Green Proving Ground

ALTERNATIVE WATER TREATMENT FOR COOLING TOWERS

GSA WATER CONSERVATION GUIDANCE

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This report expands upon GPG 044: GSA Guidance—Alternative Water Treatment Systems for Cooling Towers by Jesse Dean, Gregg Tomberlin, and Andrea Silvestri

Contents

AWT Guidance

Appendices

AWT Overview

Use this guide to assess and select an AWT system for your facility.

Cooling towers are responsible for some of the largest potable water loads in commercial office buildings. Traditional chemical-based cooling tower water treatment systems routinely flush, or "blowdown," as much as half of cooling tower water to control mineral buildup. Alternative water treatments (AWT) for cooling towers use different methods to control scale and can reduce both water and chemical use.

About 80% of the floor space in federally owned facilities under GSA's jurisdiction, custody, and control is conditioned by chilled water plant cooling towers. In light of rapidly escalating water costs and mandated water-reduction targets, the GSA Green Proving Ground (GPG) program evaluated seven AWT technologies, most of which rely on proprietary technology offered by individual vendors. This document provides guidance on selecting, installing, and operating AWT systems and summarizes the findings from the GPG program evaluations.

Drivers for Reducing Water Use

Cooling tower water consumption represents, on average, 28% of the water use in commercial buildings.[1]

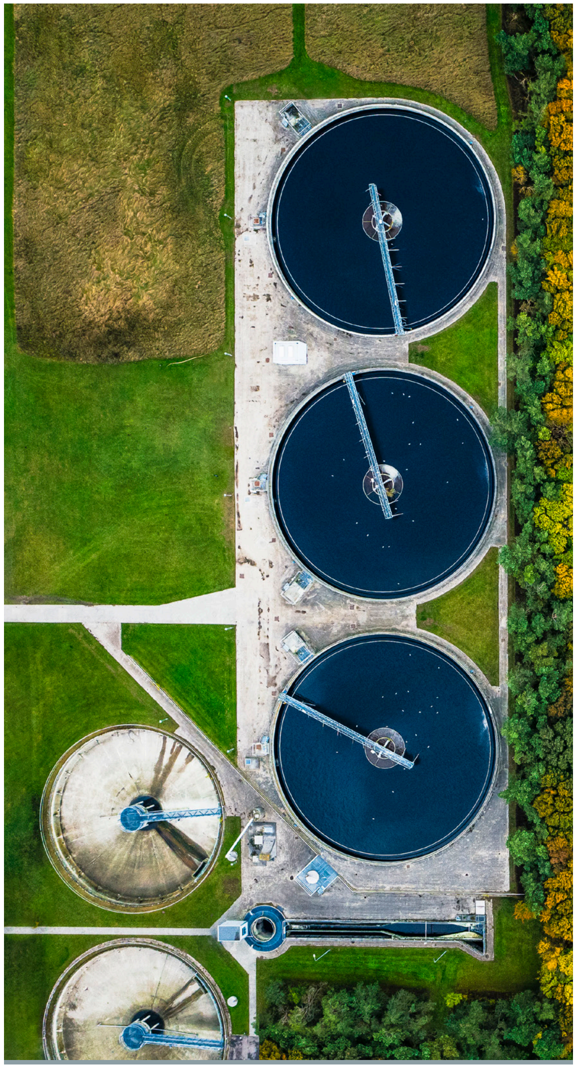
Water Cost

Water rates have increased more rapidly than any other utility for GSA. In the past 10 years, they have increased more than 40%. The average combined GSA water/sewer rate in 2023 was $18.41/kgal, but regional averages range from $9.53/kgal in the Rocky Mountain Region (Region 8) to $25.83/kgal in the National Capital Region (Region 11).

The Federal Emergency Management Program (FEMP) report, *Water and Wastewater Annual Price Escalation Rates for Selected Cities Across the United States: 2023 Edition*, provides water and wastewater annual price escalation rates from utilities throughout the United States. Across the entire survey, the average price escalation rate for water was 4.0% annually; the highest escalation rate was 8.8%. The average annual price escalation rate for wastewater was 3.2%, with the highest escalation rate reported at 10.2%. This report recommends that the preferred source for forecasting annual water and wastewater price escalation rates is the local water or wastewater utility—as infrastructure projects often drive large variances in price escalations across water and sewer service providers.

Varied water costs across cities result in significantly different outcomes. For example, cities with high water rates can generate the largest cost savings despite not conserving the most water. The Potential Water and Cost Savings with AWT section further explores cost savings potential and modeled water savings across the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) climate zones.

[1] Gregg Tomberlin, Jesse Dean, Jimmy Salasovich (NREL), *Electrochemical Water Treatment for Cooling Towers*, December 2018, 9.



Greenhouse Gas Emissions

Water and wastewater systems generate greenhouse gas (GHG) emissions to source, treat, and distribute water.

The Carbon Footprint of Water report, funded by The Energy Foundation, calculates that in the U.S., emissions from water use represent 5% of all carbon emissions.

CDP's *Global Water Report 2022* estimates that global water use, storage, and distribution contribute 10% of worldwide carbon emissions.

Resilience

Using less water improves resilience. Because of water shortages, many parts of the country are facing water restrictions that are forecasted to continue or worsen in the future. Installing more water-efficient equipment, metering water by use type, and developing and maintaining a water management plan are all part of effective resilience.

Water resilience resources:

- Water Vulnerability Assessment Tool
  FEMP
- Aqueduct Water Risk Atlas
  World Resources Institute
- U.S. Monthly Drought Outlook
  NOAA
- Technical Resilience Navigator
  FEMP, PNNL, NREL

Sustainability Goals & Mandates

Federal buildings are subject to mandated water savings and reduction goals and requirements. Such mandates include:

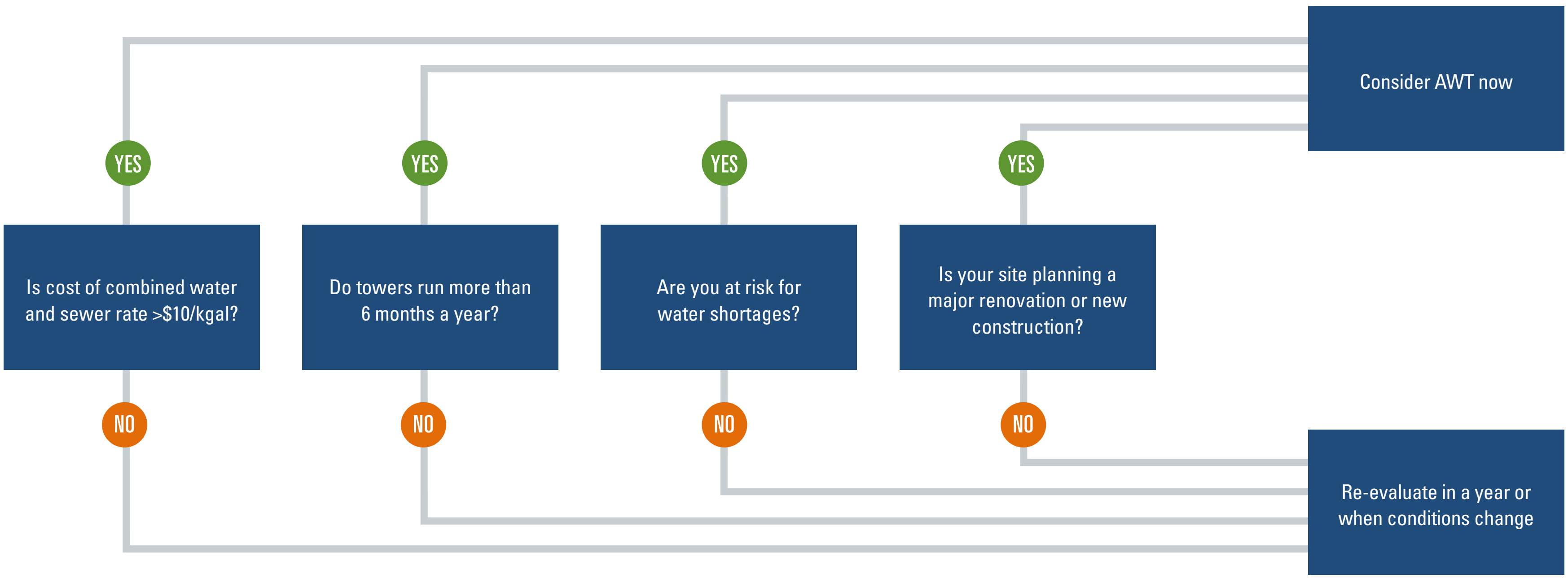
Energy Independence and Security Act of 2007 (EISA), section 432, which amended the National Energy Conservation Policy Act (42 U.S.C. § 8253) to include the "[u]se of energy and water efficiency measures in federal buildings" and mandates the following for facility energy managers:

- **Energy and Water Evaluations:** Complete a comprehensive energy and water evaluation annually for approximately 25% of facilities and ensure each facility is evaluated at least once every 4 years.
- **Implementing Energy and Water Efficiency Measures:** No later than 2 years after completing each evaluation, implement any life cycle cost-effective energy- or water-saving measure identified in the evaluation and bundle individual measures of varying paybacks together into combined projects.
- **Implementation Followup:** Ensure energy and water savings are measured and verified.

Executive Order 14057: Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability, 2021 requires agencies to establish targets to reduce potable water use intensity by 2030.

Figure 1
When to Consider an AWT System

The questions shown in the flowchart in Figure 1 can help determine if an AWT system will be cost-effective for your facility. If you answer yes to any question, consider an AWT system now. If you answer no, reevaluate in a year or when conditions change.



Cooling Tower Considerations

Many multistory commercial buildings > 200,000 ft^2 rely on a central chilled water plant and cooling towers for air conditioning. Open-loop cooling towers reject heat into the atmosphere through evaporation. As water is evaporated, minerals and chemicals become concentrated in the remaining water, which can lead to accelerated scale (i.e., mineral deposits) and corrosion.

The typical approach to controlling scale, corrosion, and biological growth combines chemical treatment, monitoring, and blowdown—discharging water to the sewer from the bottom of the cooling tower basin, where dissolved solids are most concentrated. Makeup water is introduced to dilute the remaining solids and chemicals and replace water lost through blowdown and evaporation.

For more information, see:

Best Management Practice Cooling Tower Management (FEMP)

Report: Side Stream Filtration for Cooling Towers (FEMP/PNNL,10-2012)

Fact Sheet: Side Stream Filtration for Cooling Towers (FEMP/PNNL,10-2012)

Understanding Cooling Towers and How to Improve Water Efficiency (FEMP, 02-2011)

Measurements Required to Calculate Water Savings

Cooling tower water use depends on three factors: make-up water, evaporation, and blowdown. Typical water-related costs include makeup water due to evaporation losses and blowdown, and blowdown discharge. Use and discharge are usually combined as a single fee. It's important to measure the flow rates of makeup water entering the system and blowdown water leaving the system, using flow meters on both lines. See the section on Measuring AWT Performance for more information.

Figure 2 shows the key measurements used to verify cooling tower water savings:

- Makeup water consumption
- Blowdown water consumption
- Conductivity* of makeup and blowdown water

*Conductivity is a measurement of the water's ability to conduct electricity and a relative indication of the total dissolved mineral content of the water. Higher conductivity levels correlate to more dissolved salts in solution. Purified water has very little dissolved minerals present, meaning the conductivity will be very low. (*Understanding Key Components of Cooling Towers and How to Improve Water Efficiency*, Federal Energy Management Program)

Measuring Cycles of Concentration

Cycles of concentration (CoC) describes the mass relationship between the amount of makeup water and the amount of blowdown discharged to the drain. CoCs are the most common metric used to represent water efficiency in cooling towers; high CoCs are related to low levels of blowdown, and low CoCs are related to high levels of blowdown.

Two common ways of measuring CoC are using water balance and conductivity:

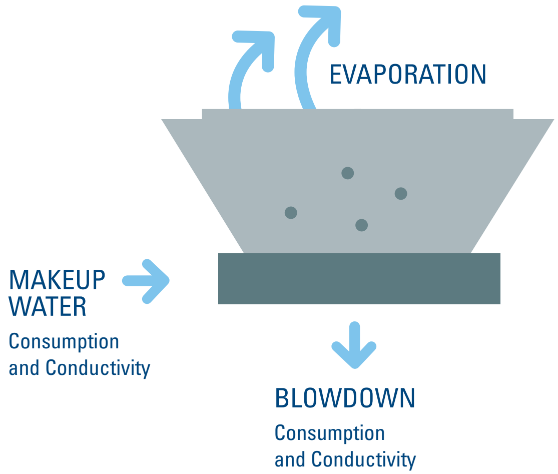
CoC Water Balance =
Makeup / Blowdown

CoC Conductivity =
Blowdown Conductivity / Makeup Conductivity

The CoC Water Balance method is recommended to measure water savings before and after the deployment of AWT systems to properly capture the net effects. Some AWT systems treat water between the makeup input and blowdown output stages, so using the CoC Conductivity method does not correctly capture the impact.

Measuring changes in the makeup water's conductivity is important to determine whether the realized water savings are due to the AWT system or to a change in the quality of the supplied makeup water.

Figure 2
Measurements for Cooling Tower Water Use



Majority of Water Savings Captured by CoC of 10

Typically, CoCs for GSA facilities using traditional chemical water treatment are between 3 and 6, indicating that a relatively high volume of cooling tower makeup water consumption is used for blowdown. Water savings from reducing blowdown and increasing the CoC is nonlinear; most of the makeup water savings come from increasing CoCs from 3 to 10. Increasing CoCs beyond 10 provides diminishing water savings as depicted in Figure 3.

Tower Performance is Location-Specific

Incoming water quality variables, such as hardness, total dissolved solids (TDS), alkalinity, conductivity, seasonal changes to water quality, airborne particulate matter, and local insect populations, all impact cooling-tower water treatment system strategies and effectiveness. These factors influence biological growth levels, scaling, and corrosivity.

Water Savings are Site-Specific

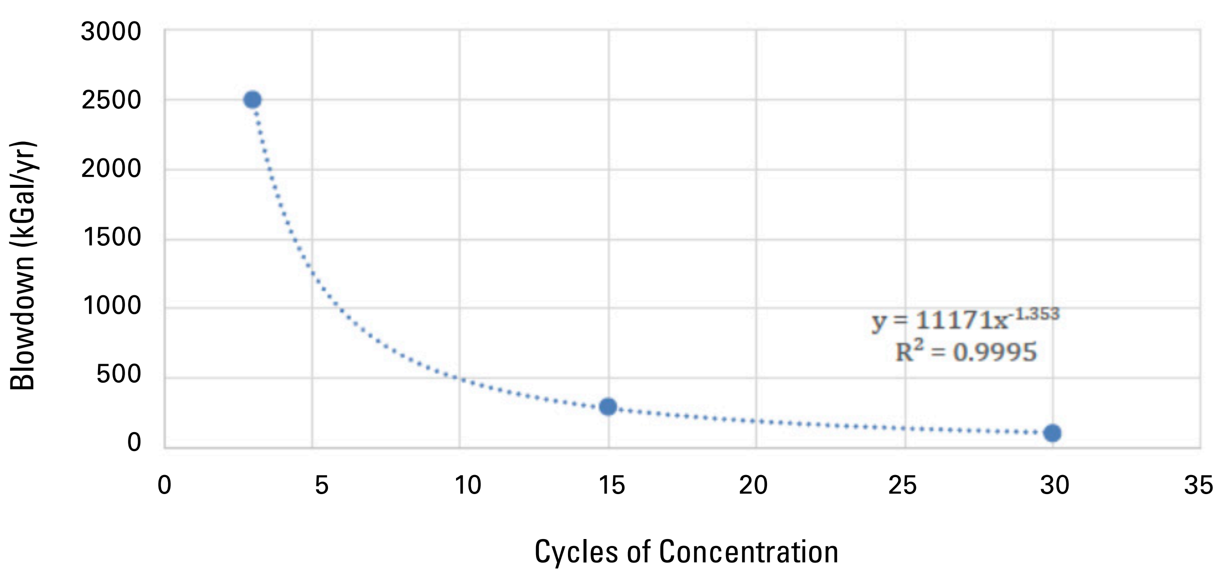
Sites in hot climates with long cooling seasons and long cooling tower run times will typically have the largest water savings. Water quality also impacts performance. Locations with excessively hard water, high pH, or high TDS typically operate at lower CoCs, use more water treatment chemicals, and will have the greatest opportunity for savings.

Biofilm in Conjunction with Scale Impacts Efficiency

In addition to scale, biofilms have a significant impact on heat-transfer efficiency. The high water content in biofilms creates an insulating layer that inhibits energy transfer to a much greater degree than mineral scale alone. All AWT systems need to adequately control and reduce biological growth.

Figure 3

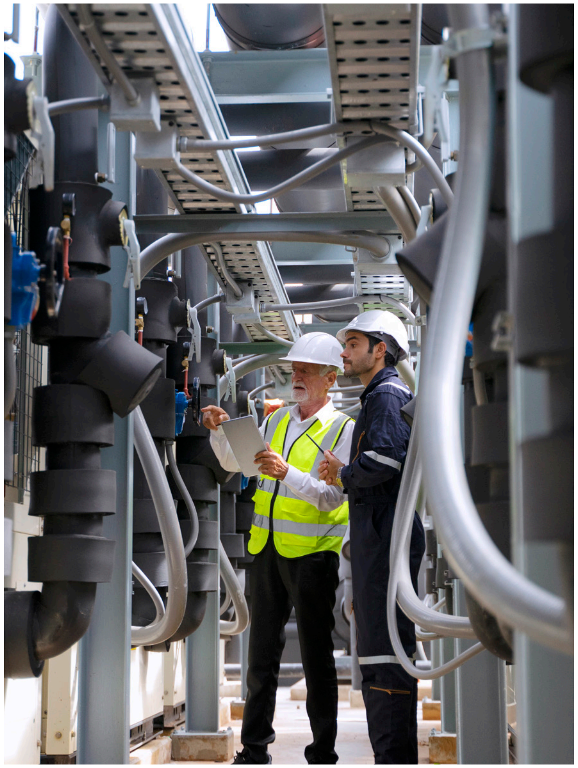
Modeled Blowdown vs. CoCs for a Large Office Building in Phoenix, AZ



Selecting an AWT System

When selecting an AWT system, agencies are encouraged to obtain estimates and choose the most cost-effective option for their location. Consider ongoing maintenance costs when selecting an AWT system. Some AWT technologies either completely eliminate or significantly reduce the amount of cooling-tower water treatment chemicals used.

For AWT to be implemented widely, ensure local operation and maintenance (O&M) teams are part of decision-making and receive adequate training on the new systems. Most AWT systems rely on a proprietary technology offered by individual vendors.



Specification and Contract Recommendations

- Bidder must have previous experience with three systems of equal size that have been in operation for at least three years and provide references.
- Bidder must provide a minimum 5-year limited warranty for replacing defective system components from the date of system acceptance.
- Bidder must provide a limited workmanship warranty for 1 year from customer acceptance.

Evaluate systems on their ability to:

Conserve energy, water, and chemical costs. The proposed system performance must result in a minimum of 15% water savings over current operation (baseline established by information provided to AWT vendors, refer to Appendix C).

Minimize maintenance costs, extend system longevity, and improve reliability.

Inhibit all system metallurgies against corrosion to prevent system failure and operation interruptions. Use corrosion coupons to measure corrosion. GSA's *Facilities Standards for the Public Buildings Service*, PBS- P100, requires quarterly measurement. 90-day coupons are more accurate than 30-day coupons.

Control microbiological growths that can contribute to corrosion and deposit formations (i.e., prevent biofilm, minimum inhibitory concentration [MIC], and Legionella). Weekly measurement is recommended.

Inhibit scale formations and deposit accumulations. Monthly measurement is recommended. See the section on Measuring AWT Performance for more information.

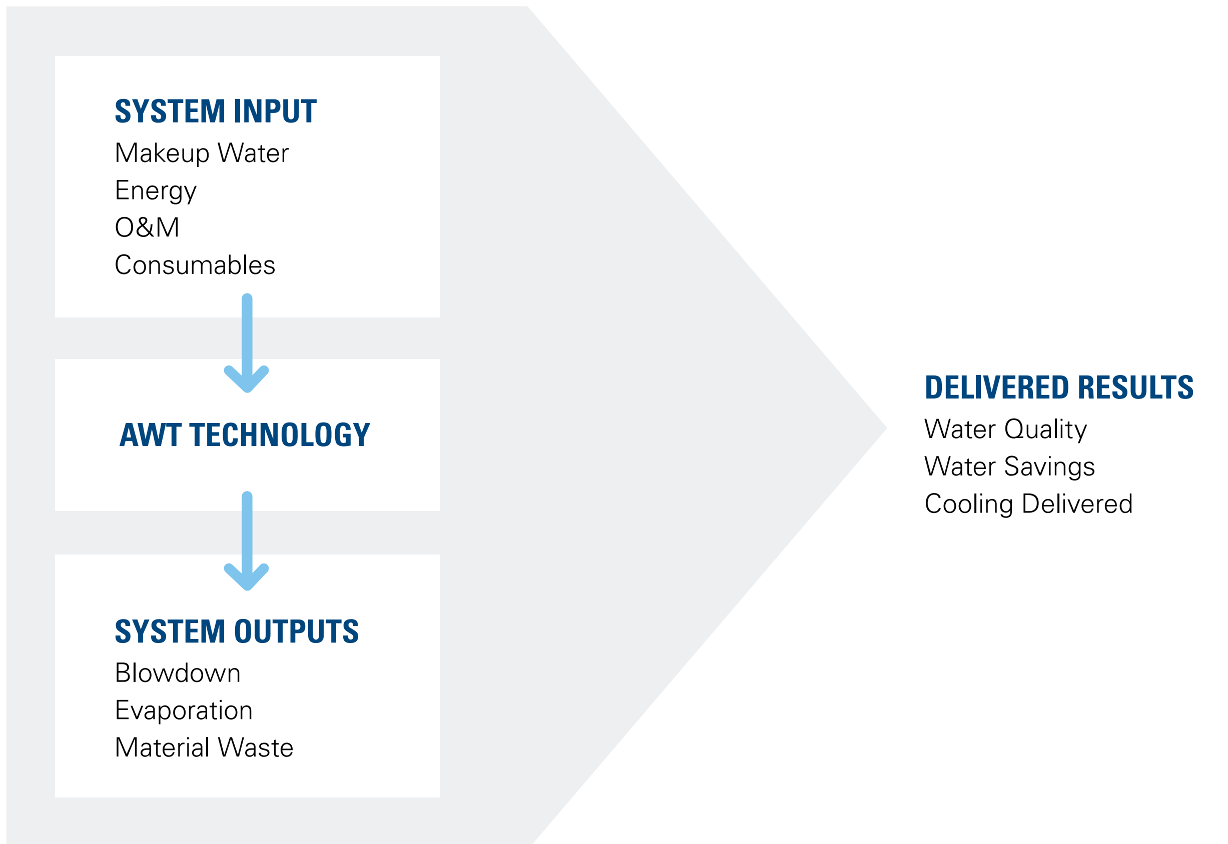
Work with site conditions. AWT systems need to be designed for the specific facilities in which they will be installed, and it is critical to ensure that the site can meet the AWT system's needs.

Measuring AWT Performance

Figure 4 shows the framework that should be used to establish a baseline and track AWT performance at your site.

The measurements that most directly impact the verification of cooling tower water savings are makeup water and blowdown water. DOE's Office of Scientific and Technical Information provides an excellent guide, Water Metering Best Practices, on selecting appropriate water meters for buildings. To establish a solid baseline before an AWT system is installed, the following meter points are desirable. A year's worth of records is ideal. However, meter data over the cooling season is usually sufficient.

Figure 4
Framework Used to Establish Baselines and Track AWT Performance



Establish Methods for Measuring Performance

Measure water savings targets over a minimum 3-week period during the cooling season. To measure water savings accurately, monitor water usage over a 3-week period after implementing changes. Allow for a transition period after making changes to water practices before evaluating the impact on water consumption.

Continue measuring water use over an entire cooling season and adjust based on the average load compared to the baseline.

Establish a requirement for measuring ongoing water savings. This will require flow meters on both the makeup and blowdown lines.

Monitor water quality every month, regardless of whether chemical treatment is used.

Example water reports required by GSA Region 8 over a 4-year period:

- Monthly field service reports
- Monthly analysis for makeup and system water conductivity or TDS
- Monthly water usage reports based on actual makeup meter readings
- Monthly bleed-off waste based on actual bleed meter readings

Measurements Needed to Measure AWT Performance

Required: Baseline metering*

- Makeup water for cooling tower (gal)
- Blowdown water for cooling tower (gal)

Nice-to-Have: Likely available from water treatment reports**

- Makeup conductivity, if available (avg µS/cm or mS/cm), likely available from water treatment reports
- Blowdown conductivity, if available (avg µS/cm or mS/cm)

Nice-to-Have: Likely available from BAS

- Cooling tower (condenser water) supply and return temperatures (°F)
- Cooling tower (condenser) flow rate (gpm) or water pump status (ON/OFF) and speed
- Chiller water supply and return temperatures (°F)
- Chiller flow rate (gpm) or water pump status (ON/OFF) and speed
- Outdoor air temperature (°F) and humidity (%) or Weather Underground data, or equivalent external source

*GSA Region 8 staff have had the best results with inline magnetic flow meters because they eliminate issues with turbulence caused by pipe turns and can capture low-flow conditions with better accuracy.

**Recommend integrating the cooling tower meter into the building automation system (BAS) for increased visibility.

Best Practices and Lessons Learned

Considerations for Selecting an AWT System

Space, weight, and access required to install the technology. Will the technology fit through doors? Will a crane be needed for installation? Will the roof structure support additional equipment?

AWT installation location. For instance, if an AWT system is installed in the mechanical room, check if the floor is sealed and that nearby floor drains are operational.

Cybersecurity considerations. Is the equipment IP addressable? Does it require internet connectivity?

Service requirements and availability of local support.

Required changes in O&M practices, staff training, and safety procedures.

Appropriateness of technology for local water chemistry and environmental conditions.

Size of the cooling tower. Some AWT technologies have restrictions concerning the maximum basin size they can effectively handle.

The AWT system's power consumption and local electricity rates.

Interface requirements with existing systems (e.g., plumbing, electrical, communication, drain lines).

Available options for AWT systems (e.g., system auto-cleaning options, power feed options, control communication protocols, suggested on-site spare parts) and whether AWT has any specialized requirements, such as compressed air.

Local limitations on sewer discharge. Some localities have restrictions on salt-based water softening. For example, Texas only allows salt-based softening with proof of associated water savings. Other regions have prohibited it for residential water softening.

Conductivity setpoint. Some systems may require the conductivity setpoint to be changed to realize savings. Ensure that the O&M team and water treatment staff are aware of and comfortable with this requirement.

Ongoing maintenance costs. Some of the evaluated technologies either completely eliminated or significantly reduced the amount of cooling-tower water treatment chemicals used.

Ability for the site to meet AWT requirements. Carefully analyze the AWT system needs to ensure the site can meet them. GSA staff recommends that the manufacturer supply a checklist outlining the necessary system conditions. Subsequently, the design team should verify whether the existing conditions align with these requirements. Consider system attributes such as flow rate (measured in gallons per minute), pressure, electrical connections, and predetermined water conductivity set points.

Installing an AWT System

Confirm that the system has been installed according to the design specifications provided by the vendor. GSA found several AWT installations with minimum water flow and drain capacity needs that were not initially met, which compromised AWT system performance.

Establish a baseline for your site prior to AWT installation so that cooling tower water savings can be measured in gal/MMBtu or gal/ton-hr after AWT installation.

Install metering for makeup water and blowdown during installation to verify savings. Use an industry-standard chemical controller to save water data. See the section on Measuring AWT Performance for more information.

Capture water rebates where available, by working with your local water utility.

Incorporate water savings requirements into O&M contracts. For example, reduce cooling tower water use by 15% compared with baseline operations.

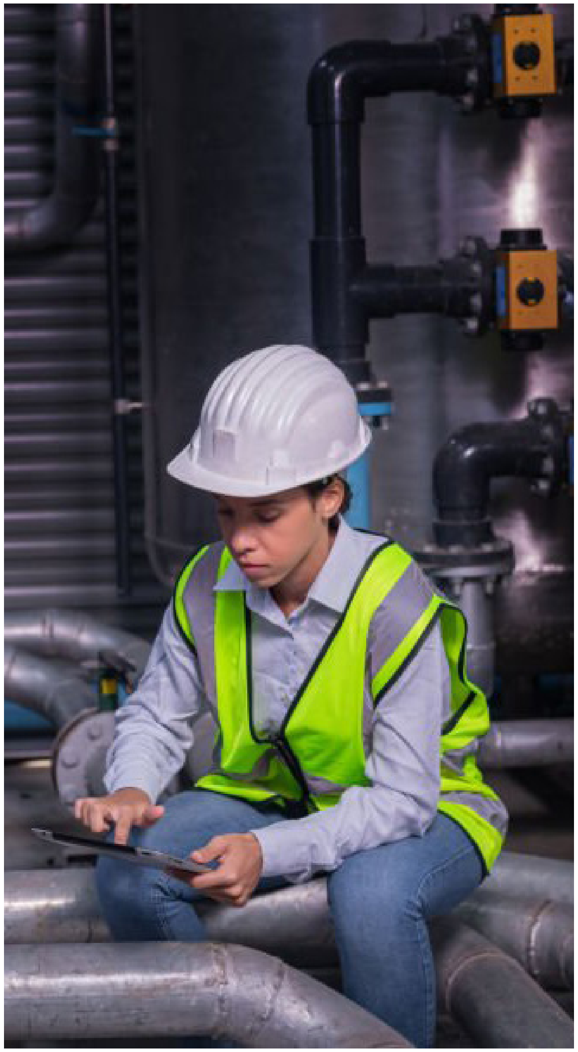
Consider a side-stream filtration system with a backwash glass media system for open cooling towers, which are prone to collect dirt and debris, or in locations where the incoming water has a high level of TDS.

Consider a tower sweeper when installing a new cooling tower or doing a major renovation to deal with sediment that collects at the bottom of the basin, especially if the cooling tower is subject to significant airborne debris from the local environment.

Consider integrating AWT technology with building management systems, or programmable logic controllers to help monitor performance.

Commissioning should be initiated immediately following installation (not delayed to a future date). The installer or manufacturer should provide proof of performance and be responsible for documenting and fixing any outstanding issues. It is also important to verify labeling on hardware, coordinate startup, and provide training and documentation.

AWT systems should not replace redundant systems. In one GSA installation, a redundant cooling heat exchanger for process cooling was eliminated, which created issues for the facility.



Maintaining an AWT System

Add equipment as a maintained asset in the National Computerized Maintenance Management System. Several AWT installations have not been regularly maintained because there was no maintenance plan created. If systems are added to the National Computerized Maintenance Management System, they become the responsibility of the O&M team to maintain them.

Continue water monitoring after the AWT system is installed. After installing an AWT system, water monitoring must continue in some form, whether by a water treatment company, AWT vendor, or staff with specialized training.

Include maintenance in Energy Savings Performance Contracts. See Appendix D for more guidance on what to include in an energy savings performance contract (ESPC).

Establish a protocol and cadence with the vendor for ongoing communication and support.

Consider having the vendor or authorized third party maintain the AWT system. The AWT systems evaluated by GPG were successfully operated during the evaluations, but once the vendor was no longer involved, some of these systems stopped working as designed.

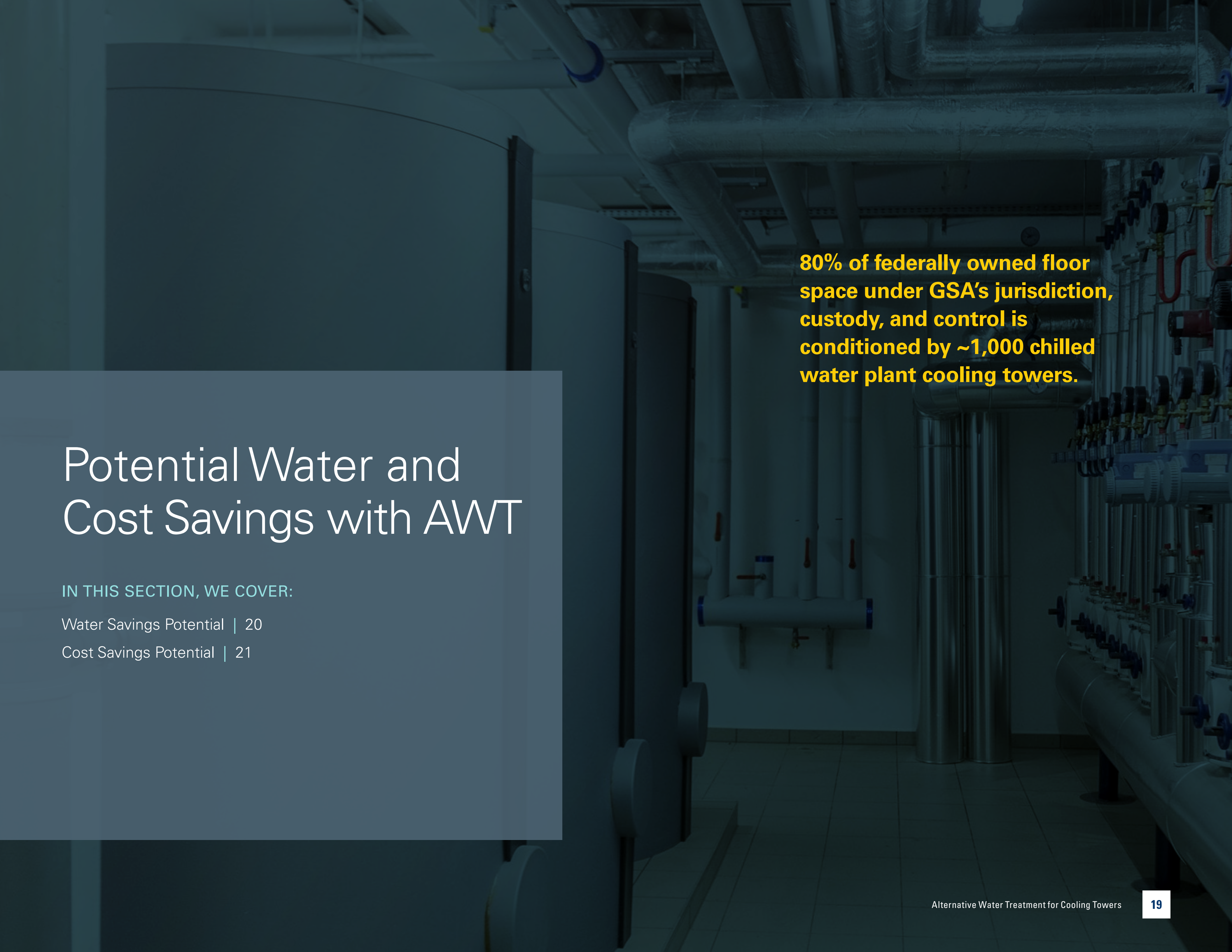
Train local maintenance teams on operating the installed AWT system. An AWT system installed at the U.S. Department of Justice – Bureau of Alcohol, Tobacco, Firearms and Explosives headquarters building in Washington, DC, required changes to the conductivity setpoint for water savings to be realized. But after water treatment providers had changed, this knowledge was lost, and the setpoint was not changed, therefore, negating savings.

Transfer O&M requirements when contracts change. Identify and document a continuity of operations process with respect to water treatment providers.

Require coupons for monitoring steel and copper corrosion. A GPG evaluation in the GSA Greater Southwest Region (Region 7) found that linear polarization resistance corrosion monitoring was not as effective.

Modify O&M contracts to reflect reduced chemical costs, when applicable.

Consider remote monitoring so vendors ensure their systems are working as designed. This will require additional cybersecurity clearance.



80% of federally owned floor space under GSA's jurisdiction, custody, and control is conditioned by ~1,000 chilled water plant cooling towers.

Potential Water and Cost Savings with AWT

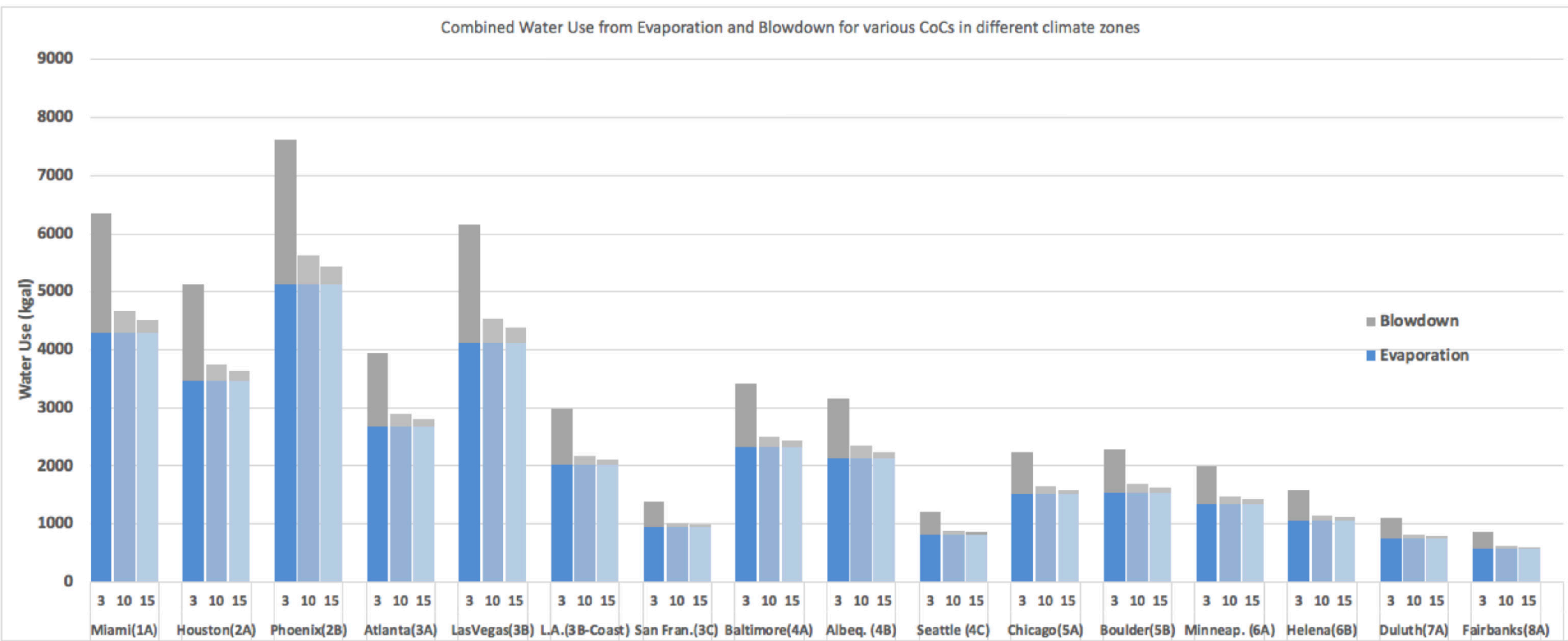
IN THIS SECTION, WE COVER:

Water Savings Potential with AWT

NREL used the whole-building modeling software EnergyPlus® to model water savings potential for a large office building (498,588 ft^2) across the ASHRAE climate zones. Hot, arid climates show the greatest water savings (see Figure 5).

Figure 5

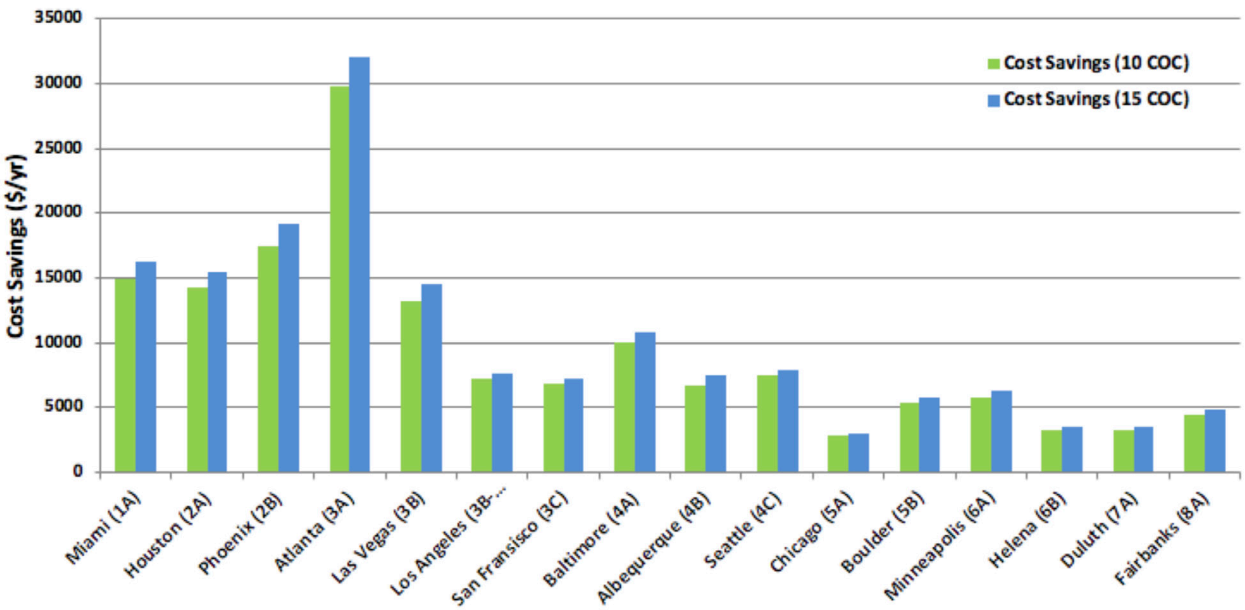
Annual Evaporation and Water Savings: Moving from 3.0 CoCs to 10.0 and 15.0



Cost Savings Potential with AWT

Water costs fluctuate widely across the county resulting in more varied savings. Atlanta, Georgia, had the greatest annual cost savings despite not having the most water savings.

Figure 6
Cost Savings: Based on combined water and sewer rates*



*Cost savings do not factor in an increase or decrease in O&M or increased electricity use.

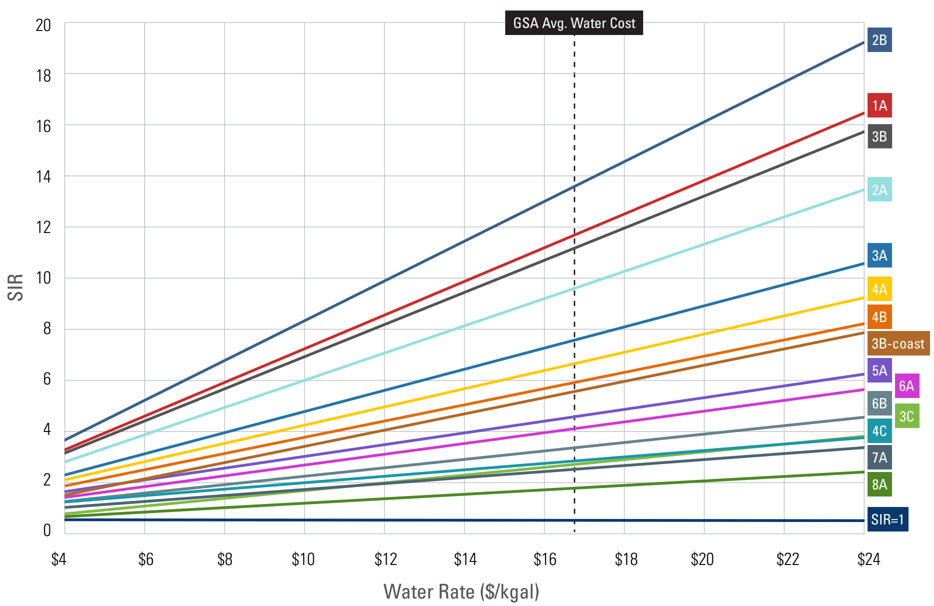
Table 1
May 2018, Combined Water and Sewer Rates**
for Sample Cities Across 16 ASHRAE Climate Zones

Climate Zone /Location	Combined Water and Sewer Rate ($/kgal)	Climate Zone /Location	Combined Water and Sewer Rate ($/kgal)
1A Miami	$13.62	**4B** Albuquerque	$4.98
2A Houston	$10.38	**4C** Seattle	$25.18
2B Phoenix	$7.76	**5A** Chicago	$7.76
3A Atlanta	$29.12	**5B** Boulder	$9.32
3B Las Vegas	$8.25	**6A** Minneapolis	$9.98
3B-Coast LA	$8.88	**6B** Helena	$8.30
3C San Francisco	$24.01	**7A** Duluth	$13.51
4A Baltimore	$12.30	**8A** Fairbanks	$22.07

**Combined water and sewer rates from local water utility's websites, assuming each site is on a 6-inch water line and uses more than 200,000 gallons per month.

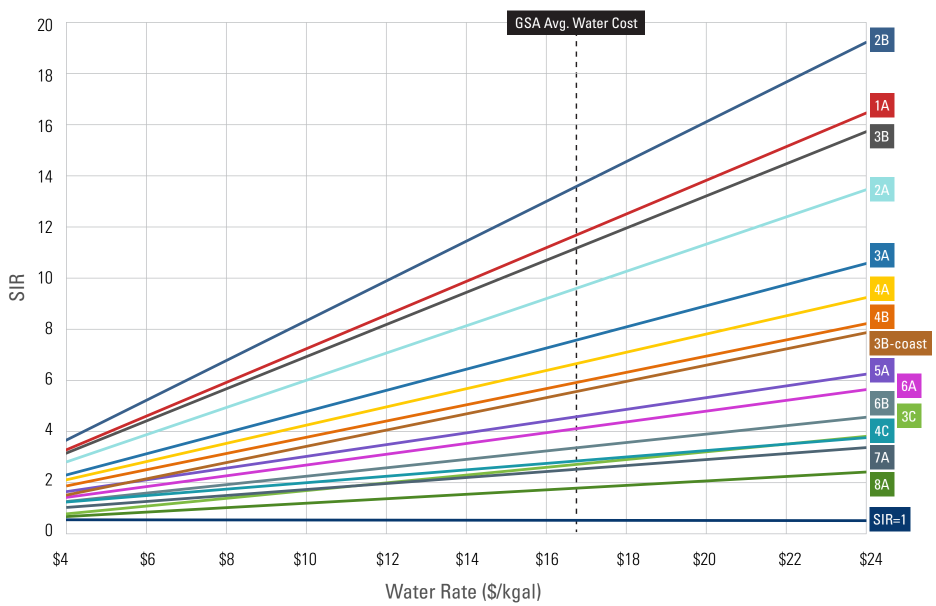
NREL calculated life cycle cost-effectiveness using a Savings-to-Investment Ratio (SIR). Savings exceed investment when SIR is > 1. The SIR analysis assumed moving from a CoC of 3 to 10 and that other annual operating costs remained the same. The $20K low-cost AWT system, showin in FIgure 7, is life cycle cost-effective across all 16 climate zones when the combined water and sewer rate is more than $4/kgal. The $35K high-cost AWT system, shown in Figure 8, is life cycle cost-effective (SIR > 1) across all 16 climate zones when the combined water and sewer rate is more than $8/kgal.

Figure 7
$20K System Cost Sensitivity Analysis*



*Based on a 15-year project life

Figure 8
$35K System Cost Sensitivity Analysis*



Appendices

Table 2
Summary Results From GPG Evaluations

Evaluations were conducted over many years, and equipment costs have not been updated. Follow up with vendors to get updated pricing for your building.

	Chemical				Non-Chemical	
	Blowdown Recovery: Aqualogix	**Monitoring & Partial Softening: Aqualogix**	**Chemical Scale Inhibition: Terlyn**	**Salt-Based Ion Exchange: WCTI**	**Electrochemical: Dynamic Water Technologies**	**Advanced Oxidation: Silver Bullet**
M&V Period	2022	2019	2013	2013	2017	2016
Cooling Tower Location	Lloyd D. George Federal Building Las Vegas, NV	Lloyd D. George Federal Building Las Vegas, NV	Denver Federal Center (Bldg 25, 67) Denver, CO	Denver Federal Center (Bldg 25) Denver, CO	Juliette Gordon Low Federal Building Savannah, GA	Denver Federal Center (Bldg 95) Denver, CO
Cooling Tower Size (tons)	1,150 (one 450 ton, two 350 ton)	1,150 (one 450 ton, two 350 ton)	1,200 (two 600 ton)	1,500 (three 500 ton)	300 (two 150 ton)	500 (two 250 ton)
Baseline CoC	2.8	2.8	Not measured	4.42	3.9	7.9
Technology CoC	4.4	4.2	13–18	30–75	200+	11
Blowdown Reduction	53%	52%	94%	99%	99.8%	Not measured
Water Savings (%)	16%	15%	24%	23%	32.0%	23% to 30%
Water Savings Per Ton-Hour of Cooling (gallons)	0.35	0.33	0.42	0.58	0.64	Not measured
Equipment Cost	$35,403	$30,016	$17,103	$18,100	$30,340	$22,040
Installation Cost	$11,422	$8,355	$15,408	$11,500	$15,000	$1,385
Annual Electricity Increase (@ $0.11 kWh)	$390	$590	—	—	$3,049	$582
Payback (yrs) @ ($18.41/kgal)*	2.4	2.1	2.1	4.0	2.2	2.4
Savings to Investment Ratio	6.1	7.1	7.0	3.7	6.9	6.2
Chemical Use	Operates alongside traditional chemical treatment	Salt is added on top of traditional chemical treatment	Proprietary scale inhibitor, corrosion inhibitor, biocide	Brine	100% chemicals eliminated	Eliminated all scale and corrosion inhibitors; biocide used as needed
Footprint	Skid ~300 ft² of floor space, shipping weight 920 lbs, wet weight ~2,400 lbs	Skid – 91 tall, 40" x 40", weight, 1275 lbs. Additional brine tank 30" x 30"	~8 ft² of floor space three 5-gallon containers, double-walled mixing basin, sand filter	~ 8 ft² of floor space two brine tanks	Skid – 1' x 4' x 5.5' 500 lbs	24" x 45" x 10" 100 lbs
Notes	Includes limited side-stream filtration can be combined with Partial Water Softening	Includes limited side-stream filtration can be combined with Blowdown Recovery	Includes side-stream filtration			

*Payback does not reflect changes in O&M costs.

Blowdown Recovery

The blowdown recovery system from Aqualogix evaluated by the GSA GPG program is designed to optimize chilled water system performance by capturing and purifying a percentage of the blowdown. The system is designed to return water to the condenser water system with zero hardness. The technology incorporates sidestream filtration, carbon filtration, reverse osmosis, demineralization, and a control system.

Implementation Considerations

Works in tandem with proper chemical water treatment. Maintaining the blowdown recovery system includes semi-annual system checks and annual instrument calibration.

Operational conductivity setpoint remains unchanged. The operating CoC remains unchanged with the blowdown recovery system, but the effective CoC is higher. Because a percentage of blowdown is returned as purified water, the concentrated water that goes to the sewer has a higher CoC. At the testbed, the operational CoC was 2.8, but the effective CoC was 4.2.

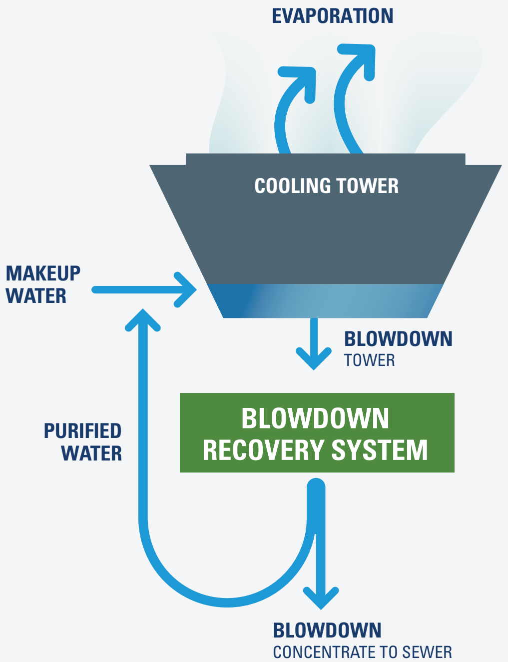
Can be run as a standalone unit or combined with the continuous monitoring and partial water softening system from the same manufacturer. The vendor estimates up to a 93% reduction in blowdown when the systems are combined. Savings for the combined system will be highest for sites that have hard water and moderate conductivity, e.g. less than 500 microsiemens per centimeter (µS/cm). At the GPG program testbed in Las Vegas, Nevada, water total hardness was 278 ppm, and conductivity was 992 µS/cm.

Reverse osmosis membranes typically require replacement every 5 years. Using auto-cleaning systems and antiscalants can prolong the membrane's lifespan. At the testbed's 700-ton cooling tower, five membranes were used in the system, each costing $125.

Increases energy use. The technology draws 0.404 kW per hour. At the testbed, annual electricity use increased by 3,541 kWh.

Integrates through piping modifications and drain. The piping to and from the skid is the most variable expense, but piping runs can be short if the skid can be located close to the cooling water supply and return piping. The skid also requires a nearby drain for discharge and 120/240/480V electricity. The system is shipped in a crate that fits through a 3-ft wide door.

Figure 9
Blowdown Recovery:
Recovers blowdown and purifies it for reuse



Blowdown Recovery

1,150-ton cooling tower

Testbed Equipment Dimensions

- Ships in a crate that fits through a 3-ft wide door
- Equipment size is approximately 10′ L X 3′ W
- Required skid footprint is 300 ft^2
- Skid weight is 920 lbs dry, 2,400 lbs wet
- Includes a 250-gallon make-up reservoir

The skid-mounted blowdown recovery system is located in the chiller room at the Lloyd D. George U.S. Courthouse.
Photo credit Aqualogix

Find Out More

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GPG Report 052: Blowdown Recovery System

2022 Testbed Savings and ROI

Water Savings
16% makeup water savings
53% blowdown reduction

Material Cost
$35,403

Installation Time
< 1 week

Payback
2.4 years at $18.41/kgal

Monitoring and Partial Softening

Monitoring and partial softening from Aqualogix supplements legacy chemical water treatment instead of replacing it. The technology consists of two components:

- Continuous programmable logic control to determine the optimal amount of blowdown required to satisfy all water chemistry targets.
- Monitoring and side-stream filtration with partial water softening to remove suspended matter while dispensing softened water to achieve targeted makeup-water hardness.

Implementation Considerations

Monitors CoC and prevents the inlet/outlet valve from opening should the conductivity fall below a preset limit.

Works in tandem with proper chemical water treatment. Maintaining the system consists of monitoring and replenishing salt. At the 1,150-ton testbed site in Las Vegas, three to five 50-lb bags are replaced every 2 weeks.

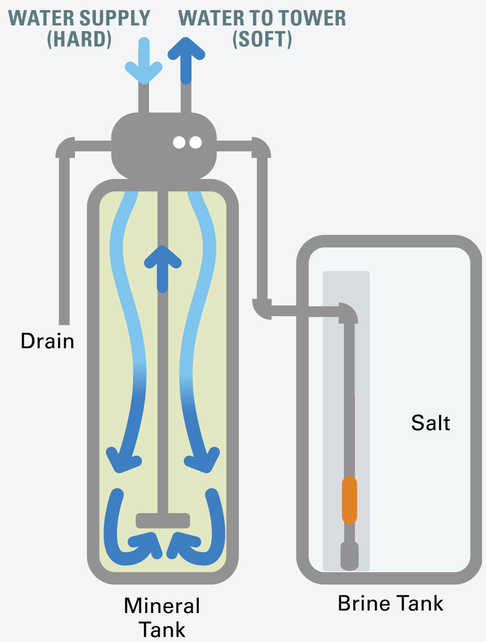
Can be run as a standalone unit or combined with the blowdown recovery system from the same manufacturer. The vendor estimates up to a 93% reduction in blowdown when the systems are combined. Savings for the combined system will be highest for sites that have hard water and moderate conductivity (e.g. less than 500 microsiemens per centimeter [µS/cm]). At the GPG testbed in Las Vegas, Nevada, water total hardness was 278 ppm, and conductivity was 992 µS/cm.

Integrates through piping modifications and drain. The piping to and from the skid is the most variable expense, but piping runs can be short if the skid can be located close to the cooling water supply and return piping. If the skid can be situated close to the cooling water supply and return piping, the slipstream piping runs are short. Because the system takes over blowdown, installation costs can also be reduced if the skid can be situated near an existing drain.

Stand-alone monitoring or integration with building management system. If scaling conditions are present, an alarm is generated, so the anti-scale chemical dosage can be checked or changed.

Increases energy use: The technology draws 0.833 kW per hour. At the testbed's 700-ton cooling tower, annual electricity use increased by 7,735 kWh.

Figure 10
Monitoring and Partial Softening:
Supplemental system determines optimal blowdown



Monitoring and Partial Softening

1,150-ton cooling tower

Testbed Equipment Dimensions

- Small footprint skid size: 40" L x 40" W x 91" H
- Skid dry weight is 1,275 lbs, operating weight is 1,625 lbs
- Separate brine tank is required

AWT system setup at Lloyd D. George Courthouse.
Photo credit Gregg Tomberlin, NREL

Find Out More

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GPG Report 045: Continuous Monitoring and Partial Water Softening

2019 Testbed Savings and ROI

Water Savings
15% makeup water savings
52% blowdown reduction

Material Cost
$30,016

Installation Time
~1 week

Payback
2.1 years at $18.41/kgal

Chemical Scale Inhibition

The chemical scale-inhibition system from Terlyn uses proprietary chemicals to control water hardness and a programmable logic controller to monitor CoC continuously. The controller is typically set for CoCs greater than 20 and automates blowdown when this level has been reached.

Implementation Considerations

Increases chemical costs. Proprietary chemicals increased annual chemical costs at the 1,200-ton cooling tower testbed by $5,100. The chemicals are concentrated and GSA Region 8 reports that one 10-gallon jug can last a year.

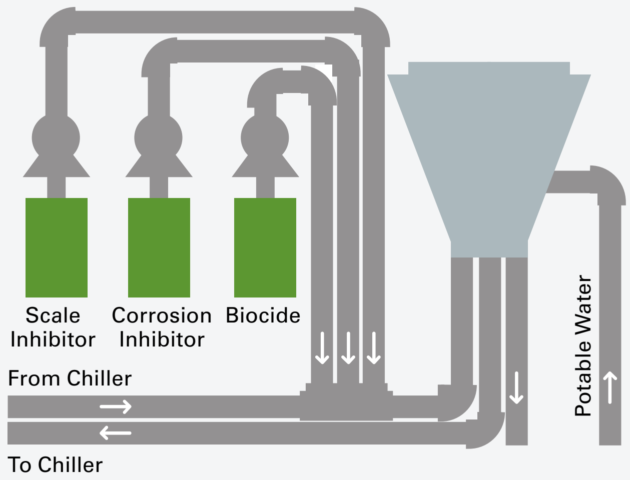
Remote monitoring possible. The controller can send alarms when water quality parameters fall outside the desired range, though this capability would need to be cleared with GSA information technology (IT) security.

Water savings may not be seen during the first year until the system is cleaned of all scale. Scale should be removed gradually over the course of a year to make the scale cleanup manageable.

Install a side stream filtration system to improve operation.

Corrosion control is excellent. In 2023, corrosion coupons for eight GSA Region 8 sites running chemical scale inhibition demonstrated negligible to excellent results for copper alloy and very good to excellent results for carbon steel.

Figure 11
Chemical Scale Inhibition:
Proprietary chemicals inhibit scaling and corrosion



Chemical Scale Inhibition

1,200-ton cooling tower*

Testbed Equipment Dimensions

- ~6–8 ft^2 of floor space
- Three 5-gallon containers of chemicals
- Double-walled mixing basin
- Sand filter

*The Denver Federal Center added 10 more chemical inhibition systems. A review by the water treatment provider found they saved between 38% and 59%.

Chemical containers and side stream filtration system used by the chemical scale inhibition system.
Photo credit Doug Baughman, GSA

Find Out More

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GPG Report 040: Chemical Scale Inhibition for Cooling Towers

2013 Testbed Savings and ROI

Water Savings
24% makeup water savings
94% blowdown reduction

Material Cost
$17,103

Installation Time
~1 week including side stream filtration

Payback
2.1 years at $18.41/kgal

Salt-Based Ion Exchange

This salt-based ion exchange system from Water Conservation Technologies International, Inc. uses salt to remove low-solubility ions, reduce scale potential, and increase the solubility of TDS. The system consists of twin fiberglass ion exchange media tanks, alternating polyethylene regeneration tanks, and a brine tank.

Implementation Considerations

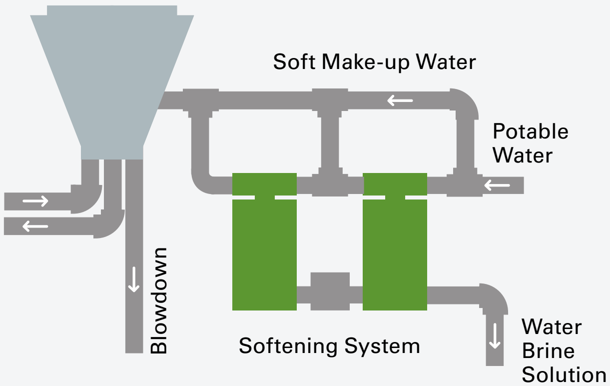
Replaces scale and corrosion inhibitors with salt. At the testbed, it reduced annual chemical costs by over 80%, as salt is relatively inexpensive.

Requires daily water testing, which is more frequent than the other AWT systems evaluated.

Lowest installed cost per ton of AWT systems evaluated.

Web-based remote access for reporting and control is available; however, this capability was not tested and would need to be cleared with GSA IT security.

Figure 12
Salt-Based Ion Exchange:
Removes hardness without additional chemicals



Salt-Based Ion Exchange

1,500-ton cooling tower

Testbed Equipment Dimensions

- 4 ft x 4 ft mounting space required in mechanical room
- ~8 ft^2 floor space required for the two brine tanks

Tanks for treating the make-up water entering the AWT system at Denver Federal Center Building 25, in Denver, CO.
Photo credit Dylan Cutler, NREL

Find Out More

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Building 25
Denver, Colorado

Tyler Cooper
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Region 8 has deployed 5 additional units.

AWT Vendor
Water Conservation Technologies
International, Inc.
Franklin, Tennessee

savewater@water-cti.com

GPG Report 040: Salt-Based Ion Exchange

2013 Testbed Savings and ROI

Water Savings
23% makeup water savings
99% blowdown reduction

Material Cost
$18,100

Installation Time
~2 days

Payback
4 years at $18.41/kgal

Electrochemical

Electrochemical treatment from Dynamic Water Technologies applies a small amount of direct current to promote scaling in an easy-to-clean reactor rather than in the chiller or cooling tower. The process strips hydrogen ions from the chloride naturally present in water and creates chlorine, which acts as a biocide and eliminates the need to add other chemicals to the water. Treatment is continuous, with 10% to 20% of the total flow through a side stream filtration system.

Implementation Considerations

Eliminates a majority of ongoing chemical costs. The region found that the chlorine levels produced were not sufficient and additional chlorine was required.

Requires quarterly cleaning of the reactor rods (4 hours per quarter).

Required a crane for testbed installation, which increased installation complexity and cost.

Can be installed without replacing the legacy water treatment piping.

Requires O&M buy-in and training. Continue a maintenance contract with a water treatment provider. After the GPG testbed evaluation, there was a gap in the maintenance contract, which resulted in chiller scaling and catastrophic failure.

Uses electricity. At the 300-ton test bed, kWh energy use increased 27K for the year.

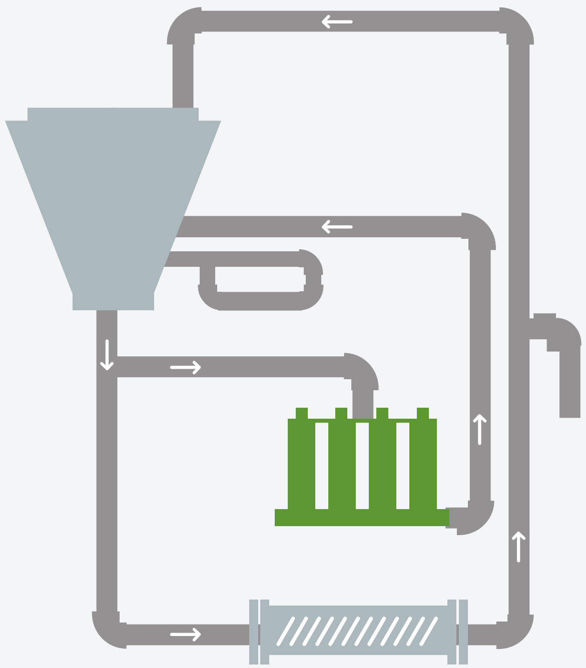
Raises CoC. CoC increased from 3.9 to 200+ at the test bed.

Facility Experience

After the GPG program evaluation, the facility understood the system to be self-cleaning, so the system was not monitored or cleaned for ~8 months. After this time, staff noticed heavy scaling. They tried to chisel the reactor rods and punch tubes, but they were unable to recover operations, and the electrochemical treatment was discontinued. Water at the testbed in Savannah, Georgia, is very hard. The vendor now has a self-cleaning system that may eliminate these issues. Facility staff suggest installing this technology only if an energy service company or the vendor handles ongoing operations.

Figure 13

Electrochemical Treatment:
Electrolysis sequesters scale in reactor tubes and creates chlorine, a natural biocide



Electrochemical

300-ton cooling tower

Testbed Equipment Dimensions

- Reactor skid (4-ft L x 1-ft W x 5.5-ft H)
- Required a crane for installation at the testbed
- System requires compressed air and electrical connection
- Equipment dry weight < 500 lbs

Scraping scale off the reactor rod of the electrochemical water treatment system.
Photo credit Gregg Tomberlin, NREL

Find Out More

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GPG Report 038: Electrochemical for Cooling Towers

2017 Testbed Savings and ROI

Water Savings
32% makeup water savings
99.8% blowdown reduction

Material Cost
$30,340

Installation Time
< 2 days

Payback
2.2 years at $18.41/kgal

Advanced Oxidation

The advanced oxidation technology from Silver Bullet Water Treatment pulls air from the surrounding environment and passes it through patented sleeves that contain ultraviolet lamps and other proprietary components to modify the air's composition. The new composition oxidizes minerals and contaminants in the water, kills bacteria, reduces biofilm and biocorrosion, and breaks down calcium buildup.

Implementation Considerations

Simple and straightforward installation process.

Eliminates all scale and corrosion inhibitors. A small amount of commercial biocide (chlorine) may be needed, particularly when pollen or other debris accumulates in the tower water, which can promote algae growth.

Least biological growth in a follow-up analysis by NREL of three AWT systems (Advanced Oxidation, Salt-Based, and Chemical Scale Inhibition) installed at the Denver Federal Center (DFC).

Legacy treatment system is unaltered and can revert to the previous model if issues arise.

Requires O&M buy-in and training. This approach to water treatment is very different from current practice.

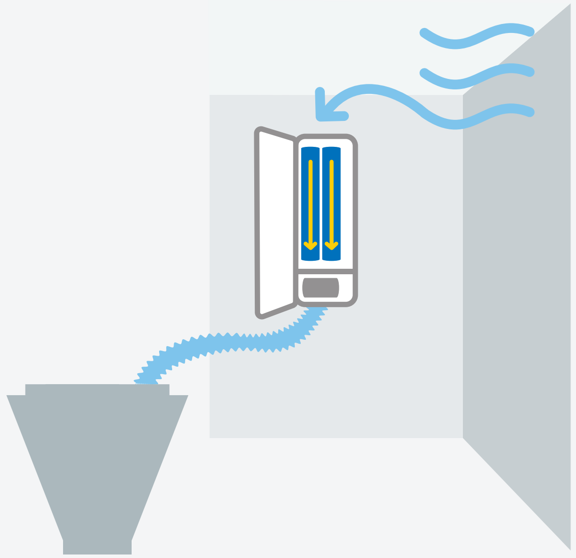
Increases energy use: +5,250 kWh/yr for 500-ton cooling tower

Consider leasing. DFC staff indicated that for future installations of this technology, they would pursue leasing instead of purchasing as part of the service contract with the vendor. The cost of the lease, combined with a service contract, is comparable to the cost of traditional chemical treatments.

Facility Experience

DFC had trouble maintaining proper system operation after the 2-year evaluation. After algae growth and corrosion were found, the system was discontinued.

Figure 14
Advanced Oxidation: Photochemical treatment oxidizes minerals and contaminants



Advanced Oxidation

Testbed Equipment Dimensions

Size	Weight (lbs)	Dimensions	Tower Cooling	Power Draw
Small	43	20″ H x 15″ W x 6″ D	Up to 400 tons or 1,200 gpm	396 watts
Large	101	45″ H x 24″ W x 10″ D	Up to 2,000 tons or 6,000 gpm	720 watts

An inside cabinet view of the advanced oxidation technology setup.
Photo credit Silver Bullet Water Treatment Company

Find Out More

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AWT Vendor

Silver Bullet Water Treatment
Golden, Colorado

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GPG Report 039: Advanced Oxidation Process for Cooling Towers

2016 Testbed Savings and ROI

Water Savings
26% makeup water savings (+/- 4%)

Material Cost
$22,040 for 500-ton cooling tower

Installation Time
< 1 day

Payback
2.4 years at $18.41/kgal

Water Quality for Open Systems

Table 3
GSA-P100 2022, Section 5.3.5 – Water Quality Ranges for Open Systems*

Test	Acceptable Ranges
pH	7.5–9.5
T alkalinity (ppm)	100– 500
Iron (ppm)	< 3
Soluble Copper (ppm)	< 0.2
Total Dissolved Solids (ppm)	< 1500
Aerobic plate count	1,000 organisms/ml
Legionella	10 CFU/ml

*GSA's *Facilities Standards for the Public Buildings Service,* PBS-P100, establishes mandatory design standards and performance criteria for federally owned buildings under GSA's jurisdiction, custody, and control.

Coupon codes must be installed 30 days after submission of the water treatment plan, if not already present. Laboratory analysis of coupons must be at least quarterly. At a minimum, a two-station coupon rack must be installed for each loop and used to monitor mild steel and copper pipes.

Table 4
Classification of Corrosion Rates for Open Systems** (Corrosion, mills per year [mpy])

Description	Carbon Steel (mpy)	Copper Alloy (mpy)
Negligible or Excellent	≤ 1	≤ 0.1
Mild or Very Good	1–3	0.10–0.25
Good	3–5	0.25–0.35
Moderate to Fair	5–8	0.35–0.50
Poor	8–10	0.50–1.00
Very Poor to Severe	> 10	> 1

**Association of Water Technologies, Standards for Corrosion Rates (April 28, 2000). GSA Region 8 requires less than 3 mpy for carbon steel and less than 0.2 mpy for copper alloy.

Table 5
Other Water Quality Metrics to Consider

Conductivity (mmHos)
Water Appearance
Phosphate (ppm)
Calcium Hardness (ppm)
Magnesium Hardness (ppm)
Chlorides (ppm)
Salt (ppm)
Sulfates (ppm)
Silica (ppm)
ORP (mV)
Chloride (ppm)

Cooling Tower Data

Provide the following facility information to AWT vendors

- ☐ **12 months of consecutive water use data including both cooling tower make-up and blowdown.** If you provide copies of city water reports, identify relevant meters.
- ☐ **12 months of water treatment reports**. Ideally, use the same consecutive 12 months as for monthly water usage.

OR If water treatment reports are unavailable, provide:

  - ☐ Site makeup water quality from city water reports
  - ☐ Conductivity of water tower loop and typical Cycles of Concentration (CoCs)
  - ☐ Calcium hardness

- ☐ **Existing water treatment description:** Briefly describe existing water treatment system, and whether you have an existing fixed-price contract with a water treatment contractor where cost of chemicals are included
- ☐ **Potential AWT sites:** Briefly describe the size and location of candidate AWT spaces (mechanical room or outside)

☐ **Cooling tower setup**

____________ # of cooling tower cells	____________ Cooling tower(s) capacity (tons)
____________ Cooling tower age	____________ Water conductivity (µS/cm)
____________ Water temperature range (°F)	____________ Ambient temperature range (°F)
____________ Water peak flow rate (gal per min)	____________ Peak water pressure (psi)
____________ # of chillers	____________ Chiller(s) capacity (tons)
____________ Compressed air available (psig)	____________ Power available (volts)

Technology Specifications

Request the following from AWT vendors

Unit weight (dry) __________ lbs

Unit weight (wet) __________ lbs

Shipping box dimensions (inches) _________" x _________" x _________"

Water conductivity __________ µS/cm

Peak flow rate __________ gpm

Peak water pressure __________ psi

Power requirement __________ amps __________ volts

Electrical connections

____

____

Instrumentation

____

____

Piping

____

____

Valves including relief valves

____

____

Recommended spare parts

____

____

Maintenance schedule

____

____

Controls

____

____

Control communication protocol type (e.g., BACnet)

____

____

Guidance for ESPC Contracting

When including an emerging technology in an energy savings performance contract (ESPC), project managers should:

- ☐ **Determine whether the ESCO or the O&M contractor is best positioned** to provide operations and preventative maintenance. It is recommended that ESCOs provide preventive maintenance on new equipment that is atypical for the first 3 years of performance.
- ☐ **Require the ESCO to provide a proposal for a 3-, 5-, and 10-year extended warranty** for equipment that is atypical for GSA facilities.
- ☐ **Capture the real cost of additional O&M** in the life cycle costing and task order financial schedules, if including in the ESPC.
- ☐ **Enter all new energy conservation measures (ECMs)** into the National Computer Maintenance Management System.
- ☐ **Ensure that the O&M contract is modified** to include the new equipment and preventative maintenance.
- ☐ **Not accept systems until they are fully commissioned.** It is recommended that ESCOs be responsible for the commissioning process.

ESCO responsibilities should include:

- ☐ **Preventive maintenance** for 3-years for all new equipent that is atypical for GSA facilities.
- ☐ **Extended warranties** (3-, 5- or 10-years) for equipment that is atypical for GSA facilities.
- ☐ **Commissioning.** The proof of performance period should be long enough to allow testing under various operating conditions and across different seasons.
- ☐ **Training ESPC team members for operations and maintenance of the new systems** to avoid unnecessary equipment failures. Annual training should be provided to ensure all installed ECMs are operated and maintained within design specifications.
- ☐ **Verifying that PMs are completed during inspections** to ensure that building systems are running optimally and the guaranteed savings are achieved.

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GSA. GPG-039, Advanced Oxidation Process for Cooling Towers.

GSA. GPG-040, Salt-Based and Chemical Inhibition for Cooling Towers.

GSA. GPG-045, Continuous Monitoring and Partial Water Softening.

GSA. GPG-052, Blowdown Recovery System.

List of Figures and Tables

Center for Emerging Building Technologies | Green Proving Ground

U.S. General Services Administration

National Renewable Energy Laboratory

Visit: www.gsa.gov/gpg

Email: gpg@gsa.gov

U.S. General Services Administration. 07.24