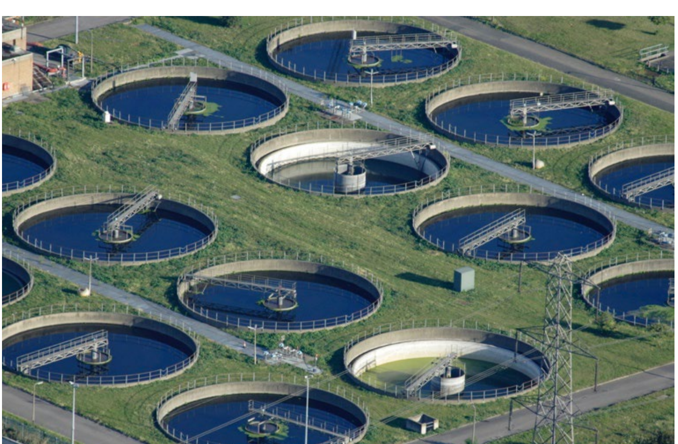
WaterSense at Work

Getting Started With Water Management

1.5 Water-Energy Nexus



Best Management Practices for Commercial and Institutional Facilities

EPA WaterSense

November 2023

WaterSense® is a voluntary partnership program sponsored by the U.S. Environmental Protection Agency (EPA) that seeks to protect the nation's water supply by transforming the market for water-efficient products, services, and practices.

WaterSense at Work is a compilation of water efficiency best management practices intended to help commercial and institutional facility owners and managers from multiple sectors understand and better manage their water use. It provides guidance to help establish an effective facility water management program and identify projects and practices that can reduce facility water use.

An overview of the sections in *WaterSense at Work* is below. This document, covering the water-energy nexus, is part of **Section 1: Getting Started With Water Management**. The complete list of best management practices is available at www.epa.gov/watersense/best-management-practices. WaterSense has also developed worksheets to assist with water management planning and case studies that highlight successful water efficiency efforts of building owners and facility managers throughout the country, available at www.epa.gov/watersense/commercial-buildings.

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This document is one section from *WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities* (EPA-832-F-23-003). Other sections can be downloaded from www.epa.gov/watersense/best-management-practices. Sections will be reviewed and periodically updated to reflect new information. The work was supported under contract 68HERC20D0026 with Eastern Research Group, Inc. (ERG).

Overview

Community, state, and national-level water and energy systems are interdependent. Water is used in the production of electricity, and energy is required to extract, treat, convey, and heat water, as well as to collect and treat wastewater. Therefore, every gallon of water saved will reduce energy consumption and every kilowatt-hour (kWh) of electricity reduced will save water. This connection has been termed the “water-energy nexus.”

Water scarcity, variability, and uncertainty in water supplies and weather patterns—exacerbated by climate change—can cause vulnerabilities in U.S. utility systems. This is particularly true in the western and southwestern United States, where extreme or exceptional drought conditions are more prevalent and can have long-term impacts.[1] Understanding the water-energy nexus provides a broader perspective on the need for and benefit of using water and energy as efficiently as possible. Even simple savings measures can have a direct impact on local and regional water supplies and water and energy infrastructure.

Commercial boiler that uses energy to generate steam for building heating

Building or campus-level water and energy use is also interdependent. Water is often used to manage building heating and cooling loads, and energy is needed to heat and pump water throughout the building. In some cases, trade-offs may be required, as pursuing efficient use of electricity may come at the cost of using more water, and vice versa. Therefore, understanding the interdependencies between water and energy use can help facility owners and managers better prioritize efficiency opportunities that leverage water and energy reductions and cost savings and improve return on investment.

This section explains the water-energy nexus as it relates to water and energy production and the interdependencies of water and energy use within facilities. It is by no means an exhaustive discussion of the water-energy nexus, but is meant to provide the broader context for the importance of saving water and energy. It also suggests many of the best management practices and resources that facilities can consider to maximize their impact, understand potential conflicts that may arise between energy efficiency and water efficiency, and, wherever possible, achieve the benefits of both water and energy savings.

[1] U.S. Drought Monitor. https://droughtmonitor.unl.edu/.

Water Used to Produce Electric Power

Water used in the production of electricity is significant. A 2018 U.S. Geological Survey report estimated that 41 percent of total water withdrawals in the nation in 2015 were for thermoelectric power generation.[2] Thermoelectric power plants withdraw water from sources such as rivers or lakes to cool and condense the steam used to power their turbines. After withdrawal, the water is either lost to evaporation or diverted or discharged back into a body of water, often with altered water quality and temperature. Data from the U.S. Energy Information Administration suggests that withdrawals by thermoelectric power plants have been declining since 2014, largely due to a shift in the mix of electricity generation (e.g., increase in renewable energy sources).[3] Following suit, overall water intensity of total U.S power generation—the average amount of water withdrawn per unit of total net electricity generated—has fallen from 15.1 gallons (57.2 liters) per kWh in 2014 to 13.0 gallons (49.2 liters) per kWh in 2017, though still accounting for the withdrawal of 52.8 trillion gallons (200 billion kiloliters).

Energy Used to Pump, Treat, and Distribute Water and Collect and Treat Wastewater

Wastewater aeration tanks require energy to treat wastewater

The energy required to extract, treat, and transport water and collect and treat wastewater can be the largest energy use for many municipalities, often accounting for 30 to 40 percent of total energy consumed.[4] The amount of energy used in water production is source-specific and can vary regionally, locally, or even from one source of water to another for the same utility. The amount of water pumping and treatment required are the largest variables. Nationally, a 2013 Electric Power Research Institute (EPRI) report estimated that nearly two percent of the electricity used in the United States goes toward moving and treating water and wastewater by public and private entities.[5] In some locations, based on water resource management practices and the mix of energy used in the region, the energy use for water can be even greater. For

[2] U.S. Geologic Survey (USGS). Thermoelectric Power Use. www.usgs.gov/mission-areas/water-resources/science/thermoelectric-power-water-use?.

[3] U.S. Energy Information Administration (EIA). November 2018. “Water withdrawals by U.S. power plants have been declining.” www.eia.gov/todayinenergy/detail.php?id=37453.

[4] EPA. Energy Efficiency for Water Utilities. www.epa.gov/sustainable-water-infrastructure/energy-efficiency-water-utilities.

[5] Electric Power Research Institute. November 2013. *Electricity Use and Management in the Municipal Water Supply and Wastewater Industries*. www.epri.com/research/products/000000003002001433.

example, estimates from 2001 indicate that 20 percent of California's electricity and 30 percent of its natural gas were consumed pumping, heating, and treating water.[6] Though they have some limitations, these estimates are considered a good starting point for understanding the magnitude of energy demands for providing water services.

Commercial and Institutional Water and Energy Use

Water and energy are connected in two primary ways within commercial buildings: hot water generation and consumption; and building and equipment heating and cooling. Table 1 provides a general breakdown of energy use within the U.S. inventory of commercial buildings. In addition to water heating, which is a direct use of water and energy, functions marked with an asterisk (*) indicate energy uses that generate heat inside the building, which is commonly removed via evaporative cooling through the heating, ventilation, and air conditioning (HVAC) system, thus resulting in an indirect use of water. Depending on the type of building and its primary activities, some sectors may have more significant energy demands that require water for cooling.

Table 1. Commercial Building Energy Use

Function	Precent of Energy Use	
	Electricity[7]	Natural Gas[8]
Water Heating	2.0%	10.0%
Space Heating	5.9%	68.6%
Ventilation, Cooling, and Refrigeration	41.0%*	0%
Lighting	17.4%*	0%
Office Equipment and Computers	7.8%*	0%
Cooking	2.2%*	17.1%*
Other	23.7%*	4.3%*
TOTAL	100%	100%

*Energy uses that impact a building's heating load that must be removed by the building's cooling system, which, in the case of evaporative cooling, impact building water use.

Hot Water Generation and Consumption

Many end uses of water within a commercial building require hot water. Examples include water use from faucets, showers, laundry operations, dishwashers, and other commercial kitchen equipment. Each gallon of hot water used requires 0.17 kWh of electricity or more,

[6] Public Policy Institute of California (PPIC). November 2018. *Energy and Water*. www.ppic.org/wp-content/uploads/californias-water-energy-and-water-november-2018.pdf.

[7] EIA. December 2022. *2018 Commercial Building Energy Consumption Survey. Table E5. Electricity consumption (in kilowatt-hours [kWh] by end use, 2018 (All Buildings).* www.eia.gov/consumption/commercial/data/2018/ce/xls/e5.xlsx.

[8] EIA. December 2022. *2018 Commercial Building Energy Consumption Survey. Table E8. Natural gas consumption and energy intensities (in cubic feet) by end use, 2018 (All Buildings).* www.eia.gov/consumption/commercial/data/2018/ce/xls/e8.xlsx.

depending on the temperature of incoming water, the set point of the water heater, the efficiency of the water heater, and the desired temperature at the point of use.[9] According to the 2018 Consumer Buildings Energy Consumption Survey (CBECS),[10] commercial buildings in the United States use more than 24 billion kWh of energy each year for water heating. Energy use for heating water is most significant in buildings where the primary activities are foodservice, lodging, malls, and offices, making these facility types conducive to saving energy by reducing their hot water use.

Commercial water heaters

Building and Equipment Heating and Cooling

Mechanical systems such as cooling towers, chilled water systems, and boiler and steam systems typically rely on water as a heat transfer medium. For heating, hot water or steam is generated and distributed throughout a building or campus to provide radiant heat. For building or process cooling, water is used to absorb heat generated by equipment. In some cases, the cooling water is sent directly to the drain (i.e., single-pass cooling); however, some buildings use cooling towers or other forms of evaporative cooling to reduce the temperature of the cooling water so it can be recirculated to provide additional cooling. Depending on the facility type and climate, mechanical equipment used for building heating and cooling can account for 50 percent or more of the total water use within a facility. Therefore, reducing energy demands and minimizing the heat load of energy-using processes and equipment that require cooling water will have corresponding water savings.

Cooling towers used for building and process cooling

[9] EPA's WaterSense program. Data and Information Used by WaterSense. www.epa.gov/watersense/data-and-information-used-watersense.
[10] EIA, December 2022, *2018 Commercial Building Energy Consumption Survey. Table E5.*, *op. cit.*

Best Practices to Reduce Water Use and Save Energy

Commercial facilities that have substantial water heating needs can reduce hot water demand through more efficient operation and by retrofitting or replacing fixtures, fittings, and appliances that use hot water. EPA's *WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities*—available at www.epa.gov/watersense/best-management-practices—provides information on savings opportunities for hot water-using fixtures and appliances. Each section of *WaterSense at Work* also includes equations for calculating the potential water and energy savings and project payback of various measures. Generally speaking, facility owners and managers should look for hot water use and savings opportunities in the following areas:

- In restrooms, locker rooms, or break rooms that include faucets and showerheads
- In laundry areas with residential or commercial washing machines
- In commercial kitchens with combination ovens, steam cookers and kettles, dipper wells, pre-rinse spray valves, and commercial dishwashers
- Outside, if a facility has a heated pool
- Within steam boiler systems
- In laboratories that use steam sterilizers, glassware washers, and vivarium washing equipment

Understanding the full picture of water, energy, and cost savings may reduce the project payback period and make implementation more appealing to building management.

WaterSense at Work: Where to Find It

Sections of *WaterSense at Work* that address systems where reducing water use can also contribute to energy savings include:

- *Section 3.3: Faucets*
- *Section 3.4: Showerheads and Bath and Shower Diverters*
- *Section 3.5: Laundry Equipment*
- *Section 4.1: Pre-Rinse Spray Valves*
- *Section 4.2: Commercial Ice Machines*
- *Section 4.3: Combination Ovens*
- *Section 4.4: Steam Cookers*
- *Section 4.5: Steam Kettles*
- *Section 4.7: Dipper Wells*
- *Section 4.10: Commercial Dishwashers*
- *Section 5.3: Commercial Pool and Spa Equipment*
- *Section 6.5 Boiler and Steam Systems*
- *Section 7.3: Steam Sterilizers*
- *Section 7.4: Glassware Washers*
- *Section 7.6: Vivarium Washing and Watering Systems*

These sections can be found online at www.epa.gov/watersense/best-management-practices.

Best Practices to Reduce Energy Use and Save Water

Building and equipment heating and cooling, often some of the largest uses of energy in commercial facilities, can also be some of the largest uses of water. *WaterSense at Work* provides an overview of the mechanical systems and equipment commonly found in many commercial and institutional facilities that use water for building and equipment heating and cooling, including cooling towers, chilled water systems, boiler and steam systems, and single-pass water cooling.

WaterSense at Work: Where to Find It

Sections of *WaterSense at Work* that address systems where reducing energy use can also contribute to water savings include:

- *Section 6.2: Single-Pass Cooling*
- *Section 6.3: Cooling Towers*
- *Section 6.4: Chilled Water Systems*
- *Section 6.5: Boiler and Steam Systems*

These sections can be found online at www.epa.gov/watersense/best-management-practices.

Based on the recommended mechanical system best practices found in EPA's *WaterSense at Work* guide, the sections below outline some key strategies for reducing energy use to save water. ENERGY STAR®[11] also provides resources and strategies that commercial facilities can implement to reduce building heating and cooling loads and more efficiently operate mechanical systems, thereby saving energy and water.

Examine Cooling Tower and Chiller Efficiency

Look for opportunities to optimize chiller system and cooling tower efficiency, such as altering/automating operational cycles based on cooling demand or applying variable fan speed controls to circulation pump motors. Efficiently operated chillers and pump motors transfer less heat into the condenser system and reduce water loss through evaporation. Improving chiller efficiency from 1.0 to 0.75 kilowatts per ton of cooling can cut water usage by 10 percent or more.[12]

Chilled Water Plant Optimization Resources

- *ENERGY STAR Building Upgrade Manual*
- *ASHRAE Fundamentals of Design and Control of Chilled-Water Plants*
- *ASHRAE GreenGuide: The Design, Construction, and Operation of Sustainable Buildings*

[11] ENERGY STAR. Save Energy. www.energystar.gov/buildings/save_energy_commercial_buildings.
[12] FacilityManagement.com. Saving Water in Your HVAC System. https://facilitymanagement.com/hvac-energy-consumption/.

Optimize HVAC Systems

If a facility's cooling tower is using more than three gallons of water per ton-hour of cooling, the HVAC system may be running inefficiently. HVAC optimization can cut that usage to 2.5 to 2.0 gallons per ton-hour of cooling while reducing energy use and costs.[13]

HVAC Optimization Resources

- *ENERGY STAR Building Upgrade Manual*
- U.S. Department of Energy's Better Buildings: Space Conditioning

Following are some best management practices for HVAC system optimization:

Cooling tower maintenance professional evaluating tower operation

- Have a professional evaluate the building's heat load and make sure the system is the right size for the heating and cooling needs.[14]
- Conduct routine maintenance to ensure the system components are operating efficiently.
- Assess other optimization strategies, including automatically controlling HVAC equipment as a holistic system 24 hours per day, to use the least amount of energy without sacrificing building performance. The chillers, boilers, air handling units, ductwork, diffusers, thermostats, and sensors must work together to yield the full benefits.
- Use advanced optimization software to continually analyze system data and determine additional measures that will improve efficiency, such as calculating the right amount of air to condition for a particular space at a particular time.[15,16,17]
- Where possible, if the building has some temperature flexibility, consider turning up the thermostat a degree or two; dialing the temperature up from 67 or 68 degrees to between 69 and 71 degrees will reduce the load on air handling

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[13] *Ibid*.
[14] Industrial Utility Efficiency Chiller & Cooling Best Practices. "Barriers to HVAC Optimization and How to Overcome Them." https://coolingbestpractices.com/industries/hvac/barriers-hvac-system-optimization-and-how-overcome-them.
[15] *Ibid*.
[16] *Consulting-Specifying Engineer*. August 2018. "How to optimize an HVAC system." www.csemag.com/articles/how-to-optimize-an-hvac-system/.
[17] FacilityManagement.com, *op. cit*.

systems and cut back on the use of chilled water, and most employees won't feel a difference in their workspace.[18]

- Be sure to evaluate the full impact of any changes so that optimization in one area does not result in increased energy or water use in another. For example, setting an overly ambitious chilled water reset to save energy could cause the air handler fans to ramp up, resulting in more fan energy usage across the building.

Manage Connections to the Chilled Water System

Chilled water systems are often used to cool air passing through air handling units, but they can also be used to cool a number of other systems and equipment. Look for opportunities to reduce the demand of equipment connected to the chilled water loop or replace water-cooled equipment with air-cooled models. However, if considering switching to air-cooled models, be cognizant of the water-energy trade-off, discussed in more detail below.

Common Equipment Connected to Chilled Water Systems

- Air handling units
- Air compressors
- Hydraulic equipment
- CAT scanners
- Degreasers
- Welding machines
- Vacuum pumps
- X-ray equipment
- Ice machines

Build in Strategies to Reduce Heat Loads

Consider other building design and operation strategies to reduce building heat load, and thus the need for building cooling through mechanical systems. Building Green provides some specific strategies for reducing heat load in new and existing buildings including:[19]

- *Reduce solar gain*. Site buildings carefully to avoid east-west orientation. Designers can also use trees and vegetation to provide shade, reduce window size, use low-solar transmittance glazing, install window treatments, and specify vegetative or highly reflective roofs.
- *Reduce infiltration and ventilation heat gain*. New building design should include a tight building envelope and provide adequate insulation. Once occupied, keep exterior doors closed or install revolving doors and use ventilation fans only when necessary.

Building Heat Load Reduction Resources

- ENERGY STAR Checklists of Energy-Saving Measures
- *ENERGY STAR Building Upgrade Manual*
- Building Green "Keeping the Heat Out: Cooling Load Avoidance Strategies"
- ASHRAE 189.1 *Standard for the Design of High-Performing Green Buildings*

[18] FacilityManagement.com, *op. cit*.
[19] Building Green. "Checklist for Reducing Cooling Loads Reducing Solar Gain." www.buildinggreen.com/feature/keeping-heat-out-cooling-load-avoidance-strategies/checklist/1.

- *Reduce internal heat gains*. Designs should specify energy-efficient lighting, refrigerators, office equipment, and other electrical loads. Installers should insulate cooling system ducts and water heater and hot water pipes. Make sure to provide ventilation for heat sources (e.g., dryers, kitchen equipment).

Consider Free Cooling

Air- and water-side economizers can be used to reduce both energy and water use. Economizers work by utilizing cold, outside air (when it is available) to provide space or chilled water cooling, rather than depending on mechanical cooling. This is often referred to as “free cooling.” The water and energy savings will be dependent on the year-round cooling needs and the availability of conditions conducive to free cooling.

Free Cooling Resources

- ENERGY STAR: Water-Side Economizers
- ENERGY STAR: Air-Side Economizers

Consider Heat Recovery

Cooling towers remove unwanted heat from within the recirculating water loop. Facilities should consider installing a heat recovery unit prior to the water loop returning to the cooling tower to heat water for other uses where heat is desired. This directly reduces the amount of energy needed to provide heating to other applications and reduces the amount of heat that the cooling tower needs to dissipate from the chilled water loop, thus reducing evaporative water use.

Further Opportunities to Save

Opportunities for water and energy savings should be considered together, as many efficiency strategies can have a benefit in both areas. Following are some things to keep in mind to maximize return on investment benefits:

- Consider energy and water efficiency in building and mechanical equipment design versus retrofitting later. Equipment should be the right size for its intended use to minimize unnecessary water and energy use.
- Consider green building certification programs or “stretch” codes and standards that address energy and water use of the whole building (e.g., ASHRAE 189.1 *Standard for the Design of High-Performance Green Buildings*, LEED, Green Globes). These programs may help

***WaterSense at Work*: Where to Find It**

Sections of *WaterSense at Work* that address systems where reducing energy use can also contribute to water savings include:

- *Section 1.4: Codes, Standards, and Voluntary Programs for Water Efficiency*
- *Section 6.5: Boiler and Steam Systems*

These sections can be found online at www.epa.gov/watersense/best-management-practices.

spur conversations and initial integrated planning and design to achieve both water and energy efficiency.

- Pay particular attention to boiler and steam system maintenance. Simple measures, such as those described in *WaterSense at Work Section 6.5 Boiler and Steam Systems* at www.epa.gov/watersense/best-management-practices, can reduce the amount of water that needs to be heated and in turn reduce the amount of energy required to heat the water.
- Employ the services of water management and/or energy service company (ESCO) that can identify and bundle energy and water efficiency upgrades.
- Look for opportunities to access funding at the federal and state levels to implement energy efficiency projects that could also influence water use in a facility. The Database of State Incentives for Renewables & Efficiency (DSIRE®; www.dsireusa.org/) provides information about policies and incentives by state.
- Increasingly, companies are reporting their greenhouse gas emissions and pursuing strategies to mitigate their climate impacts. Where appropriate, consider energy and carbon savings that result from reducing water use when reporting successes.

Avoid Water-Energy Trade-offs

Some measures that save water can increase energy use, and vice versa. The ultimate use of both and the associated water, energy, and collective cost savings should be carefully considered before embarking on a project. For example, certain equipment can be either air- or water-cooled. Water cooling can reduce energy use but can significantly increase water use. There are situations when changing to air cooling (or otherwise eliminating single-pass or chilled water cooling) can result in increased energy use if fans or blowers are required to provide the cooling.

Commercial ice machines (discussed in *WaterSense at Work Section 4.2 Commercial Ice Machines* at www.epa.gov/watersense/best-management-practices) are a common example of this water-energy trade-off. An air-cooled ice machine may use 10 percent more energy than a water-cooled model;[20] however, a water-cooled ice machine that uses single-pass cooling may use 80 to 90 percent more water.[21,22]

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[20] *Easy Ice*. October 2017. "The Difference Between Air-Cooled and Water-Cooled Ice Machines." www.easyice.com/difference-between-air-cooled-and-water-cooled-ice-machines/.
[21] ENERGY STAR. *ENERGY STAR Program Requirements for Automatic Commercial Ice Makers*. www.energystar.gov/sites/default/files/Final%20V3.0%20ACIM%20Specification%205-17-17_1_0.pdf.
[22] SoCal Water$mart. Air-Cooled Ice Machines. https://socalwatersmart.com/en/commercial/rebates/available-rebates/commercial-devices/air-cooled-ice-machines/.

Additional Resources

ASHRAE. Fundamentals of Design and Control of Chilled-Water Plants. www.ashrae.org/professional-development/self-directed-learning-group-learning-texts/fundamentals-of-design-and-control-of-central-chilled-water-plants.

ASHRAE. 2023. *ASHRAE GreenGuide: The Design, Construction, and Operation of Sustainable Buildings, 6th Edition.*

ASHRAE 189.1. *Standard for the Design of High-Performance Green Buildings.*

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U.S. Department of Energy (DOE) Better Buildings program. Space Conditioning. https://betterbuildingssolutioncenter.energy.gov/alliance/technology-solution/space-conditioning.

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