Water Efficiency Management Guide for Mechanical Systems

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Water Efficiency Management Guide

Mechanical Systems

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The U.S. Environmental Protection Agency (EPA) WaterSense® program encourages property managers and owners to regularly input their buildings' water use data in ENERGY STAR® Portfolio Manager®, an online tool for tracking energy and water consumption. Tracking water use is an important first step in managing and reducing property water use.

WaterSense has worked with ENERGY STAR to develop the EPA Water Score for multifamily housing. This 0-100 score, based on an entire property's water use relative to the average national water use of similar properties, will allow owners and managers to assess their properties' water performance and complements the ENERGY STAR score for multifamily housing energy use.

This series of Water Efficiency Management Guides was developed to help multifamily housing property owners and managers improve their water management, reduce property water use, and subsequently improve their EPA Water Score. However, many of the best practices in this guide can be used by facility managers for non-residential properties.

More information about the Water Score and additional Water Efficiency Management Guides are available at www.epa.gov/watersense/commercial-buildings.

Mechanical Systems Table of Contents

Background

Mechanical systems are frequently utilized to provide heating (of water as well as living spaces) and cooling for multifamily properties. They typically fall into two categories—centralized and decentralized systems. Centralized mechanical systems provide heating and cooling from a central location, such as a mechanical room or utility penthouse. These systems are more common in mid- and high-rise multifamily properties. Centralized mechanical systems can include cooling towers, boilers, and steam systems, each of which uses water as the heat transfer medium. As a result, the use of water for building heating and cooling can be significant, and using sound management practices is a good opportunity for water savings.

Decentralized mechanical systems treat each unit of a multifamily property as its own space, as if each unit were a stand-alone single-family residence. Decentralized mechanical systems are common in low- and mid-rise multifamily properties, since they typically have lower initial purchase and installation costs. Decentralized systems do not typically use process water, so these systems are not the focus of this water efficiency management guide.

Single-Pass Cooling

When looking to reduce mechanical system water use, facilities should try to eliminate single-pass cooling or recirculate the water used for single-pass cooling. Single-pass cooling systems use water to remove heat and cool specific pieces of equipment, such as a condenser or air conditioning unit. However, after the water is passed through the equipment, it is typically discharged to the sewer, rather than being recooled and recirculated. In some cases, single-pass cooling can be the largest water user at a facility, using approximately 40 times more water to remove the same heat load than a cooling tower operating at five cycles of concentration. Most types of equipment cooled with single-pass water can be replaced with air-cooled systems.

Cooling Towers

By design, cooling towers use significant quantities of water. Cooling towers dissipate heat from recirculating water that is used to cool chillers, air conditioning equipment, or other process equipment. After assessing whether single-pass cooling can be eliminated or recirculated, property managers should focus on ensuring that cooling towers are properly maintained to minimize the need for make-up water.

Water leaves a cooling tower system in several ways: evaporation; blowdown or bleed-off; drift; and leaks or overflows.

- **Evaporation** is the primary function of a cooling tower and is the method that removes heat from the cooling tower system. The quantity of evaporation is not typically targeted for water efficiency, as it is responsible for the cooling effect. Improving energy efficiency within the system that uses the cooling water will, however, reduce the evaporative load on the tower, thus saving water in addition to energy. Regardless of cooling tower operating efficiency, approximately 1.8 gallons of water are evaporated for every ton-hour of cooling.

- **Blowdown or bleed-off** is performed to remove high concentrations of dissolved solids (e.g., calcium, magnesium, chloride, silica) from the cooling tower system. As water evaporates, the dissolved solids remain behind, and the concentration of total dissolved solids (TDS) in the cooling tower water increases. High concentrations can cause scale to form or can lead to corrosion, leading to system inefficiencies and degradation. The concentration of TDS is controlled by removing (i.e., bleeding or blowing down) a portion of the water that has high TDS concentration and replacing it with make-up water (e.g., city water, collected rainwater, collected air conditioner condensate), which has a lower concentration of TDS. Blowdown can be initiated manually or automatically, depending on your cooling tower's control method. The quantity of blowdown is dictated by the "cycles of concentration" achieved by the tower. More detail on cycles of concentration are discussed later in this document.
- **Drift** is the small quantity of water that can be carried from the cooling tower as mist or water droplets. If not managed properly with drift eliminators, drift volume can vary from 0.05 percent to 0.2 percent of the flow rate through the cooling tower. This might not sound like a lot, but in most towers, the flow rate through the cooling tower is in the range of 120 gallons to 180 gallons per ton-hour. Drift loss without proper control could therefore be 0.24 gallons to 0.36 gallons per ton-hour, which adds up over an entire cooling season. Installing drift eliminators can reduce drift loss to less than 0.005 percent.
- **Leaks or overflows** should not occur in a properly operated cooling tower, but they do happen. Most plumbing and building codes require an overflow alarm be installed so that an alarm is activated when water is flowing into the overflow drain.

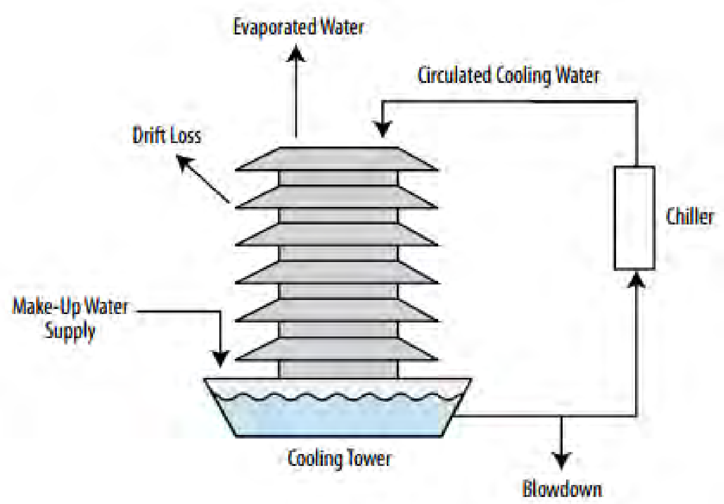
The amount of water needed by the cooling tower is dictated by the amount of water that is lost through evaporation, blowdown, drift and leaks.

Equation 1. Cooling Tower Make-Up Water (gallons)

Cooling Tower Water Use (Make-Up) = Evaporation + Blowdown + Drift + Leaks/Overflow

See Figure 1 on page 3 for an illustration of the water being recirculated, added to, or lost from a cooling tower.

Figure 1. Cooling Tower System



Efficient drift eliminators and effective leak/overflow detection should minimize water losses from drift and leaks. If that is the case, make-up water for a well-managed cooling tower is essentially only based on evaporation and blowdown rates.

Equation 2. Cooling Tower Make-Up Water With Negligible Drift and Leaks (gallons)

Cooling Tower Water Use (Make-Up) = Evaporation + Blowdown

A key parameter used to evaluate cooling tower operation is cycles of concentration (sometimes referred to as “cycles” or “concentration ratio”). The cycles of concentration are the ratio of the concentration of TDS (i.e., conductivity) in the blowdown water divided by the conductivity of the make-up water.

Equation 3. Cooling Tower Cycles of Concentration Based on Conductivity

Cycles of Concentration = Conductivity (TDS) of Blowdown Water ÷ Conductivity (TDS) of Make-Up Water

Since TDS enter the system in the make-up water and exit the system in the blowdown water, the cycles of concentration are also approximately equal to the ratio of volume of make-up water to blowdown water.

Equation 4. Cooling Tower Cycles of Concentration Based on Water Use

Cycles of Concentration = Make-Up Water ÷ Blowdown Water

To use water efficiently in the cooling tower system, the cycles of concentration must be maximized. This is accomplished by minimizing the amount of blowdown required, thus reducing make-up water demand. The degree to which the cycles can be maximized depends on the water chemistry within the cooling tower and the water chemistry of the make-up water supply. As cycles of concentration are increased, the amount of TDS that stays within the system also increases.

Facilities often employ a water treatment vendor to monitor the cooling tower, add chemicals to the system to control scaling and chemical buildup, and maximize the cycles of concentration. Critical water chemistry parameters that require review and control include pH, alkalinity, conductivity, hardness, microbial growth, biocide, and corrosion inhibitor levels. Controlling these parameters allows water to be recycled through the system longer, thereby increasing cycles of concentration. Controlling blowdown using an automatic system provides a better opportunity to maximize cycles of concentration, as the TDS concentration can be kept at a more constant set point. For guidance, Table 1 indicates maximum concentration for parameters in cooling tower water, as suggested by the U.S. Green Building Council.[1]

Table 1. Maximum Concentrations for Parameters in Cooling Tower Water

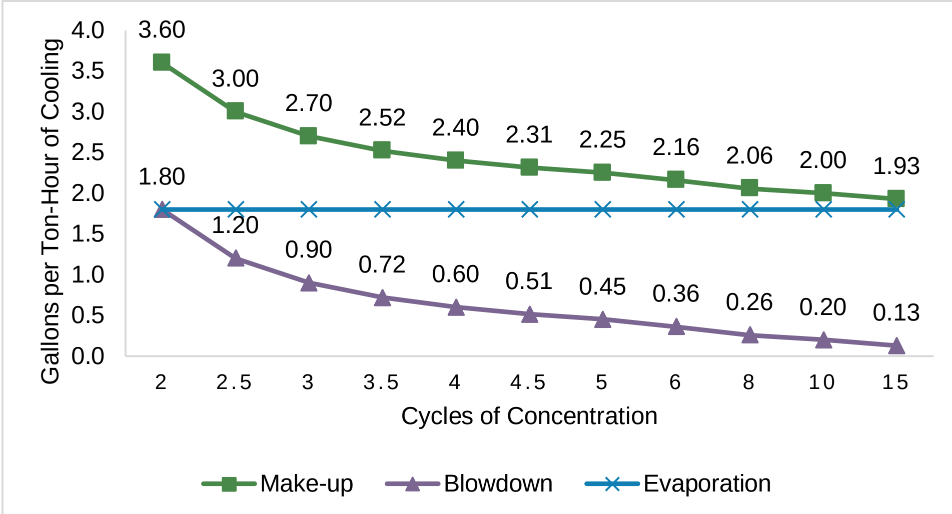
Parameter	Maximum level
Calcium (as $CaCO_3$)	1,000 parts per million (ppm)
Total Alkalinity	1,000 ppm
Silica (SiO_2)	100 ppm
Chlorine (Cl^-)	250 ppm
Conductivity (TDS)	2,000 µS/cm

Equation 3 and Equation 4 on page 3 can also be used to determine if there is a leak, overflow, or excessive drift. Since the equations assume that the water lost to drift and overflow is negligible, if cycles of concentration are calculated using both equations, and the results from Equation 4 are higher than that from Equation 3 by more than 10 percent, the cooling tower might be losing water due to one of these malfunctions.

As discussed previously, approximately 1.8 gallons of water are evaporated for every ton-hour of cooling, regardless of tower efficiency. However, the quantity of blowdown (and subsequently make-up water) is dependent on the tower's cycles of concentration. As shown in Figure 2 on page 5, the greater the cycles of concentration, the less blowdown is required.

[1] U.S. Green Building Council. Cooling tower water management (WEc5). www.usgbc.org/credits/we5

Figure 2. Cooling Tower Water Use per Ton-Hour Cooling (gallons)



Property managers can also consider alternative sources of water, such as condensate from air conditioners or rainwater, for cooling tower make-up to significantly reduce the demand for potable water. This is explained in more detail in the Retrofit and Replacement Options section below.

Boiler and Steam Systems

Boiler and steam systems can be used in multifamily properties for space and water heating. Hot water boilers are used to provide hot water for bathing, laundry, dishwashing, or similar operations. Hot water boiler distribution systems can be open or closed. Open systems provide hot water to end uses, such as bathing and laundry, and closed systems are used for building heating. Because water efficiency isn’t a primary concern for hot water boiler systems, they are not discussed in this section.

Steam boilers, such as water-tube boilers or fire-tube boilers, generate steam by burning fuel (i.e., gas or oil) and indirectly or directly heating water within the boiler system, thus generating steam. As steam is distributed throughout the property, its heat is transferred to the ambient environment and, as a result, condenses to water. This condensate is either discharged to the sewer or captured and returned to the boiler for reuse. If the condensate is discharged to the sanitary sewer, most codes require it to be cooled to an acceptable temperature before discharging (usually between 120°F and 140°F). The hot condensate is typically tempered with cool water to meet the temperature discharge requirements.

Some properties might have access to a steam utility or district steam. Ensuring that there are no onsite leaks in these instances will conserve water within the system and reduce utility costs for steam.

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 few to no additional TDS to the boiler water.
- Saves energy, since the hot condensate being returned to the boiler requires much less energy to reheat to produce steam again.

If you obtain steam from a steam utility or district steam, condensate recovery and return is likely cost prohibitive. Instead, identify whether there are opportunities for onsite reuse of condensate.

Similar to how TDS build up in a cooling tower as water is evaporated, TDS also accumulate in the boiler system as water is converted to steam. If the concentration of TDS gets too high, the TDS can cause scale to form or can lead to corrosion, causing boiler inefficiency or malfunction. As with cooling towers, the concentration of TDS is controlled by blowing down a portion of the water within the steam system. Some boiler operators practice continuous blowdown by leaving the blowdown valve partially open, requiring a continuous feed of make-up water (and potentially a continuous stream of tempering water as well for sewer discharge). This practice can waste a lot of water and subsequently energy, since the water being sent down the drain is hot water at near boiling temperatures.

Proper control of boiler blowdown water is 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 poor quality with high concentrations of TDS. Work with a trained water treatment vendor to identify your boiler's ideal operating conditions and to establish a management approach that minimizes water and chemical use.

The amount of make-up water required for a boiler is based on the condensate lost from the system and the amount of blowdown.

Equation 5. Boiler or Steam System Make-Up Water Use (gallons)

Boiler Water Use (Make-Up) = Condensate Losses + Blowdown

Understanding Mechanical System Water Use

In order to evaluate mechanical system improvements and their associated savings, it is important to first understand how much water is being used.

Dedicated make-up and blowdown meters can track cooling tower and boiler water use and allow property managers to document actual savings. Installing and monitoring a dedicated meter or submeter for properties' cooling tower and boiler make-up and blowdown lines is by far the most effective way of determining mechanical system water use and verifying if the desired cycles of concentration are occurring in each system.

For cooling towers in particular, there are several other methods that can be used to estimate water use, if a submeter is not an option for your property. However, they are less accurate.

These calculation methods provide approximations of cooling tower water use and suggest the magnitude of potential savings. Remember that all of the components of the cooling tower system must be optimized in tandem in order to realize maximum water savings and efficient operation. Additionally, human behavior plays an important role in minimizing water use; property managers, operations staff, or water treatment vendors should identify and quickly repair leaks, regularly monitor meters and controllers, and verify cycles of concentration.

Seasonal Comparison

By comparing the amount of water used during the actual cooling season to other times of the year, you can determine the amount of water used in a cooling tower throughout the year. For example, if you only operate your cooling towers from April through September, monthly water use should be higher in those months and lower/more constant from October through March. The difference between those two periods will be approximately equal to your property's total annual cooling tower water use.

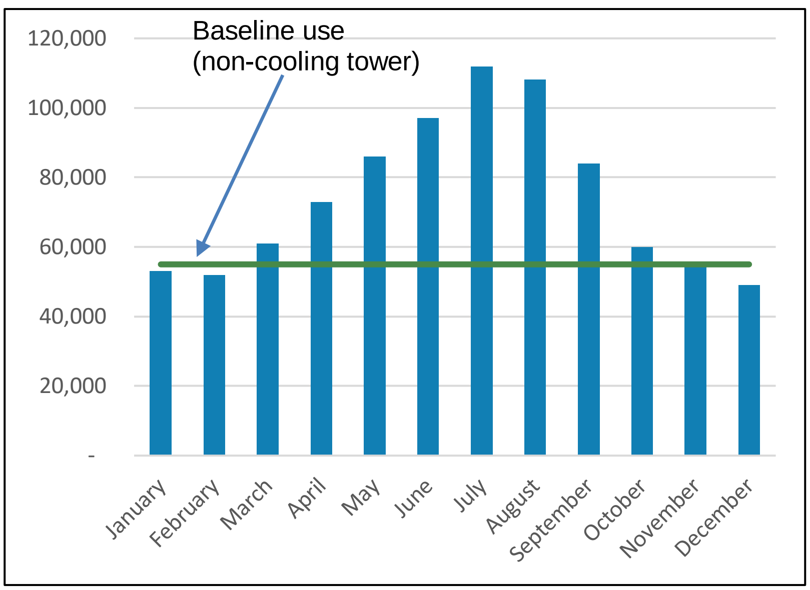
Note, however, that if other sources use water seasonally (e.g., landscape irrigation in the summer), this method may be less effective, as distinguishing between seasonal uses is impossible using billed water use information alone.

Example:

Table 2 represents water usage data for a sample property, pulled from monthly water utility bills. This information is illustrated in Figure 3 to the right of Table 2.

Table 2. and Figure 3. Example Monthly Property Water Use

Month	Water Use (gallons)
January	53,000
February	52,000
March	61,000
April	73,000
May	86,000
June	97,000
July	112,000
August	108,000
September	75,000
October	60,000
November	55,000
December	49,000
Total	890,000



In this example, a property's cooling tower operates April through September. To determine the property's baseline (non-seasonal) water use, average the monthly water use from the non-cooling months (October through March), which provides an estimated monthly baseline water use rate of 55,000 gallons. Therefore, estimated annual water use without a cooling tower is equal to:

55,000 gallons/month x 12 months = 660,000 gallons per year

To estimate cooling tower water use, subtract this estimated annual baseline water use from the metered total presented in Table 2.

890,000 gallons/year – 660,000 gallons/year = 230,000 gallons used for irrigation per year

If you have other seasonal water uses (e.g., landscape irrigation), but have a separate submeter that monitors the water used for these systems, you can subtract the submetered water used by these other sources from the total seasonal water use estimated from this method. In this example, if the irrigation system operates during a similar season (April through September) and the dedicated irrigation submeter indicated 80,000 gallons used for the year, subtract that amount from the 230,000 gallons of seasonal water use.

230,000 gallons – 80,000 gallons = 150,000 gallons use for cooling tower make-up per year

This same methodology can be used regardless of the cooling season in your area. Simply average the monthly water use across the number of months that the property is not utilizing its cooling towers. Then follow the same steps to estimate your seasonal water usage.

Electric Power Use

If your property's chiller has a dedicated electric meter (not associated with other equipment such as pumps and fans), you can determine its annual energy use. Using the chiller's rated efficiency (kWh per ton hour), you can deduce the number of ton-hours of cooling that your chiller has provided throughout the year. Per the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), cooling tower tons are approximately equal to 1.25 times the chiller tons, since ancillary equipment such as pumps and fans contribute additional heat load. Therefore, if chiller tons are known, that tonnage should be multiplied by 1.25 to obtain cooling tower tons.

Example:

An electric meter indicates the chiller system used 600,000 kWh in one year, and the chiller is rated at 0.5 kW per ton (based on the chiller nameplate or other product literature on the chiller). Therefore, cooling ton-hours for the system are expressed as follows:

Total chiller ton-hours = 600,000 kWh ÷ 0.5 kW per ton = 1,200,000 ton-hours

Chiller tons need to be converted into cooling tower tons by multiplying by 1.25.

1,200,000 chiller ton-hours x 1.25 = 1,500,000 cooling tower ton-hours

Using Figure 2 on page 5, you can determine your cooling tower's water usage based on your annual cooling tower ton-hours and your tower's cycles of concentration. For example, if your cycles of concentration are currently 2.5, then 3.0 gallons of make-up water are required for each ton-hour. Therefore, your cooling tower's total water use would be:

3.0 gallons per ton-hour x 1,500,000 cooling tower ton hours = 4,500,000 gallons

Chiller Tonnage

To estimate daily water use for a cooling tower, you will need the tonnage of your chiller (likely found on the chiller's nameplate) and the cooling tower cycles of concentration. Table 3 provides daily water use for a cooling tower system that operates a full load for 24 hours per day, based on chiller tonnage and cooling tower cycles of concentration.[2]

Table 3. Estimated Daily Water Use at Full Chiller Load

	Cooling Tower Cycles of Concentration					
Chiller Tonnage (Nameplate)	3	4	5	6	7	8
100	5,480	4,930	4,660	4,380	4,380	4,110
200	10,960	9,860	9,320	8,770	8,490	8,490
400	21,920	19,730	18,360	17,530	17,260	16,710
500	27,400	24,380	23,010	21,920	21,370	21,100
600	33,150	29,320	27,400	26,580	25,750	25,210
800	44,110	39,180	36,710	35,340	34,250	33,700
1,000	55,070	49,040	46,030	44,110	42,740	41,920
1,500	82,740	73,420	68,770	66,030	64,380	63,010
2,000	110,140	97,810	91,780	88,220	85,480	83,840
2,500	137,810	122,470	114,790	110,140	107,120	104,930
3,000	165,210	146,850	137,810	132,330	128,490	126,030
3,500	192,880	171,510	160,550	154,250	149,860	146,850
4,000	220,270	195,890	183,560	176,160	171,510	167,950
5,000	275,340	245,480	229,590	220,270	214,250	209,860

The water use levels presented in Table 3 are for 24-hour operations at full load. Most systems do not operate under these conditions, operating either at less than 24 hours per day or at a reduced load. Therefore, you will need to incorporate the number of hours and load that your system operates throughout the year. This can be done by prorating the full load value in the table. Divide the typical daily operating hours by 24 and multiply this number by the full load value in the table.

Example:

A cooling tower operates at three cycles of concentration, rejecting heat from a 500-ton chiller that typically operates at approximately 50 percent of full load for 18 hours per day. The full load daily water use from Table 3 is 27,400 gallons per day. The daily water use can be calculated:

[2] U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Federal Energy Management Program (FEMP). Estimating Methods for Determining End-Use Water Consumption. energy.gov/eere/femp/estimating-methods-determining-end-use-water-consumption

Full load water use (27,400 gallons) x (0.50 full load) x (18 hours ÷ 24 hours)
= 10,275 gallons per day

Consider performing these calculations for each month of the year separately, since the load on the cooling tower will likely vary depending on weather. For example, a cooling tower may have a 40 percent load in May and an 80 percent load in August. Add each month's estimated water use together to estimate your property's annual cooling tower water use.

Maintenance Best Management Practices

Performing periodic inspections of your mechanical systems will help keep equipment working and catch water waste before it impacts your water bill. Aim to conduct inspections at least monthly. Each system type has certain common issues to examine and verify. Table 4 provides a summary of inspection items that should be performed periodically.

Table 4. Mechanical System Operation and Maintenance Tips

System Type	Tip	Why
Single-pass cooling	Check system specifications to determine the minimum water flow rate required for cooling. If you have a solenoid valve that shuts off single-pass cooling water when the equipment is turned off, regularly check operation of the valve to make sure water is only flowing when heat needs to be removed (i.e., when the equipment is running).	A piece of equipment that requires 1 gallon per minute (gpm) of water for cooling uses 525,000 gallons of water annually and costs a facility nearly $5,800 per year at average water and wastewater rates.[3]
Cooling towers	Implement a comprehensive maintenance program for your cooling tower systems. • Clean coils, heat exchangers, and condensers of any scale, biological growth, or sediment. • Inspect insulation on chilled water piping and, where missing, install new insulation.	Maintaining system energy efficiency and ensuring heat transfer can occur unimpeded by scale and sediment will also improve the water efficiency of your cooling towers.
Cooling towers	Have operations and maintenance personnel read the conductivity meter and the make-up and blowdown flow meters regularly and log readings. Check the make-up and blowdown valves to make sure they cut off the flow of water cleanly to minimize wasted water from leaks.	Keeping a detailed log of make-up and blowdown quantities, conductivity, and cycles of concentration and monitoring trends can help to quickly identify problems and deterioration in performance.
Cooling towers and boiler systems	Cooling tower and boiler systems should be monitored and maintained by a professional water treatment vendor. Choose a vendor that can minimize water use, chemical use, and cost, while maintaining appropriate water chemistry for efficient scale and corrosion control. Property managers should read and understand the water chemistry reports that are provided by the water treatment vendor when they evaluate the water chemistry of your cooling tower(s) and boiler(s). Make sure the system characteristics (e.g., conductivity, pH, cycles of concentration) are within your target range.	Proper cleaning, maintenance, and inspections are critical to the health and safety of building occupants and the continued effectiveness of the cooling tower or boiler system. These efforts can also encourage water and energy efficiency.

[3] Estimated cost of water loss based on an average residential rate of $11.02 per 1,000 gallons for water and wastewater determined from data in American Water Works Association (Raftelis Financial Consulting), Water and Wastewater Rate Survey (2016).

Table 4. Mechanical System Operation and Maintenance Tips

System Type	Tip	Why
Boiler and steam systems	Regularly check steam traps and steam and hot water lines for leaks. Implement a boiler tune-up program on a quarterly or annual basis to maintain system efficiency.	In a steam system that has not been maintained for three to five years, the Department of Energy (DOE) estimates that between 15 and 30 percent of steam traps have failed—thus allowing steam to escape the system.[4]
Boiler and steam systems	Use a handheld conductivity meter so that boiler blowdown can be initiated only once the conductivity exceeds its target range. Better yet, install a permanent conductivity meter that automatically controls blowdown.	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.
Boiler and steam systems	When condensate is discharged to the sanitary sewer, most codes require it to be cooled to an acceptable temperature (usually between 120°F and 140°F) before discharging. The hot condensate is typically tempered with cool water to meet the temperature discharge requirements. Install and maintain a thermostatic valve that only applies tempering water when the effluent exceeds the specified setpoint temperature. Check valves periodically to make sure they're only flowing when steam blowdown is occurring or condensate is draining.	Installing a thermostatic valve eliminates the constant flow of tempering water.
Boiler and steam systems	During summer months, consider shutting down boiler systems that are primarily used for space heating. If you have multiple boilers that provide hot water and/or space heating, shift the heating load as necessary to optimize the most efficient boilers under certain operating conditions.	Shutting down your boiler system will reduce the water and energy required to maintain the system in standby mode. Annual maintenance and tune-ups can also be conducted during this time.

Retrofit and Replacement Options

Replacing a cooling tower, boiler system, or other mechanical system can be a big undertaking and requires significant capital investment; however, there are many cost-effective retrofit and replacement options that can reduce water use and operating costs in the long run.

Single-Pass Cooling

If you have equipment that uses single-pass cooling water, the most effective way to reduce mechanical system water use is to replace this equipment with air-cooled models. If considering air-cooled equipment as a replacement, evaluate the potential energy use of the equipment to ensure that increased energy use does not offset water cost savings. However, with rising water and wastewater costs, cost savings can often be achieved.

If you can't eliminate single-pass, water-cooled equipment, consider modifying it to minimize water used for cooling. Options to consider include:

[4] DOE Advanced Manufacturing Office. Energy Tips: STEAM. Inspect and Repair Steam Traps. www.energy.gov/sites/prod/files/2014/05/f16/steam1_traps.pdf

- **Modify equipment to recirculate the cooling water.** This can be achieved by installing a closed-loop recirculation system that will reuse the water instead of discharging it. The recirculation system can be connected to a dedicated air-cooled, point-of-use chiller or other heat sink that can reject heat so that the cooling water can be reused.
- **Install a solenoid valve.** A solenoid valve can shut off single-pass cooling water when the equipment is turned off or when there is no heat load present.

Cooling Towers and Boilers

Recommended retrofit options for cooling towers and boilers are similar. Installing meters, improving controls, and supplying the systems with high quality water will help improve water efficiency and allow you to better manage your system. More information is provided below.

Cooling tower make-up meter.

- **Install flow meters on make-up and blowdown lines,** if not already present. Regularly monitor and record meter readings so you can identify trends. Consider connecting meters to a building automation system or building management system so that meter readings are automatically recorded and can alert you to any spikes in water use. Contact your local water or wastewater utility to determine if installing a blowdown meter could make you eligible to receive a sewer charge deduction, since water that is evaporated is not being sent to the sewer.
- **Install a conductivity controller to automatically control blowdown.** Conductivity controllers continuously measure the conductivity of the cooling tower or boiler water and will initiate blowdown only when the conductivity set point is exceeded. Working with your water treatment vendor, determine the maximum cycles of concentration that the cooling tower and boiler can sustain without risk of scale buildup or corrosion, then program the conductivity controller to the associated conductivity set point necessary to achieve that number of cycles.
- **Automate chemical feed systems.** In addition to controlling blowdown based on conductivity, an automated chemical feed system can also regulate chemicals (e.g., biocides, scale inhibitors, corrosion inhibitors) that are being added to your cooling tower or boiler system.
- **Talk to your water treatment vendor about pretreatment or side-stream filtration.** To increase cycles of concentration, consider pretreating make-up water to remove or neutralize minerals and impurities. Potential pretreatment technologies include water softeners, water conditioners, reverse osmosis systems, or demineralization. As an alternative for cooling towers, install a rapid sand filter or high-efficiency cartridge filter on a side stream taken from the cooling tower basin. This system can filter out sediment and minerals from the basin water.
- **Install a condensate recovery system.** For steam boilers, condensate can be recovered and returned to the boiler for reuse. This feature can save substantial water and energy. Not only is less boiler make-up water needed, but because less condensate is being sent to the sewer, tempering water is also reduced.

Another opportunity to reduce water used within your mechanical systems is to utilize appropriate onsite alternative water sources as cooling tower or boiler make-up water. Collecting and reusing condensate from air conditioners or rooftop rainwater are likely the most suitable retrofit options for sourcing alternative water, particularly if your property doesn't already have a graywater system installed.

- **Condensate from air conditioning equipment:** Condensate is generated when water vapor comes in contact with an air conditioner's cooling coils, and is commonly discharged to a drip pan or directly to a floor drain. Condensate from air conditioning equipment is high quality, cold water that is free of minerals and TDS, making it ideal to use as cooling tower make-up water. Even better, condensate from air conditioners is generated in the highest volumes during period of high cooling loads, which mirrors times when cooling towers are operating the most. Typically, condensate can be fed directly into the cooling tower basin as make-up water without any treatment, but work with your water treatment vendor to see if they have any concerns with this approach. To determine whether condensate capture is a viable in your area, review the Federal Energy Management Program (FEMP) Condensate Capture Potential Map.[5]

- **Rainwater:** Rainwater that runs off rooftops is typically high quality, making it suitable for many end uses, including cooling tower make-up, boiler make-up, and irrigation. Rainwater can be collected from gutters or roof drains into a storage cistern. Gutter screens should be used to remove debris. Similar to condensate, talk to your water treatment vendor about whether water treatment is necessary before directing collected rainwater to your cooling tower or boiler. To determine rainwater harvesting potential in your area, review the FEMP Rainwater Availability Map.[6]

Storage tanks for rainwater collected from roof drains.

If you are in the market for a replacement cooling tower or boiler, first implement energy efficiency measures to reduce cooling and heating loads, respectively. This may make it feasible to reduce the size of your cooling tower or boiler, saving money on both the initial purchase and on operating expenses and improving system energy and water efficiency.

For a new cooling tower, include the following features in your set of requirements.

- Make-up and blowdown meters (if they're not already installed in your property).
- Conductivity controller and/or automated chemical feed system.
- Drift eliminators that reduce water losses to less than 0.005 percent of the cooling tower flow rate.
- Overflow alarm.

[5] DOE EERE FEMP. Condensate Capture Potential Map. energy.gov/eere/femp/condensate-capture-potential-map
[6] DOE EERE FEMP. Rainwater Availability Map. energy.gov/eere/femp/rainwater-availability-map

These features are required by most building and plumbing codes and standards, but regardless, are encouraged for all new installations to facilitate efficient operation and management of cooling towers.

For a new boiler system, consider installing multiple small boilers instead of one or two large boilers. Multiple small boilers offer reliability and flexibility to meet boiler load fluctuations without compromising efficiency. This also helps limit boiler “short cycling,” which occurs when an oversized boiler quickly satisfies space heating demands, and then shuts down until heat is again required. Boilers operate more inefficiently when short cycling occurs or when the boiler has a low firing rate.[7]

Water Savings Calculations and Assumptions

The following calculations can be used to estimate water savings from improving the operation of heating and cooling systems. Some calculations will utilize submeter information or water use estimates that you’ve previously prepared based on the Understanding Mechanical System Water Use section of this guide.

Single-Pass Cooling

Water used for single-pass cooled equipment can be eliminated by replacing existing equipment with a recirculating system or replacing it with air-cooled equipment. Potential savings from replacing existing single-pass-cooled equipment with air-cooled equipment can be estimated by measuring the existing cooling water discharge with a bucket and a stop watch and determining how often the cooling water flows (e.g., how many hours per day, how many days per week). In many applications, single-pass cooling water flows continuously. To estimate potential water savings, use Equation 6.

Equation 6. Water Savings From Eliminating Single-Pass Cooling (gallons per year)

☐	X	☐	X	☐	X	☐	X	☐	=	☐
Flow Rate (gpm)		Runtime (minutes/hour)		Hours per Day		Days per Week		Weeks per Year		Total Annual Water Use (gallons)

If single-pass cooling is eliminated by replacing equipment with air-cooled models, a property may see an increase in energy usage. The increased energy use, depending on how significant, may increase the payback time and decrease replacement cost-effectiveness.

[7] DOE Advanced Manufacturing Office. Energy Tips: STEAM. Minimize Boiler Short Cycling Losses. energy.gov/sites/prod/files/2014/05/f16/steam16_cycling_losses.pdf

Cooling Towers

Significant water savings can be achieved by improving the cooling tower management approach and by maximizing cooling tower cycles of concentration. Table 5 shows the percentage of make-up water savings that can be expected by increasing a cooling tower's cycles of concentration. For example, increasing cycles of concentration from three to six can reduce water use by 20 percent. To estimate water savings from improving cycles of concentration in cooling towers, use Equation 7.

Equation 7. Water Savings From Increasing Cooling Tower Cycles of Concentration (gallons per year)

	X		=	
Annual Cooling Tower Water Use (gallons)		Percent Savings Based on Increased Cycles of Concentration		Gallons Saved per Year

Table 5. Percent of Cooing Tower Make-Up Water Saved by Maximizing Cycles of Concentration

		2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	10.0
	1.5	33%	44%	50%	53%	56%	58%	60%	61%	62%	63%	64%
	2.0	–	17%	25%	30%	33%	38%	40%	42%	43%	44%	45%
	2.5	–	–	10%	16%	20%	25%	28%	30%	31%	33%	34%
	3.0	–	–	–	7%	11%	17%	20%	22%	24%	25%	26%
	3.5	–	–	–	–	5%	11%	14%	17%	18%	20%	21%
	4.0	–	–	–	–	–	6%	10%	13%	14%	16%	17%
	5.0	–	–	–	–	–	–	4%	7%	9%	10%	11%
		–	–	–	–	–	–	–	3%	5%	6%	7%

Boilers

Switching to an automatic control system (i.e., conductivity controller) can reduce a boiler's energy use by 2 to 5 percent and reduce blowdown by as much as 20 percent. To estimate water savings, use Equation 8.

Equation 8. Boiler Water Savings From Installing a Conductivity Controller (gallons per year)

[ ]	X	20%	=	[ ]
Annual Boiler Water Use (gallons)		Percent Savings		Gallons Saved per Year

Additional Resources

Alliance for Water Efficiency. Resource Library. Condensate Water Introduction.
www.allianceforwaterefficiency.org/Condensate_Water_Introduction.aspx

Alliance for Water Efficiency. Resource Library. Introduction to Cooling Towers.
www.allianceforwaterefficiency.org/cooling_tower_intro.aspx

U.S. Department of Energy (DOE) Advanced Manufacturing Office Resources:

Energy Tips: STEAM. Inspect and Repair Steam Traps.
www.energy.gov/sites/prod/files/2014/05/f16/steam1_traps.pdf

Energy Tips: STEAM. Minimize Boielr Short Cycling Losses.
energy.gov/sites/prod/files/2014/05/f16/steam16_cycling_losses.pdf

DOE Office of Energy Efficiency and Renewable Energy (EERE) Federal Energy Management Program (FEMP) Resources:

Best Management Practice #8: Steam Boiler Systems.
energy.gov/eere/femp/best-management-practice-8-steam-boiler-systems

Best Management Practice #9: Single-Pass Cooling Equipment.
energy.gov/eere/femp/best-management-practice-9-single-pass-cooling-equipment

Best Management Practice #10: Cooling Tower Management.
energy.gov/eere/femp/best-management-practice-10-cooling-tower-management

Condensate Capture Potential Map.
energy.gov/eere/femp/condensate-capture-potential-map

Cooling Towers: Understanding Key Components of Cooling Towers and How to Improve Water Efficiency. DOE/PNNL-SA-75820. February 2011.
energy.gov/eere/femp/downloads/cooling-towers-understanding-key-components-cooling-towers-and-how-improve-water

Rainwater Availability Map.
energy.gov/eere/femp/rainwater-availability-map

EPA's WaterSense program. *WaterSense at Work. Best Management Practices for Commercial and Institutional Facilities.*
www.epa.gov/watersense/best-management-practices

Appendix A: Summary of Water Efficiency Measures and Savings

This appendix can be used to summarize water efficiency measures, upgrades, and projects that are identified at your property, based on a water assessment and/or review of this Water Efficiency Management Guide.

Summary of Water Efficiency Measures and Savings

Item Number	Location	Measure or Project Name and Description	Projected Annual Water Savings (gallons)	Projected Annual Water, Wastewater, and Energy Cost Savings ($)	Total Measure or Project Cost ($)	Simple Project Payback (years)
Example	*Cooling tower*	*Work with cooling tower water treatment vendor to increase cycles of concentration for 2.5 to 4.*	*240,000 gallons*	*Water Cost Savings: $2,640*	*Included under current contract agreement.*	*N/A*
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						