Better Buildings
Space Conditioning Technology Team

National Renewable Energy Laboratory

February 14, 2020, 1-2 PM EST

Agenda

- Introductions
- HVAC Research Team
  - Marcus Bianchi, NREL – Senior Research Engineer
  - Miles Hayes, NREL – Research Engineer
- Speakers
  - Michael Deru, NREL
- HVAC Research Team Updates
- Discussion

Better Buildings Summit 2020

https://betterbuildingsinitiative.energy.gov/summit

HVAC Research Team Updates

Recent Publications

- Evaluation of High Rotor Pole Switched Reluctance Motors to Control Condenser Fans in a Commercial Refrigeration System
  - https://www.nrel.gov/docs/fy19osti/72476.pdf
- Planning for Failure: End-of-Life Strategies for HVAC Systems
  - (ASHRAE Journal, December 2019)
- AWT: GSA Guidance for Cooling Towers
  - https://www.gsa.gov/governmentwide-initiatives/sustainability/emerging-building-technologies/published-findings/water/awt-gsa-guidance-for-cooling-towers
- Energy Performance Validation of a Gaseous Air Cleaning Technology for Commercial Buildings
  - https://www.nrel.gov/docs/fy20osti/74545.pdf
- Provider and User Perspectives on Automated Fault Detection and Diagnostic Products for Packaged Rooftop Units
  - https://www.nrel.gov/docs/fy20osti/75461.pdf
- Testing and Evaluation of a Chemical Free Cooling Tower Water Treatment Technology
  - https://www.nrel.gov/docs/fy19osti/73911.pdf

Looking Ahead

- RTU AFDD data analysis
- Thermal Energy Storage outreach, feedback & guide
- BAS to GEB, Building automation in grid interactive efficient buildings; outreach, feedback

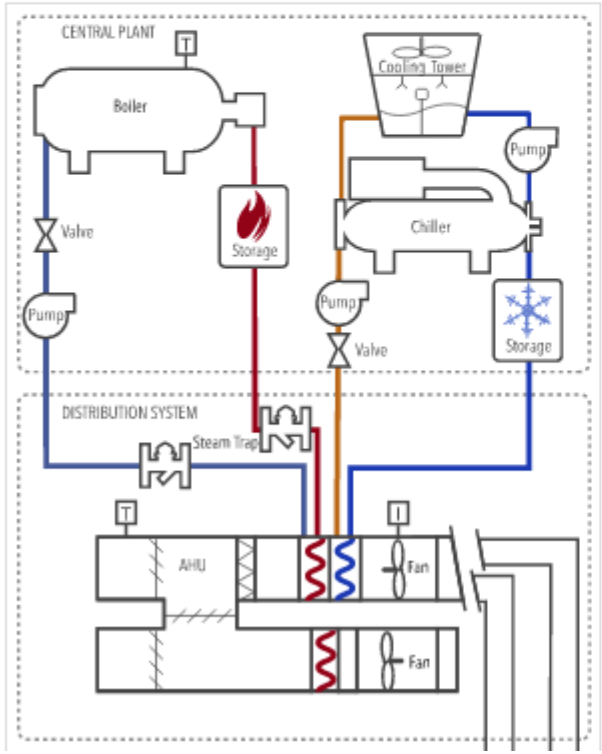
HVAC Resource Map

Better Buildings® U.S. DEPARTMENT OF ENERGY

www.HVACresourcemap.net

HVAC Home | Central Plant | Distribution | Space Loads | Contributors

HVAC Resources



What is this resource?

The Central Plant Resource Map is an intuitive graphical interface that provides quick access to a broad array of quality information on operations and maintenance best practices and energy and water efficiency measures. The resources cover the central plant, distribution systems, and zone systems. The primary audiences for this resource are facility managers, operations staff, and design engineers who are looking to improve central plant and distribution efficiency but don't have time to search for these resources.

This Resource Map is not a repetition of guidance provided in codes and standards. It should not be used in lieu of professional engineering services.

Explore HVAC Resources

Use the horizontal navigation above or the interactive diagram to dive into resources on different HVAC components.

The resources listed on this site have been carefully selected to help narrow your search for helpful information.

Michael Deru, NREL

Cooling Tower Water Treatment

Acknowledgements: Jesse Dean, Gregg Tomberlin, Dylan Cutler, Jennifer Daw

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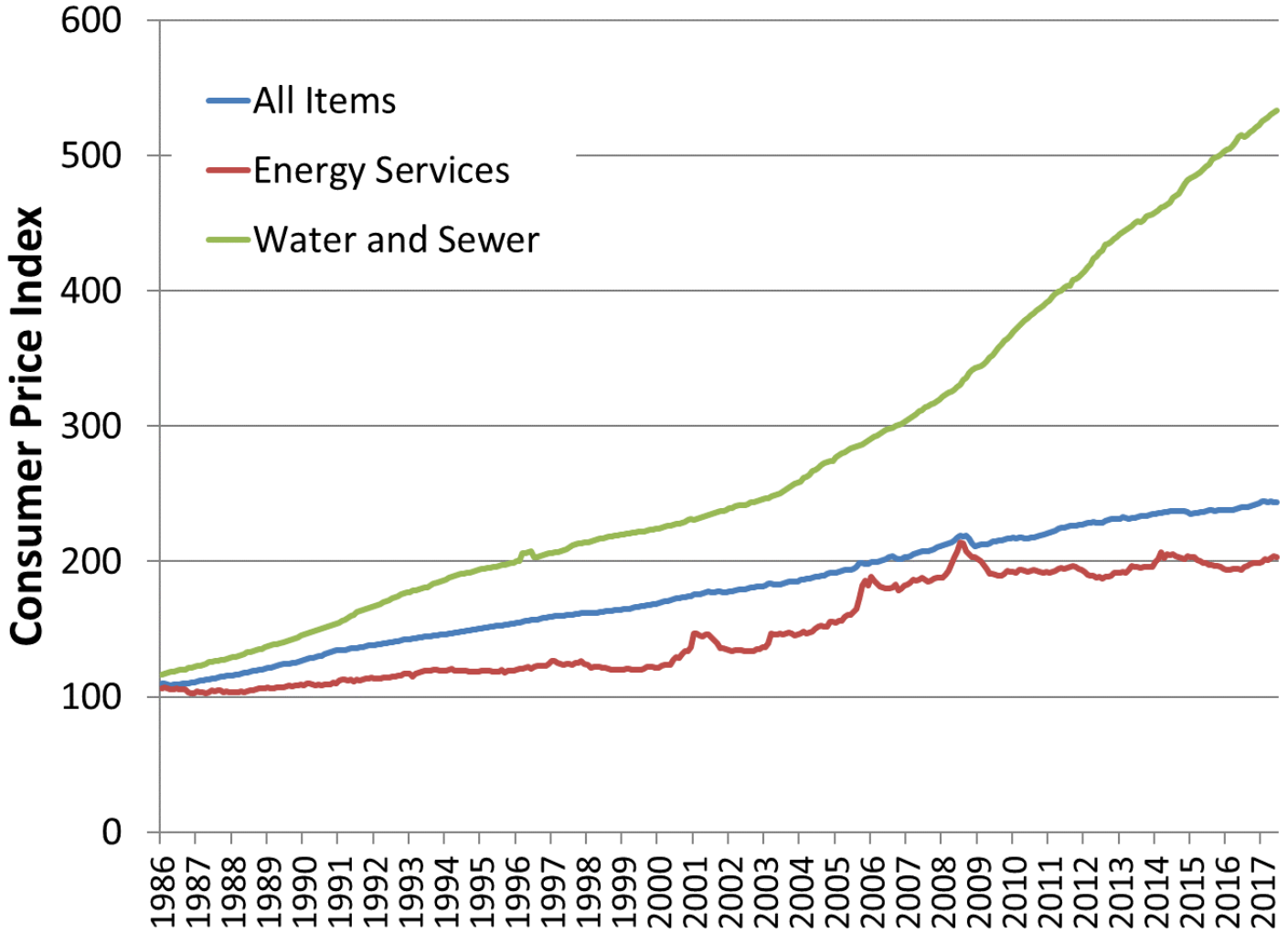
What's the Cost of Water?



Over 400% increase

Costs are very regionally dependent

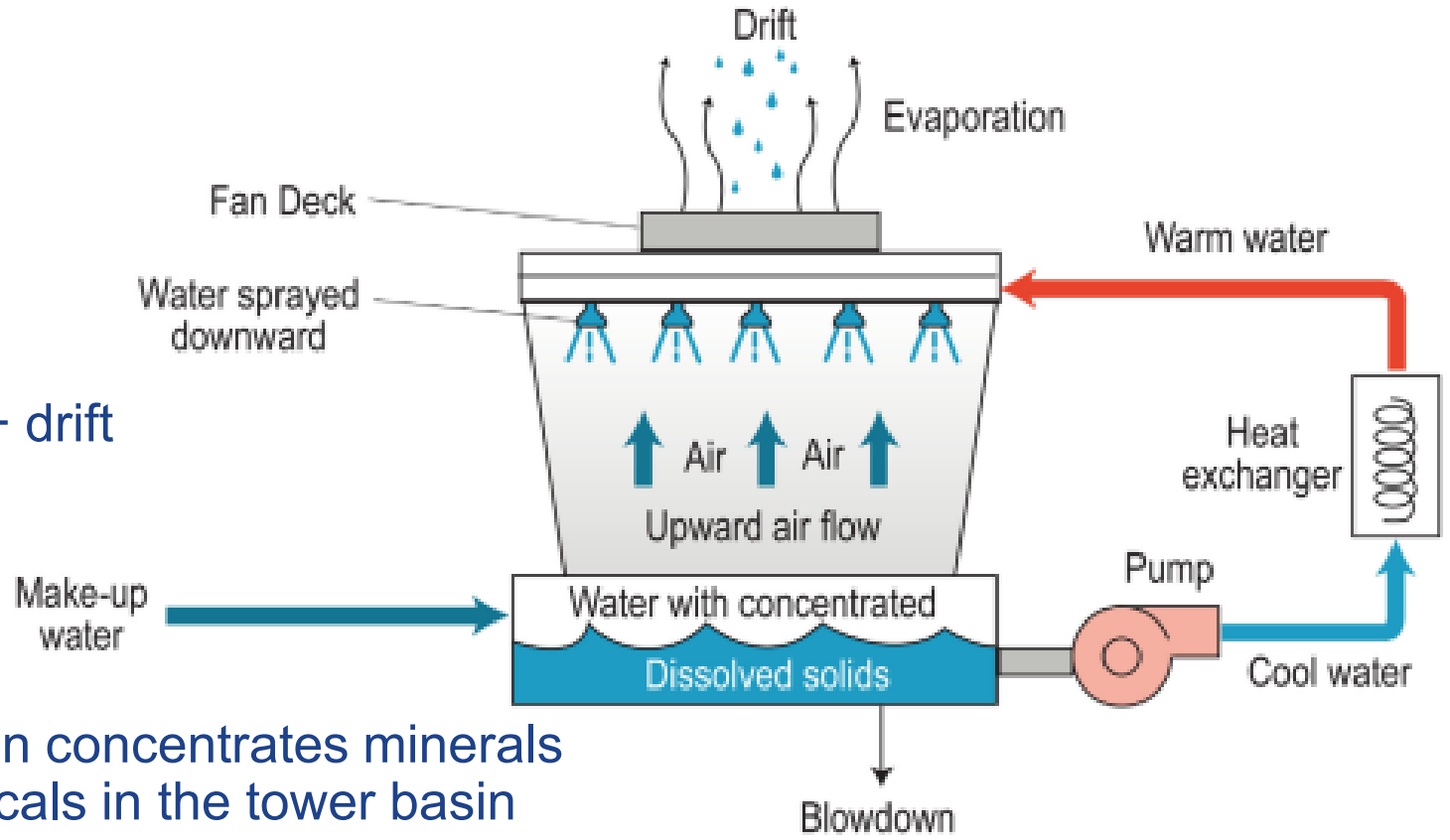
Source: U.S. Bureau and Labor Statistics

Cooling Tower Basics

Evaporation: 1 lb water ≅ 1,000 Btu

Evaporation rate ~ 1.8 gal/ton-hr

Make-up = Evaporation + Blowdown + drift



Evaporation concentrates minerals and chemicals in the tower basin

Source: DOE/PNNL-SA-75820 • February 2011

Apply water treatment programs to control scale, corrosion, biological growth, and fouling

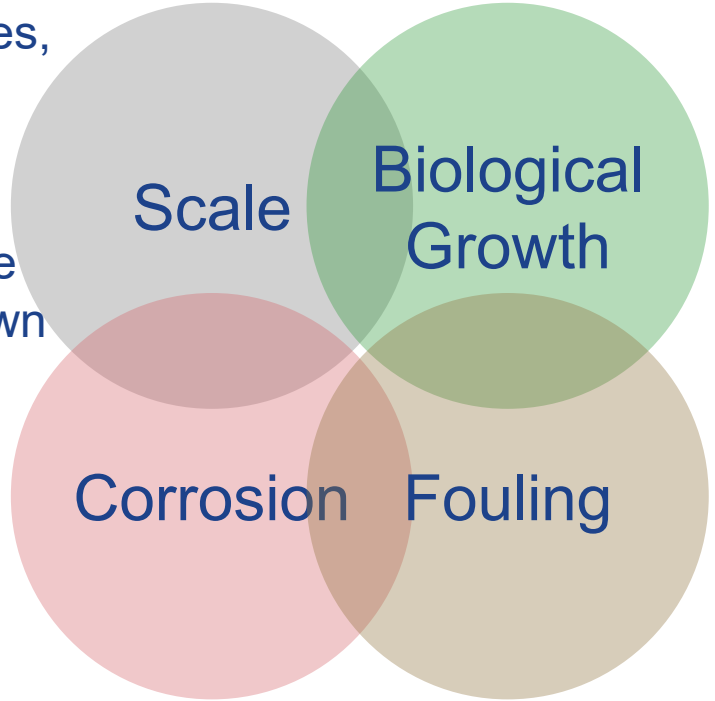
Balancing Cooling Tower Water Quality

Scale

Bad: Reduce heat transfer, plug orifices, sites for corrosion or bacteria growth
Good: Small amounts can reduce corrosion
Control: Scale inhibitors, acid, remove minerals, balanced chemistry, blowdown

Corrosion

Bad: Corrosion, reduce heat transfer, sites for biological growth
Good: None
Control: Corrosion inhibitors, balanced chemistry



Biological Growth

Bad: Potential health hazard, reduce heat transfer, plug orifices, biocorrosion, sites for corrosion or scale
Good: None
Control: Biocides, balanced chemistry, reduce light, blowdown, regular cleaning

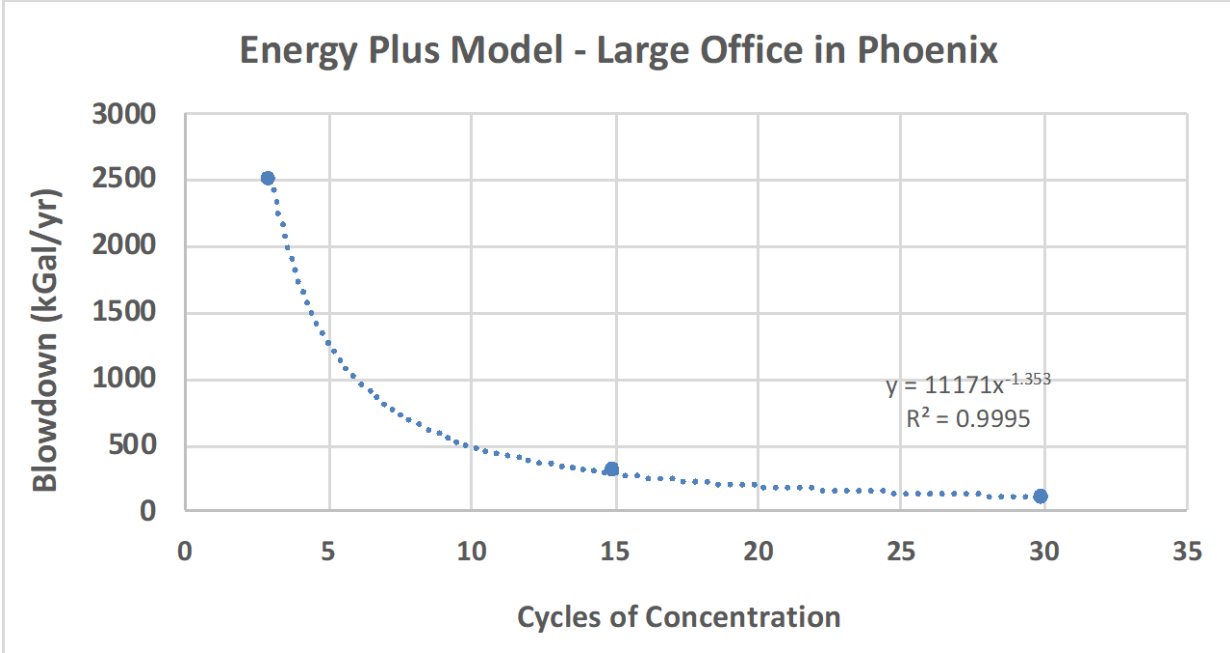
Fouling

Bad: Reduce heat transfer, plug orifices, sites for corrosion or bacteria growth
Good: None
Control: balanced chemistry, blowdown, regular cleaning

Challenging to maintain balanced water chemistry!

Cycles of Concentration

- Cycle of Concentration (CoC):
  Ratio of concentration of dissolved solids or chemical in blowdown vs make-up water
- CoC ≅ Make-up/Blowdown
- Typical CoC: 2.5 to 7
- At a CoC of 3, around 33% of cooling tower water make-up is wasted as blowdown



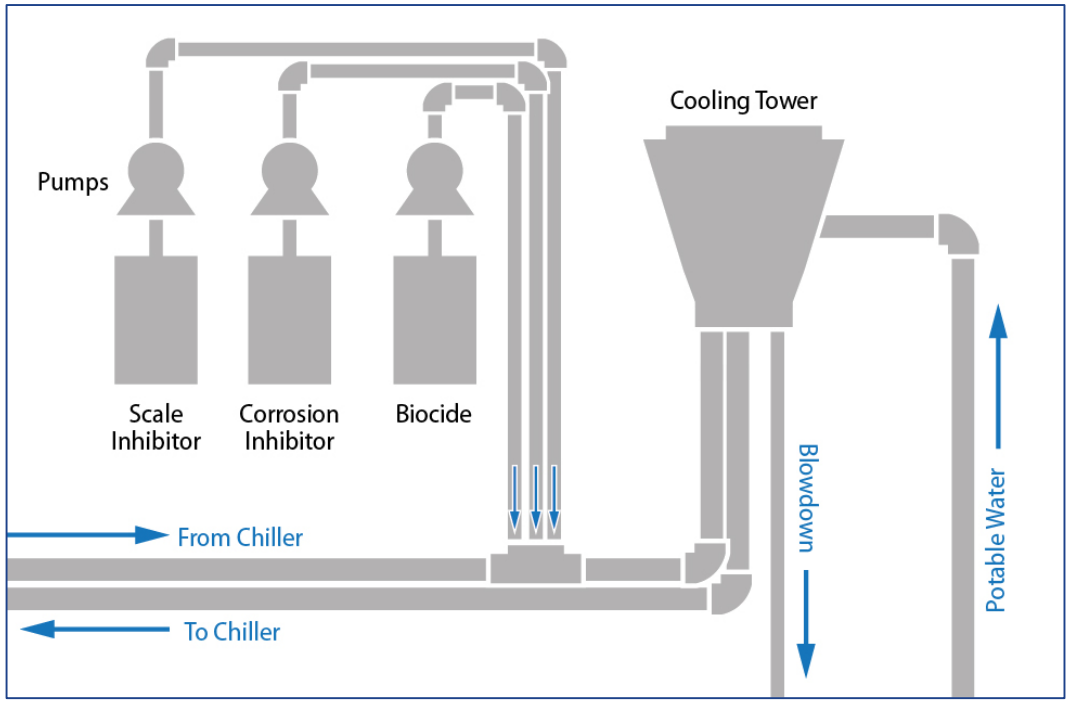
Water Treatment Technologies Tested

Four technologies tested through GSA GPG and DOE HIT programs

Technology	Building	Chillers	Cooling Towers
Strong scale inhibitor with side stream filtration	Office, 342,722 ft^2 Lakewood CO	1 900-ton 1 450-ton	2 600-ton
Salt based water softening	Office/Lab, 360,797 ft^2 Lakewood CO	2 500-ton	3 500-ton
Advanced oxidation potential	Office/Lab, 163,206 ft^2 Lakewood CO	2 250-ton	2 250-ton
Electrolysis	Office, 240,000 ft^2 Savannah, GA	2 250-ton	2 150-ton
	Office, 530,000 ft^2 Los Angeles, CA	2 800-ton 2 500-ton	4 600-ton

AWT #1 Chemical Water Treatment

- Uses a very strong scale inhibitor, new PLC controller, side stream crushed glass media filter
- Controller set 13-18 CoC's based on TDS
- Filter is backwashed for 30 seconds once a day, using 300 gallons/day



Representative diagram of system design for Building 67 (Credit: Joelynn Schroeder, NREL)

AWT #1 Water Savings and Water Quality

Water Savings

- Measured CoC ranged from 13-18
- Measured 94% reduction in blowdown
- Saved 824,448 gal/year

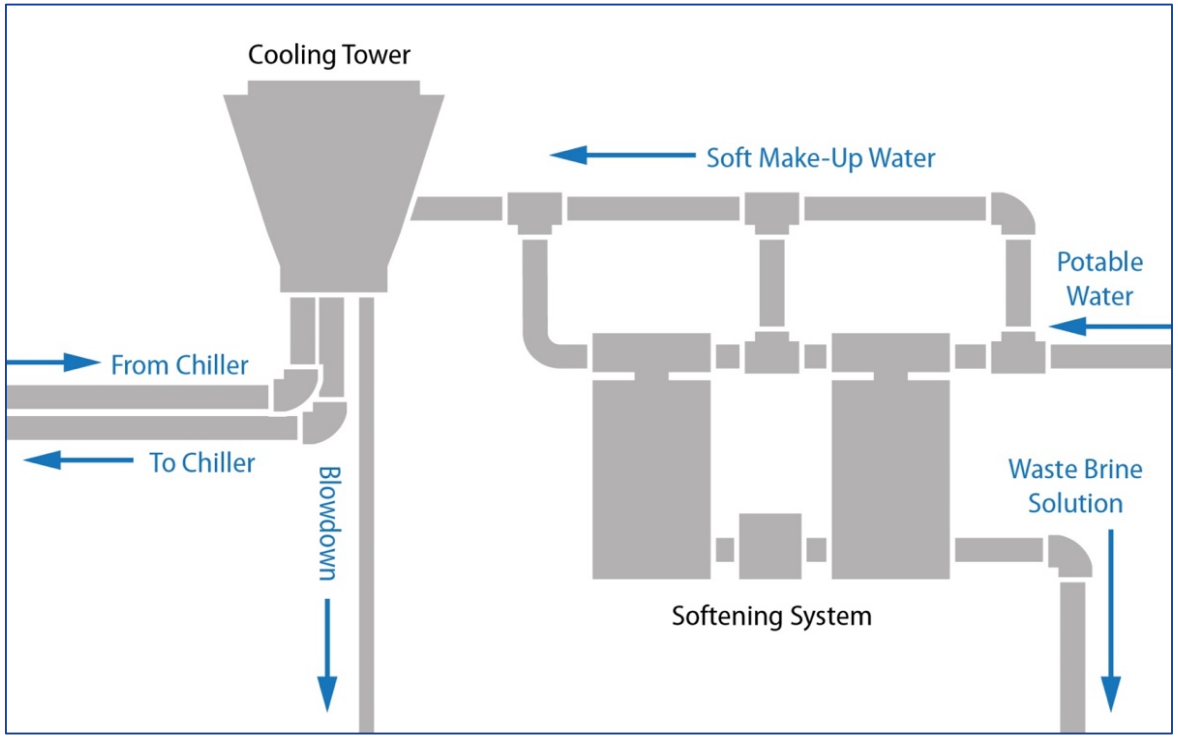
Water Quality

- Significant reduction in scaling
  - Increased run time of free cooling
- Observed improvements in water quality

Photo by Doug Baughman, U.S. General Services Administration (GSA)

AWT #2 Salt based water softening

- Water softening system removes hardness
- No need for corrosion or scale inhibitor, very little biocide
- Regeneration uses 70 gallons, 2-3 times/week in summer, 1 time/week spring / fall



Representative diagram of system layout for Building 25 (Credit: Joelynn Schroeder, NREL)

AWT #2 Water Savings and Water Quality

Water Savings

- Measured CoC ranged from 12-80
- Measured 99% reduction in blowdown
- Saved 366,640 gal in 2012 and 435,700 gal in 2013

Water Quality

- Reduction in O&M
- Increased run time free cooling
- Observed improvements in water quality

AWT #2 Controller

AWT #2 Regeneration and Brine Tank

Photos by Dylan Cutler, NREL

AWT #3 Advanced Oxidation Potential

- Uses a combination of ozone (O_3), hydrogen peroxide (H_2O_2), and/or UV lights to generate highly reactive hydroxyl (OH^-) and oxygen free radicals
- Air tube is run into cooling tower basin and pumps AOP treated air into cooling tower basin
- Elimination of scale inhibitor, corrosion inhibitor, potential elimination of biocide

AWT #3 Water Savings and Water Quality

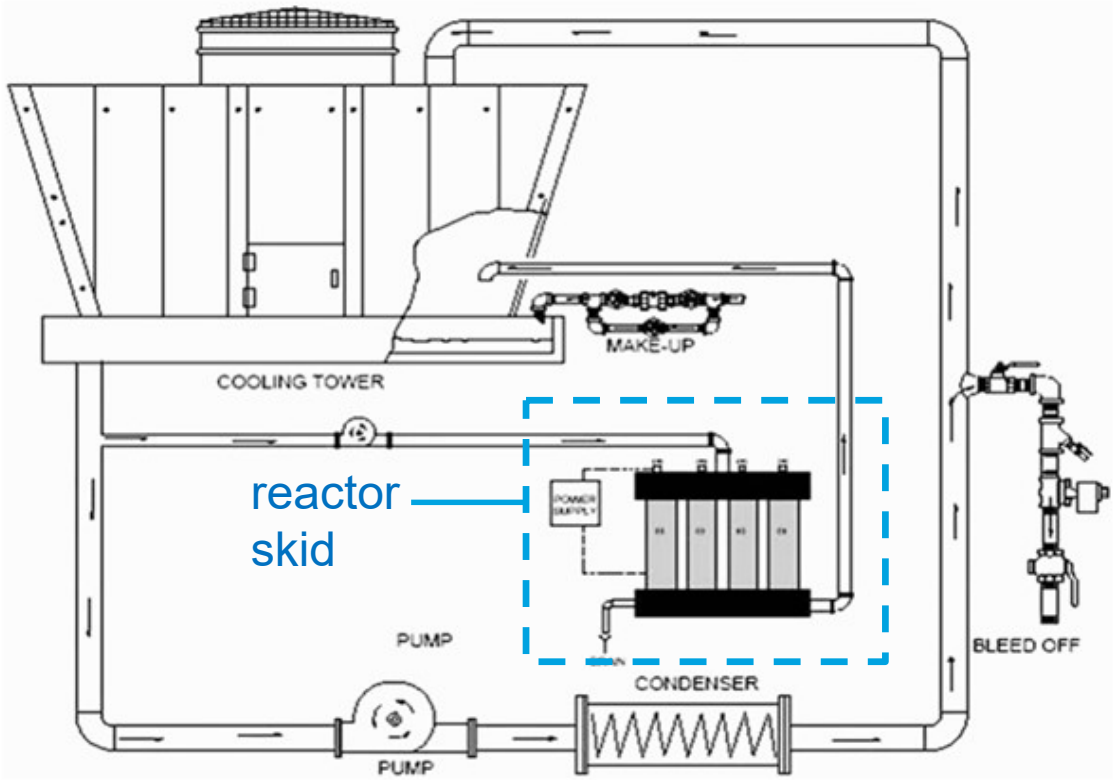
Water Savings

- Measured CoC ranged from 5.1-14.4
- 26% reduction in makeup water (blowdown not measured)
- 1,475,480 gal/year savings

Water Quality

- Realized reduction in chiller condenser tube fouling
- Elimination of scaling / corrosion inhibitor, uses small amount of biocide

AWT#4 Electrolysis



Scale control
Electro-catalytic process accelerates scale formation in the reactors
Scale is easily removed from reactors

Corrosion control
Maintains balanced pH and mineral content to minimize corrosion

Biological Growth control
Forms HOCl and Cl_2 from the chlorides in the water for biocides

AWT #4, Site #1 Water Savings and Water Quality

Water Savings

- Measured CoC > 30
- Measured 98% reduction in blowdown
- > 1 million gal saved annually

Water Quality

- No measured reduction in scaling
- Noticeable reduction in biological growth and cleaning requirements
- Observed improvements in water quality

Photo by Gregg Tomberlin, NREL

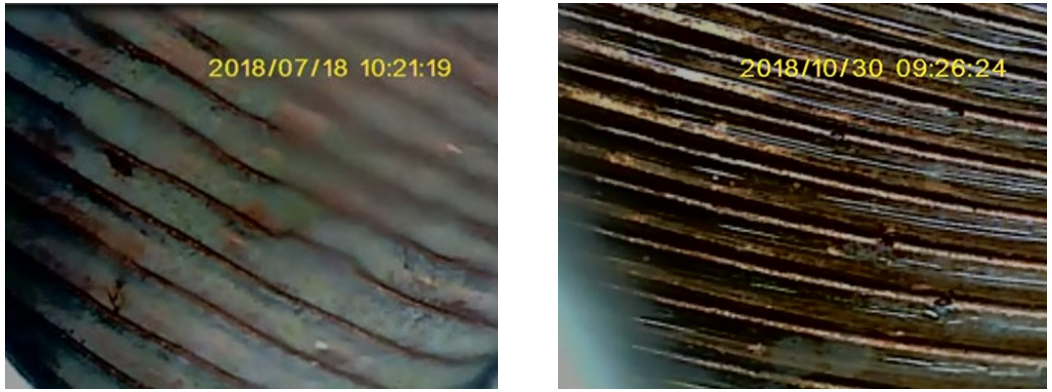
AWT #4, Site #2 Water Savings and Water Quality

Water Savings

- 80% reduction in blowdown
- 20% make-up water reduction
- > 1 million gal saved annually

Water Quality

- Noticeable reduction in scaling on condenser tubes and tower media
- Noticeable removal of existing scale from condenser tube
- Observational improvements in water quality



Before and after condenser tubes

Results Summary

Parameter	Strong scale inhibitor GSA Colorado	Salt-based water softener GSA Colorado	AOP GSA Colorado	Electrolysis Site #1 GSA Georgia	Electrolysis Site #2 LA City Hall California
Initial Cost ($)	$39,900	$29,600	$23,425	$45,340	$188,674
Cooling Tower Size (tons)	1,200	1,500	500	300	2,400
Water Savings (Gal/yr)	824,450	401,170	577,791	1,133,860	1,161,610
Water Savings (%)	24%	23%	26%	32%	20%
Water and Sewer cost ($/1,000gal)	$16.76	$16.76	$16.76	$16.76	$10.51
Water and Sewer Cost Savings ($/yr)	$13,818	$6,724	$8,846	$19,003	$15,766
Annual O&M savings ($/yr)	($3,300)	$2,768	($2,522)	($720)	$18,339
Simple Payback with O&M (yr)	3.8	3.1	2.2	3.0	5.5

- Installed costs higher than normal due to Fed Gov. added factors
- No rebates for GSA sites, $11,326 rebate for LA City Hall

Lessons Learned

Performance is Location-Specific, Best results for …

- Long cooling season
- Hard water conditions
- High water and sewer costs

Biofilm Impacts Efficiency and Corrosion

- Adequately control biological growth

Areas with significant airborne debris

- Install screening and/or tower basin sweep

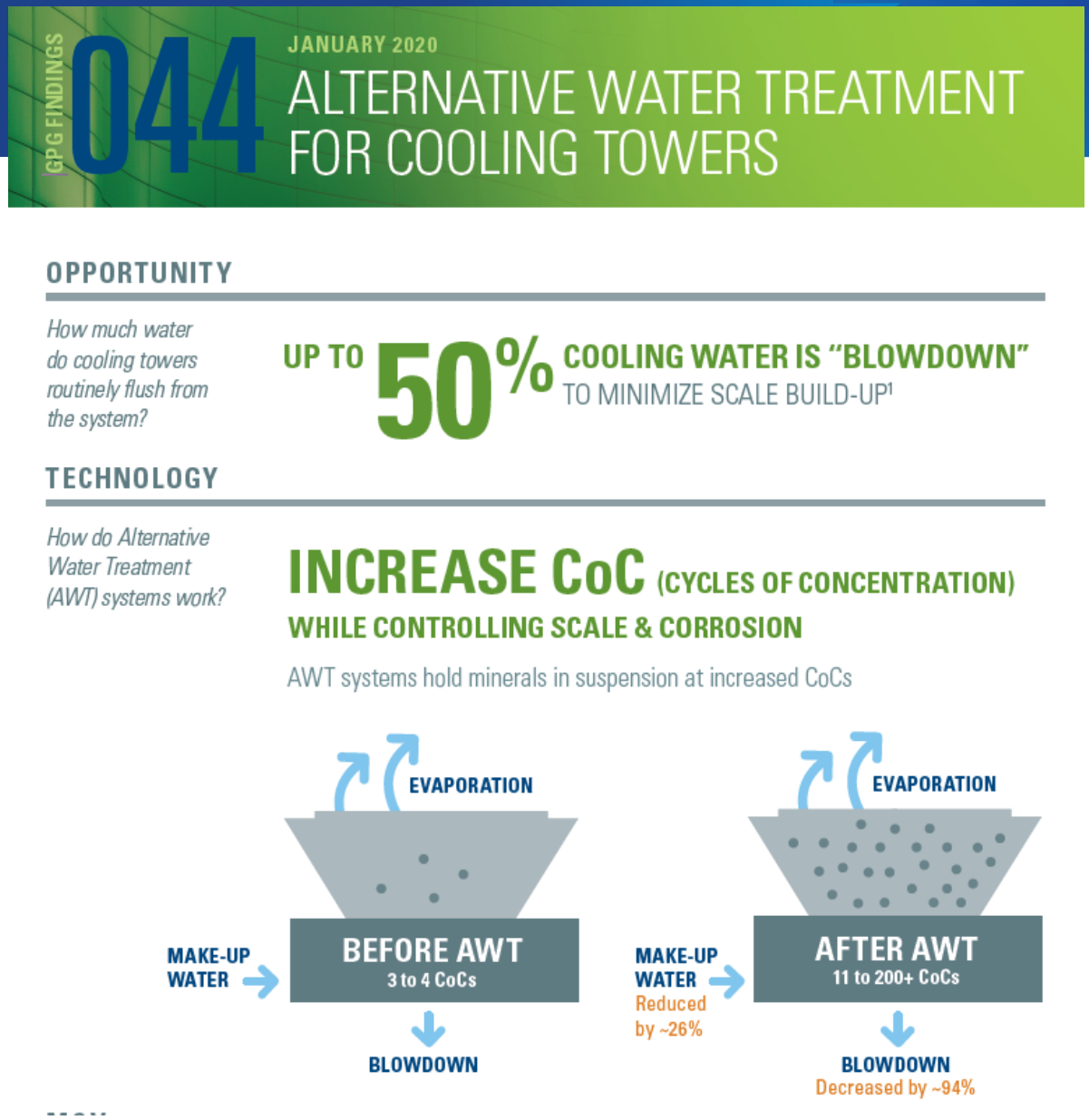
Resources

AWT: GSA Guidance for Cooling Towers

https://www.gsa.gov/governmentwide-initiatives/sustainability/emerging-building-technologies/published-findings/water/awt-gsa-guidance-for-cooling-towers

Testing and Evaluation of a Chemical Free Cooling Tower Water Treatment Technology

https://www.nrel.gov/docs/fy19osti/73911.pdf



Thank you

Questions
New challenges
New project results
Topics for next call