other water sources should be developed.

In addition, agencies producing and supplying recycled water must be educated and fully understand the unique water supply and quality needs of potential CII customers.

Implementers: DWR, WateReuse California, recycled water user, trade groups, environmental advocacy groups and ACWA

Example: The University of California San Diego recycled water project provides an example of how awareness barriers can be overcome. In 1998, the faculty opposed using recycled water on campus. The City of San Diego arranged a tour of the North City Water Reclamation Plant which calmed the faculty's fears when they understood the level of effort being put in the treatment to ensure the safety of the public.

Solution 10.3.2–Create and Promote Information on use of Recycled Water in CII

WateReuse California, in conjunction with industrial trade associations, should create and disseminate information on recycling opportunities in various CII settings. The newly created Industrial Reuse Committee of the WateReuse Association would be a good source for this information. This committee was formed to promote and maximize the use of recycled water in industrial settings, and it includes representation from both the public (municipal agencies) and private (industrial users and potential users) sectors. The committee's work addresses the use of recycled water in cooling towers, high purity settings, food/beverage processing, industrial processes in general, and internal reuse.

In addition, WateReuse California, in conjunction with industrial trade associations, should increase awareness by providing information at trade shows and in trade publications, and by speaking in non-traditional settings.

Potential responsible implementers: WateReuse California

10.4 PUBLIC/CUSTOMER ACCEPTANCE

Successful implementation of water recycling projects requires support from

- the general public
- customers of recycled water
- neighbors of customers using recycled water

- policy makers and decision makers

As surveys have shown, public acceptance declines as the potential for human exposure increases. Some members of the public and policy-makers have an aversion to water recycling, often based on a misunderstanding of its safety. To the extent that potential CII users perceive that their customers will not accept products produced with recycled water, or neighbors will resist use of recycled water in the community, CII users will prefer other water supplies. Indirect and direct potable reuse projects, which are needed to achieve the State's recycling goals, are especially dependent on public acceptance.

Solution 10.4.1– Educate and Promote Recycled Water

The public and policy-makers should be educated by providing information to industries, residential customers, and water utilities about the safety, environmental, energy, and green house gas benefits of recycled water. As the RWTF concluded, the public responds positively to projects responsive to community needs, such as the need for a safe, reliable water supply. Recycled water must be promoted within this broader context. Thus, it is important that the public understand the water cycle in general, and the urban water cycle in particular.

An effective State-wide information campaign would offer authoritative views from recognized experts including SWRCB, DWR, CDPH, and independent research groups, such as the Pacific Institute and environmental NGOs. This campaign would be similar in scope to the State's multi-year and highly effective efforts to promote solid waste recycling and energy conservation ("Flex Your Power"). It would position water recycling like other types of recycling: as being part of good citizenship. Consider aligning water reuse with the sustainability/green movement. Business and industry groups should also actively support and promote recycled water use throughout their industry and with their local elected officials. Additionally, a "tool kit" should be developed for use by agencies involved in producing or marketing recycled water. Finally, it will be important to avoid conflicting Statewide and local messages by using complementary programs and materials.

Potential responsible implementers: DWR, WateReuse California, ACWA, and Industry groups.

Examples: The Del Sur Planned Community Homeowners Association in the City of San Diego is an excellent example of how homeowners have been made aware of recycled water use and signage in public areas. Del Sur's vision is to be eco-friendly and embrace many environmental practices. Additionally, the City of San Diego has implemented the Water Purification Demonstration Project, which will examine the safety of augmenting a surface water reservoir with highly treated recycled water. The demonstration phase includes a strong public outreach element as the city is giving tours to the public of the demonstration facility. Seeing and understanding the treatment facilities can raise the public's level of confidence in the safety of the water supply.

Solution 10.4.2 – Implement Community Value-based Decision-making Model for Project Planning

Public participation and representation is founded on the idea that those who are affected by decisions or policies are capable and should participate or be represented in policy-making processes. The public should be involved throughout all project phases, including planning, deliberation, decision, design, and implementation. The public commonly has full access to information on proposed projects, such as through the environmental review processes required by the California Environmental Quality Act (CEQA) and the federal National Environmental Policy Act (NEPA), but under these acts, the minimum public notification requirements are sometimes inadequate to engage the public. Public agencies that develop recycled water projects are required to hold public meetings and consider public input as a basis for recycled water project decisions, but members of the public sometimes lack sufficient information about local water issues and alternative water resources options to establish a well-informed position on a project. .

Early public involvement can assist the project proponent in identifying and responding to the concerns of the public. Public participation creates empowerment, and empowerment yields a sense of collaboration. With the need to supply additional water in the State and the potential use of recycled water projects to meet that need, decision-makers at water utilities and regulators should make an investment in the public arena so that their decisions will most fully benefit their constituents, customers and communities.

Determining a community's values, then making decisions based on that information is the foundation of a community value-based decision-making model. This model encourages participants to recognize that most people believe in a unified set of fundamental values then takes them further, into the realization that these values can be the basis for consistent and improved decision making. A values-based decision-making model should embody the general public participation principles listed in the introduction to this section.

Implementers: Water suppliers.

10.5 COST FOR CII USERS

Cost is often the most important factor for CII users in deciding whether to accept the use of recycled water. Generally, CII users will assess the net cost of recycled water in relation to the cost of potable or other fresh water sources. The key components of cost to CII users are the prices of recycled and potable water, the on-site costs to convert from potable to recycled water, and operating costs of using recycled water compared to potable water. Use of recycled water in some settings results in increased operating costs for the user. For example, recycled water use in cooling towers may necessitate additional treatment or fewer cycles. Recycled water can result in increased flows or waste loads to the sewer, thus increasing sewer fees in many jurisdictions. Without recycled water purveyor awareness of such costs, the pricing of recycled water can create a cost barrier. Higher net costs in using recycled water compared to using potable or fresh water can discourage CII users from accepting recycled water.

Solution 10.5.1 – Base Recycled Water Pricing on Total Cost of Use and Provide Incentives

As noted in section 10.1, on-site capital and operating costs for recycled water can be greater than that of using potable water. In addition to direct funding assistance to customers to compensate for on-site costs, water pricing is another way water suppliers can address on-site cost burdens. Recycled water should be priced relative to potable water but adjusted to reflect on-site costs. Doing so generally results in recycled water being priced at a lower rate than potable water. If customers are self-supplied and do not purchase fresh water from a water supplier, as is frequent for CII customers, the recycled water price will have to reflect the costs to the customer for obtaining water from its own source. Implementers: Retail water suppliers.

10.6 SOURCE WATER QUALITY

Many CII uses are sensitive to water quality, and recycled water typically has more minerals and organic content than many available alternative supplies. Subtle changes in water quality, such as increases or decreases of certain minerals or chemical species, can dramatically change the suitability of recycled water or the treatment requirements for use in an industrial process. Landscape plants can be sensitive to certain chemicals potentially present in recycled water, such as boron, or can be affected by changes in soil conditions caused by salinity. Indirect and direct potable reuse projects will need to be designed to protect the public health and to consider the potential for Constituents of Emerging Concern (CECs) or other public health-related issues. Many water quality concerns associated with recycled water can be and are addressed with additional treatment by the water utility, on-site treatment, or other water management practices.

Solution 10.6.1 – Provide Water Quality Suitable for Intended Use

To facilitate the use of recycled water in CII settings, water quality can either be improved by the supplier through additional treatment and/or source control, or the individual users can improve treatment and control processes.

Local agencies and WateReuse California, should work together and in cooperation with other trade groups to identify water quality issues for categories of CII users and solutions. Specific examples include:

- Collaboration between utilities and CII users to identify water quality issues and solutions. Those solutions may be technological and/or economic.
- Provide additional treatment and/or source control such that recycled water quality is fit for the purpose.
- Recycled water producers should develop rigorous water quality control practices.
- CII users should modify their operation to the extent practicable to accommodate the quality of available recycled water.

Implementers: Water supply agencies, CII users, WateReuse California, industry trade associations.

Examples:

Institutional Example: San Jose State University has completed an evaluation of source water options that proved useful in selecting its cooling tower supply choice. A computer-based modeling program helped determine the program control limits for the cooling tower using both recycled water and well water. The modeling program determined that the plant could run the cooling water system at a maximum of six cycles with the new control using either recycled water or well water, keeping the sewer flow the same regardless of water source.

Commercial Example: In 1994, the Pebble Beach Company teamed up with seven other local agencies in a unique private/public partnership to deliver recycled water for irrigation to seven golf courses in Pebble Beach, California, including world-renowned Pebble Beach Golf Links.

The golf courses began irrigating with tertiary-treated recycled water in 1994. During the first few years of operations, the project underwent constant reviewed and modification.

It became apparent that the recycled water was of low quality when he golf courses began experiencing some problems with the turf grass on the greens. The problem was determined to be caused by high sodium concentrations – at times as high as 200 mg/L – and high concentrations of total dissolved solids (TDS) concentrations – at times as high as 1000 mg/L.

As an initial solution, potable water was used periodically to flush salts away from the plant root systems. All of the involved organizations and agencies began studying technical solutions to improve water quality and quantity, as well as methods for financing the improvements. This work led the groups to begin Phase Two of the Water Reclamation Project with the intent of improving water quality and increasing the quantity of recycled water available for irrigation.

In 2006, a second project was commissioned to install advanced treatment for reducing sodium to a level satisfactory for the golf courses to use 100% recycled water without potable water flushes and to improve the storage capacity of recycled water in an abandoned reservoir to meet the peak irrigation demands of the golf courses.

After three years of operation, no water quality issues are being reported, and the reservoir is working perfectly for meeting the seasonal irrigation demands.

Industrial Example: BP Carson has overcome water quality challenges as well. Recycled water entering the refinery that is treated with RO is corrosive by nature, so a separate non-carbon steel pipeline/distribution system was built inside the refinery to accommodate the use of this water.

The Title 22 standard tertiary-treated recycled water stream coming from West Basin's facility in El Segundo is nitrified at the Carson Facility. This water is high in iron and phosphates due to upstream water quality treatments and may limit the number of cycles the water can be used in the cooling towers, an effect that is reduced by the blending of RO water into the nitrified supply.

Chemical treatment programs need to be adjusted when switching from the city water supply to a predominantly recycled supply, especially in cooling towers. The water quality from the Carson Regional Facility is generally of very consistent quality, especially compared to city water, which can change seasonally or when city water sources are switched. However, sudden quality changes can also occur with recycled water. Good communication between the recycled plant operator and the refinery operators minimize the impacts of these changes

10.7 RECYCLED WATER SUPPLY RELIABILITY

Recycled water is an extremely reliable supply in that it is produced consistently in summer and winter, and in dry and wet years. In some cases, however, recycled water treatment and distribution systems may be subject to service interruptions due to operational issues that are often more complex than typical potable water treatment and distribution systems. In some cases, recycled water distribution systems are designed to a reliability standard necessary for an expected predominant use, usually landscape irrigation, and then other uses with greater reliability needs are later connected. In addition, potable water systems tend to have a much greater level of redundancy in the conveyance and distribution system than singular recycled water production facilities. This reduced level of on-stream availability discourages reuse by potential CII and landscape users with a service interruption standard more stringent than that of the recycled water system to which they may otherwise wish to connect. Service interruption could cause production impacts or business impacts to the golf industry and, at certain types of industrial facilities, safety or environmental impacts.

Solution 10.7.1 – Consider Increased Recycled Water System Reliability Features and Backup Water Supply

The reliability of recycled water systems needs to be commensurate with the types of water demands being served and the needs of recycled water users. Alternatives include more robust recycled water treatment and delivery systems and alternative backup water supplies. Incorporating backup water supplies is often more cost-effective than increasing redundancy or capacity of recycled water facilities that will only be used in rare or infrequent situations. Alternative approaches are usually available to meet the reliability needs of the system, including:

- Improve the reliability of the recycled water infrastructure.
- Provide recycled water storage backup supply for customers intolerant of service interruption.
- Encourage CII customers to have on-site storage where appropriate
- Provide a more robust recycled water plant design that includes redundant pumping systems, backup power supplier for critical equipment.
- Provide potable or other backup water supply at individual customer sites in the event of loss of recycled water at the user facility.
- Provide the ability to add supplemental potable or nonpotable water to the recycled water distribution system to meet peak demands or replace recycled water during interruptions of recycled water availability.
- Provide a recycled water infrastructure system that can, if needed, be fed from multiple sources rather than from a single dedicated recycled water plant.

Potential responsible implementers: Water supply agencies and users

10.8 TERMINOLOGY USED IN DESCRIBING THE PROCESS

Terminology and information presented by water recycling professionals can be dauntingly technical, and often, multiple terms variously and inconsistently describe the same product or technology. This terminology, which describes treatment technology, types of recycled water, and water quality issues, derives from engineering and regulatory sources, and it can be confusing to recycled water users and other stakeholders.

For example, Title 22 requires signage stating "RECYCLED WATER – DO NOT DRINK," yet recycled water is sometimes introduced into potable water sources, such as groundwater. Some recycled water products are branded (e.g., NEWater in Singapore); some are simply called "recycled water"; and others are called reclaimed water. Professionals and public officials need to understand their audience when communicating and use appropriate terminology.

Solution 10.8.1- Establish Terminology

Water recycling professionals should establish universal terminology that is transparent, comprehensible, and consistent with State statutes and regulations. This language should be carefully used in all media contacts, in project development, and education. Likewise, technical scientific and engineering terminology is needed for communication within scientific and engineering community, and, because the general public will not readily understand it, it may not be suitable for communicating with the general public.

Potential responsible implementers: WateReuse California

Solution 10.8.2- Use New Terminology

The industry should communicate consistent, clear terminology to water industry professionals and seek its widespread use. State agencies should incorporate this terminology in laws and regulations. Those agencies should agree to recognize the language in waste discharge requirements and standardize its use.

Potential responsible implementers: SWRCB, CDPH, DWR, WateReuse California, and ACWA

10.9 DATA FOR TRACKING USE

The lack of reliable data about the quantity and types of water recycling occurring in California is a barrier to recycling in that public policies and goals about recycling need to be informed by facts. Management of the recycled water assets in California requires data.

Solution 10.9.1 – Create Unified Recycled Water Use and Compliance Reporting System

There should be consistent reporting requirements and a web-based reporting system that meets regulatory compliance needs of regional water quality control boards and data gathering needs of water supply planners. This system would help manage the data needed to evaluate attainment of State goals, such as the amount of recycled water produced, the fraction of total M&I and agricultural demand met by recycled water (DWR, SWRCB), and reduction of discharge(SWRCB, RWQCBs). One option that may serve this purpose is a comprehensive plan to manage such data using an existing SWRCB-funded database constructed by the WRF.

Potential responsible implementers: SWRCB, CDPH, WateReuse California, and DWR

10.10 INSTITUTIONAL COORDINATION BETWEEN AGENCIES

In some areas, multiple utilities are involved in providing recycled water to a customer. The retail water utility may have disincentives to substitute recycled water for the supply it currently supplies, especially in cases where the recycled water would be provided by a separate utility. Disincentives can include lost revenue.

Solution 10-.10.1 - Review Duplication of Service Regulations

A review of duplication of service and other regulations to identify possible solutions should be undertaken. Additionally, investor-owned utilities should be encouraged to build and rate-base reuse projects as allowed by the CPUC.

Potential responsible implementers: WateReuse California, ACWA, CPUC, and Legislature

Solution 10.10.2 – Provide Agency Partnering Case Studies

Provide case studies where partnering between water, waste water and other utilities has been effective in providing recycled water to CII customers.

For example, the EBMUD Board of Directors adopted a resolution authorizing work with other sanitation districts to allow those districts to provide recycled water supply within the service area and receive a waiver on "service duplication act" protections.

Potential responsible implementers: WateReuse California

Appendix X – to be included in the Appendix

Specific changes to water recycling regulations in Title 22 of the Health and Safety Code are needed to eliminate unnecessary restrictions and inconsistencies. The following are the specific recommended changes to regulations:

Revise CDPH regulations to:

- Add a definition for “Cafeteria” to Section 60301 of Title 22.

- Amend “Operation requirements” section of Sections 60301 and 60304 to Title 22 to reflect new language recently adopted by the Building Standards Commission regarding requirement for cross-connection testing every four years.
- Modify the “Use Area Requirements” in Section 60310(i) to Title 22 to conditionally allow for the use of hose bibbs at sites open to the general public.
- Revise the definition of “approved Water Supply” in Title 17 Section 7383(a) as follows: “…State or local health agency.”
- Change definition to “Water Supplier in Title 17 Section 7583(l) to read ”…is the entity that owns and/or operates the public water system.”
- Use the language found in the current Title 17 Section 7585 which does not require the water supplier to be “responsible for abatement of cross-connections which may exist within a water user’s premises.”

Appendix C: Glossary

Aggregate-level metric: A metric that does not apply to a specific set of conditions, such as system-wide or sector-wide measures.

Alternative turf: See Synthetic turf.

Alternative water source: Any non-potable water source used for irrigation purposes.

Artificial turf: See Synthetic turf.

As-built documentation: Set of reproducible drawings that show significant changes in the work made during construction and that are usually based on drawings marked up in the field and other data furnished by the contractor (MWELO, Section 491).

Back flow prevention device: A safety device used to prevent pollution or contamination of the water supply due to the reverse flow of water from the irrigation system (MWELO, Section 491).

Benchmark: (1) A particular (numerical) value of a metric that denotes a specific level of performance; (2) A current value or beginning value of a metric.

BMP: Best management practices**;** recommended methods or practices designed to increase irrigation efficiency and uniformity thereby reducing water consumption and runoff, protecting water quality.

Commercial water user: "Commercial water user" means a water user that provides or distributes a product or service. (CWC §10608.12(d)).

Confounding-factors: Factors affecting the numeric value of a metric that are not related to the purpose of a metric.

Conservation Index (CI): Nomenclature denoting conservation metric.

CII: Commercial, institutional, and industrial customers; examples of commercial users include customers who provide or distribute a product or service, such as hotels, restaurants, office buildings, commercial businesses, or other places of commerce; institutional customers include schools, courts, churches, hospitals, and government institutions regardless of ownership; industrial customers are those who primarily manufacture or process materials as defined by NAICS.

Definitional noise: The inaccuracies in both the numerator and denominator of a metric as a result of different definitions used for collecting data.

Direct potable reuse: The planned introduction of highly treated recycled water either directly into a potable water supply distribution system downstream of any water treatment plant or into a raw water supply immediately upstream of a water treatment plant. (Paraphrase of Water Code §13561(b)).

Direct reuse: The use of recycled water that has been transported from a wastewater treatment plant to a reuse site without passing through a natural body of either surface water or ground water.

Economic Efficiency: An efficiency measure that incorporates the concept of value, such as including a monetary or resource factor.

Efficiency: The ratio of output to input or vice versa. Water use metrics and benchmarks are inextricably linked to the concepts of "water conservation" and "water-use efficiency." Therefore, it is also helpful to define these concepts in the context of evaluating water use. The term "efficiency" derives from engineering practice where it is typically used to describe technical efficiency, or the ratio of output to input.

Evapotranspiration: A combination of water transpired from vegetation and evaporated from the soil and plant surfaces (ASABE, 1998).

Existing landscape: For the purposes of this BMP, an established landscape associated with a CII site.

Graywater: Untreated wastewater that has not been contaminated by any toilet discharge, has not been affected by infectious, contaminated, or unhealthy bodily wastes, and does not present a threat from contamination by unhealthful processing, manufacturing, or operating wastes. Graywater includes wastewater from bathtubs, showers, bathroom washbasins, clothes washing machines, and laundry tubs, but does not include wastewater from kitchen sinks or dishwashers. (Water Code §14876)

Groundwater recharge: The infiltration or injection of water into a groundwater aquifer.

Hardscape: Any durable material pervious and non-pervious (MWELO, Section 491).

Hydro-zones: Portion of the landscaped area having plants with similar water needs. A hydro-zone may be irrigated or non-irrigated (MWELO, Section 491).

Indirect potable reuse: The planned incorporation of recycled water into a raw water supply such as in potable water storage reservoirs or a groundwater aquifer resulting in mixing and assimilation, thus providing an environmental buffer. (Metcalf & Eddy/AECOM textbook, consistent with definition of "indirect potable reuse for groundwater recharge" in Water Code §13561(c)) Note that as "surface water augmentation" has been defined in the Water Code, it has been distinguished from direct potable reuse and would be a form of indirect potable reuse.

Indirect reuse: The use of recycled water indirectly after it has passed through a natural body of water after discharge from a wastewater treatment plant.

Industrial Water User: "Industrial water user" means a water user that is primarily a manufacturer or processor of materials as defined by the North American Industry Classification System (NAICS) code sectors 31 to 33, inclusive, or an entity that is a water user primarily engaged in research and development (CWC §10608.12(h)).

In-line irrigation: See Subsurface irrigation.

Institutional Water User: "Institutional water user" means a water user dedicated to public service. This type of user includes, among other users, higher education institutions, schools, courts, churches, hospitals, government facilities, and non-profit research institutions. (CWC§10608.12 (i)).

Irrigation scheduling: Determining when to irrigate and how much water to apply based on measurements or estimates of soil moisture or crop water used by a plant (NRCS, 1997).

Irrigation system design: Drawings and associated documents detailing irrigation system layout, and component installation and maintenance requirements (IA, 2010).

Landscape budget: A volume of water allocated to the entire landscape area for some period of time. This allowance is established by the water purveyor for the purpose of ensuring adequate supply of water resources (IA, 2010).

Maximum Applied Water Allowance (MAWA): The upper limit of annual applied water for the established landscaped area as specified in MWELO Section 492.4 (MWELO, Section 491).

Metric: A unit of measure (or a parameter being measured) that can be used to assess the rate of water use during a given period of time and at a given level of data aggregation (e.g., system-wide, sector-wide, customer level, or end-use level). Another term for a *metric* is *performance indicator*.

Microclimate: Climate of a small, specific area that may contrast with the climate of the overall landscape area due to factors such as wind, sun exposure, plant density, or proximity to reflective surfaces (MWELO, 491).

Mulch: Any organic material, such as leaves, bark, straw, and compost, or inorganic mineral material, such as rocks, gravel, and decomposed granite left loose and applied to the soil surface for the beneficial purposes of reducing evaporation, suppressing weeds, moderating soil temperature, and preventing soil erosion (MWELO, 491).

MWELO: The Model Water Efficient Landscape Ordinance of the Department of Water Resources California Code of Regulations.

North American Industry Classification System (NAICS): The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS is based on a production-oriented concept, meaning that it groups establishments into industries according to similarity in the processes used to produce goods or services.

NAICS codes: North American Industry Classification System codes provide comparable statistics about business activity across North America.

New construction landscape: For the purposes of this BMP, a new building with a landscape or other new landscape associated with a CII site.

New landscape: See New construction landscape.

Performance indicator: The same meaning as "metric."

Permeable: Any surface or material that allows the passage of water through the material and into the underlying soil (MWELO, 491).

Planned reuse: The deliberate direct or indirect use of recycled water without relinquishing control over the water during its delivery.

Process water: "Process water" means water used for producing a product or product content or water used for research and development, including, but not limited to, continuous manufacturing processes, water used for testing and maintaining equipment used in producing a product or product content, and water used in combined heat and power facilities used in producing a product or product content. Process water does not mean incidental water uses not related to the production of a product or product content, including, but not limited to, water used for restrooms, landscaping, air conditioning, heating, kitchens, and laundry. (CWC§10608.12 (l)).

Rainwater harvesting: Rainwater collection and distribution systems used as an alternative water source for irrigation (AWE, 2010).

Reclaimed water: Same meaning as "recycled water." (Water Code §26)

Recycled water: Water [that], as a result of treatment of waste, is suitable for a direct beneficial use or a controlled use that would not otherwise occur and is therefore considered a valuable resource. (Water Code §13050(n))

Rehabilitated landscape: Any re-landscaping project that requires a permit, plan check, or design review, meets the requirements of MWELO Section 490.1, and the modified landscape area is equal to or greater than 2,500 square feet, is 50% of the total landscape area, and the modifications are completed within one year (MWELO, Section 491).

Scaling variable: Variable that can be used to standardize or characterize per unit rates of water use. Also called "scaling factor."

Standard Industrial Classification (SIC): A classification system for commercial, industrial, and institutional activities that classifies establishments by their primary type of activity and organizes industries in an increasing level of detail ranging from general economic sectors (e.g., manufacturing, services) to specific industry segments (e.g., commercial sports, laundry businesses). This system organizes industries by their output. SIC was replaced by the North American Industry Classification System (NAICS) in 1997.

Soil management: Utilizing a soil analysis report that includes soil properties such as soil type and infiltration rate when designing and scheduling irrigation systems.

Subsurface irrigation: Application of water below the soil surface through emitters, with discharge rates generally in the same range as drip irrigation. The method of water application is different from and not to be confused with sub-irrigation where the root zone is irrigated by water table control (ASABE, 1998).

Surface water augmentation: The planned placement of recycled water into a surface water reservoir used as a source of domestic drinking water supply (Water Code §13561(d)) or into any surface water when discharged for the purpose of aquatic habitat enhancement.

Synthetic turf: A product manufactured to look like natural turfgrass; a permeable ground cover made from synthetic fibers.

Target: A benchmark that indicates a state of achievement expected at some time in the future.

Turf: A ground cover surface of mowed grass (MWELO, Section 491).

UM: A water use metric acronym expressed as "usage ratios" or "usage rates." The "ratio" metric designates the quotient obtained by dividing the volume of water sold over a specified period of time (day, month, season or year) by a scaling factor (e.g. number of accounts, population served or number of employees). Additional letters, superscripts and subscripts can be added to the UM acronym to designate user sector and the scaling variable being used.

Unplanned reuse: Unplanned reuse of treated wastewater effluent after disposal. Also called "incidental reuse."

Warm season turf: Grasses that grow vigorously in warm summer months and then generally enter some state of dormancy in winter thereby having a lower water need compared to cool season turf. Examples of warm season grasses include Bermuda, Zoysia and Buffalo grasses.

Water audit: Also known as an irrigation survey, a water audit is an in-depth evaluation of the performance of an irrigation system that includes, but is not limited to: inspection, system tune-up, system test with distribution uniformity or emission uniformity, reporting overspray or runoff that causes overland flow, and preparation of an irrigation schedule (MWELO, Section 491).

Water budget: Volume of irrigation water required to maintain a functional, healthy landscape with the minimum amount of water. A water budget is established through a method of water-efficiency standards for landscapes by providing the water necessary to meet the ET of the landscaped area.

Water conservation: A reduction in water use, water losses, or waste.

Water-efficient landscape: A landscape that minimizes water requirements and consumption through proper design, installation, and management (AWE, 2010).

Water use efficiency: For the purposes of this BMP, how well the irrigation water is managed and how well the manager minimizes the additional amount of water needed by the landscape after accounting for non-uniformity and weather (IA, 2010).

Water reclamation: (1) Same meaning as definition 1 for “water recycling.” (2) The treatment of water of impaired quality, including brackish water and seawater, to produce a water of suitable quality for the intended use.

Water recycling: (1) The process of treating wastewater for beneficial use, storing and distributing recycled water, and the actual use of recycled water. (2) The reuse of water through the same series of processes, pipes, or vessels more than once by one user, wherein the effluent from one use is captured and redirected back into the same use or directed to another use within the same facility of the user.

Water reuse: (1) The use of treated wastewater for a beneficial purpose, such as agricultural irrigation and industrial cooling. (2) The additional use of previously used water.

Winterization: The process of removing water from the irrigation system before the onset of freezing temperatures (IA, 2010).