CITY ENERGY
A JOINT PROJECT of NRDC + IMT

WATER AUDIT GUIDANCE FOR COMMERCIAL BUILDINGS

MAY 2019

ABOUT CITY ENERGY PROJECT AND THE CITY ENERGY PROJECT RESOURCE LIBRARY

A joint initiative of the Institute for Market Transformation and the Natural Resources Defense Council, the City Energy Project supported bold yet practical ways to deploy energy efficiency at the city level to boost local economies, reduce pollution, and create healthier, more prosperous communities nationwide.

The project partnered with 20 local governments across the U.S. from 2013–2018 to design locally appropriate energy efficiency policies and programs. Building upon the past successes and innovation of cities, the City Energy Project established best-in-class practices for energy efficiency to be customized and replicated nationwide. Models and recommendations have been distilled into the City Energy Project Resource Library. This curated set of resources contains the necessary blueprints for a city government to craft and implement customized solutions to productively manage energy efficiency initiatives across commercial, multifamily, and public buildings in its jurisdiction.

For more information on the participating cities and counties in the City Energy Project, and to search the City Energy Project Resource Library, visit cityenergyproject.org.

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[CITY NAME] PHILADELPHIA

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GLOSSARY

- **gpf** – gallons per flush
- **Lpf** – liters per flush
- **gpc** – gallons per cycle
- **gpm** – gallons per minute
- **gal/d** – gallons per day
- **L /s** – liters per second
- **Btu/h** – british thermal units/hour
- **kWh** – kilowatt hours
- **MCF** – 1,000 cubic feet
- **NPV** – net present value
- **EUI** – energy use intensity
- **CBECS** - Commercial Buildings Energy Consumption Survey
- **Gal.** - gallon
- **ROI** – return on investment
- **ECM** – energy conservation measure
- **WUI** – water use intensity
- **FTE** – full-time equivalent employee
- **sq. ft.** – square foot
- **O&M** – operations and maintenance

FOREWORD

Energy audits have been conducted for many years, and there is a well-established cohort of service providers trained to perform them in accordance with standards developed by ASHRAE and others. These standards define the process and quality of work that should be achieved for energy performance audits. However, a corresponding level of industry maturity, and an understanding of what should be included, does not yet exist for auditing water performance. This document is an initial attempt to develop such guidance based on a multi-year process drawing upon input from a working group of industry experts.

Building water audits offer clear benefits to facility managers and owners, municipalities encouraging greater efficiencies throughout their service areas, and occupants of commercial and residential buildings. Water and energy efficiency upgrades can result in lower operating costs and increased comfort for building occupants. Resulting savings can also contribute to overall municipal goals.

It is vital that audits from various professionals and for different geographical locations are comparable and consistent in format to help standardize the industry. This guide provides both an outline for procedural execution of audits and a detailed format for audit reports. The goals of this document are to:

- Provide a common basis for conducting water audits.
- Define levels of effort for water audits.
- Establish a standard for water audit reports.
- Provide guidance for building owners, managers, and governments for conducting water audits.
- Serve as a guide to best practices for water auditors.

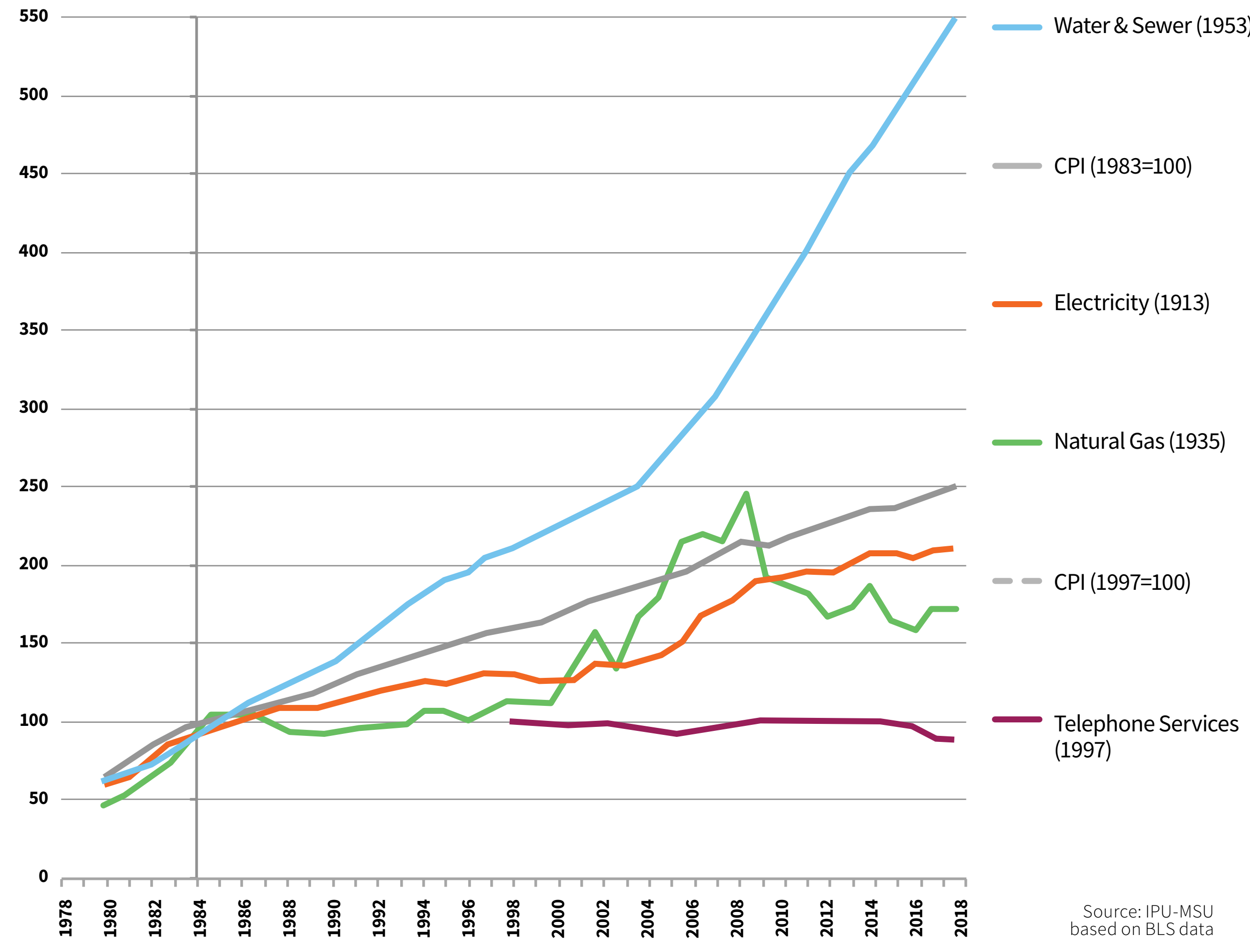
Auditors should adopt this guide as a framework for conducting thorough and consistent commercial-grade water audit. It assumes that those performing these audits will have the necessary background in water management or building water systems to conduct such an audit with minimal training. Training events to support this guide are encouraged; however, those who receive the training should not be beginners to the arena of water management.

BACKGROUND

I. THE RISING COST OF WATER AND ENERGY

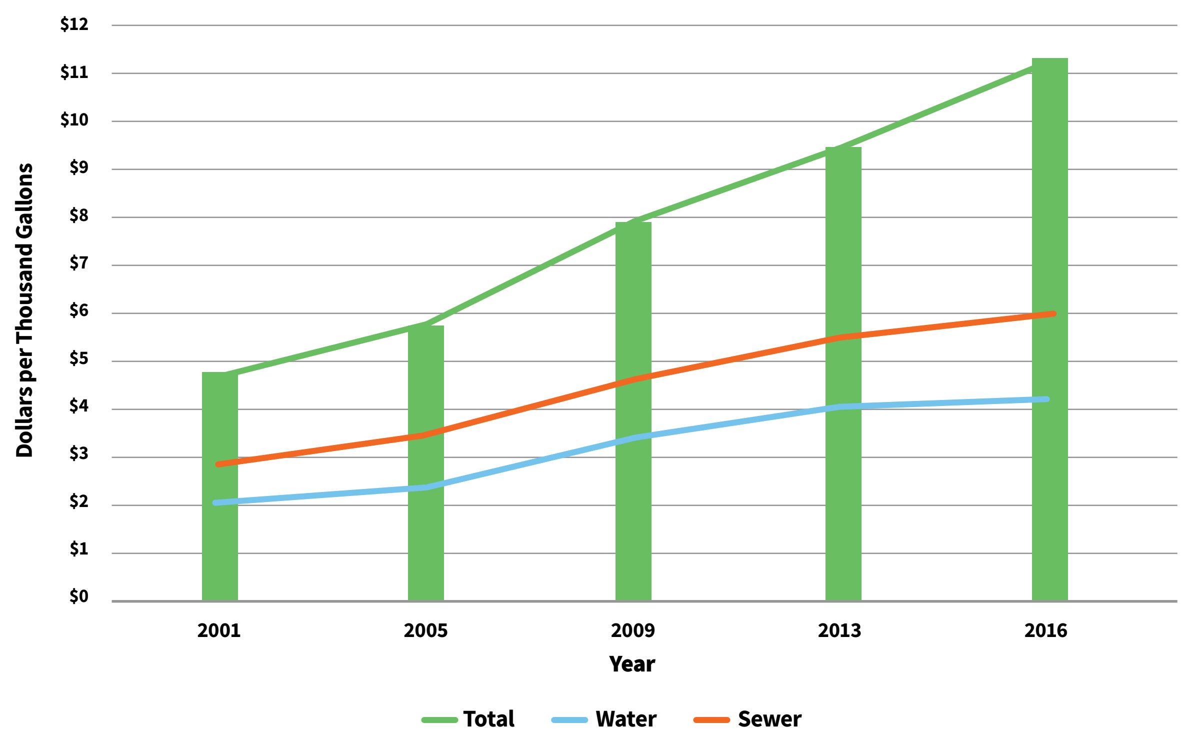
Water rates have been rising dramatically over the last several decades.[1] Based on a review of long-term history of utility consumer price indexes for all major utilities used in the United States it is clear that waste and sewer costs are escalating much faster than any other utility. Figure 1 shows consumer price index trends for utilities in the United States.

FIGURE 1. CONSUMER PRICE INDEX TRENDS FOR UTILITIES IN THE UNITED STATES



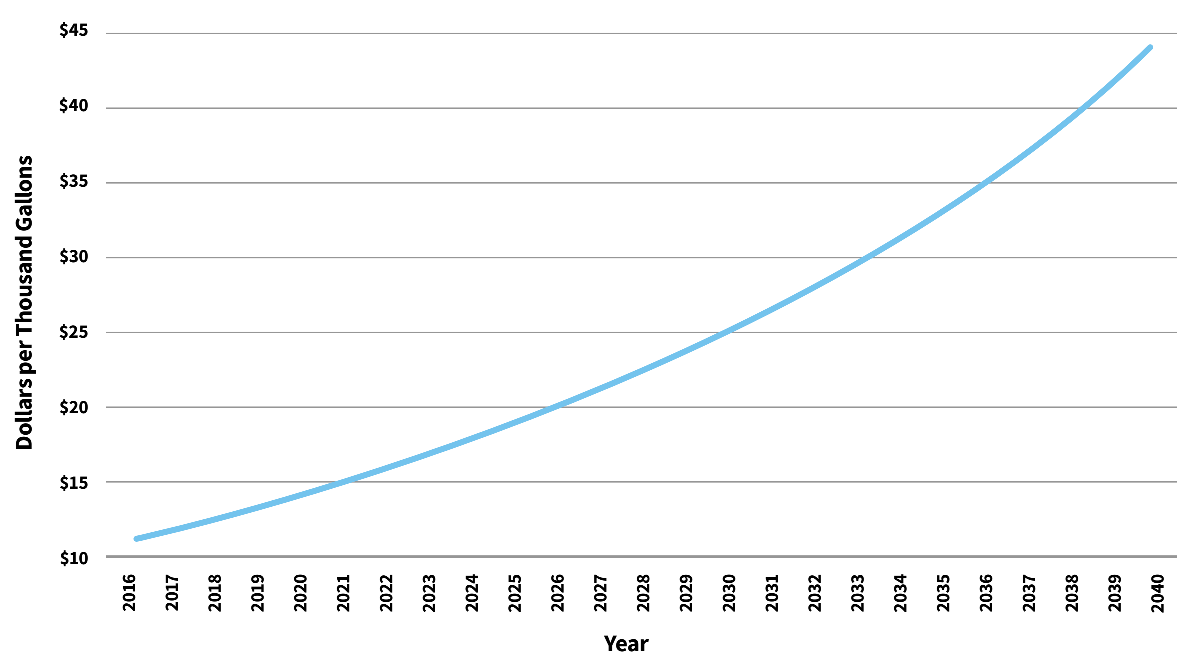
Since 2001, water rates have risen at approximately 5.9 percent per year and sewer rates have risen at 5.8 percent per year, as opposed to the overall consumer price index for urban areas of only 2.1 percent. In 2016, combined water and sewer costs averaged $11.27 per thousand gallons or 1.127 cents per gallon, almost two and a half times the cost just 15 years earlier. Figure 2 shows commercial water and sewer rates for the 50 largest cities in the U.S.

FIGURE 2. COMMERCIAL WATER AND SEWER RATES FOR 50 LARGEST CITIES IN THE U.S.[2]



With a combined water and sewer inflation rate of 5.85 percent, there is a doubling in price every 12 to 13 years. The projections are for water and sewer prices to continue to rise at near historic rates. Based on the projections there is a dramatic impact on the future costs of water: by 2030, the costs will reach $25 per 1,000 gallons, and $45 by 2040. Figure 3 shows projected water and sewer costs from 2016–2040.

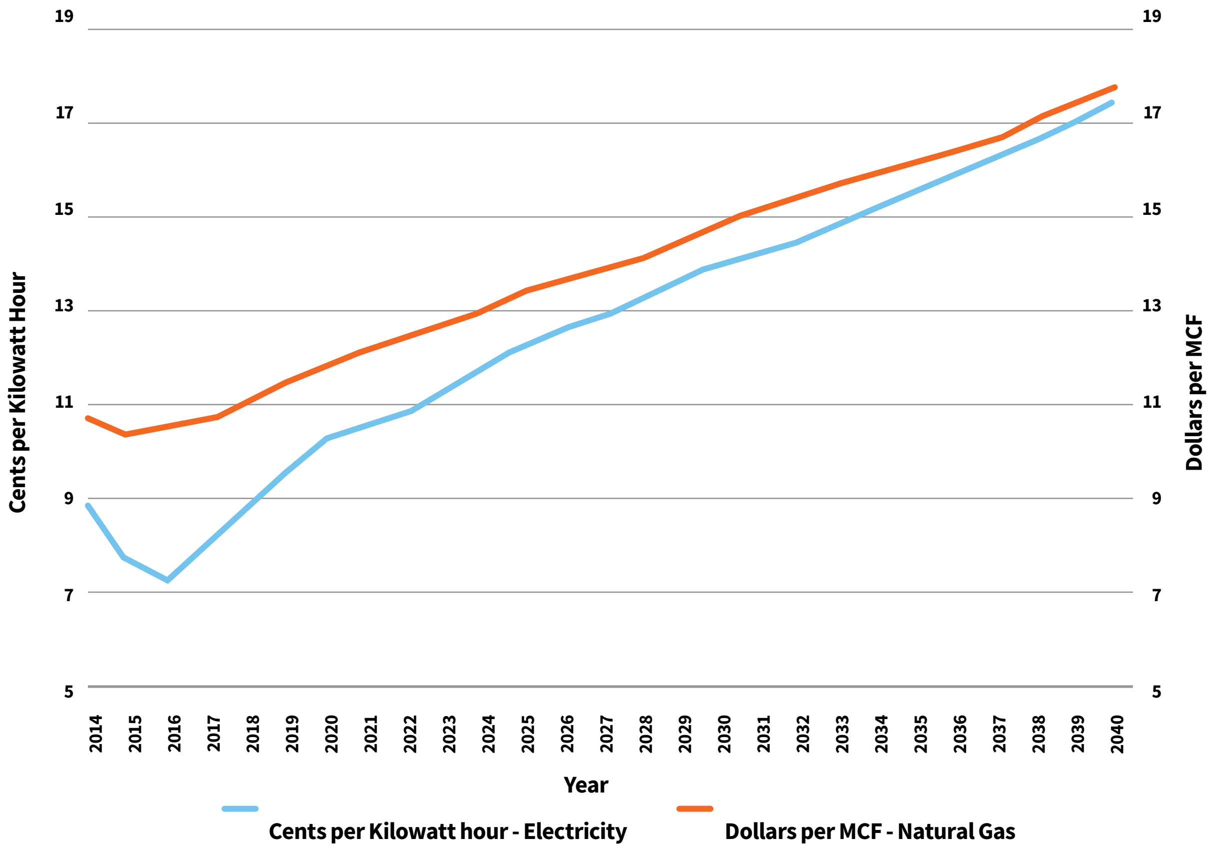
FIGURE 3. PROJECTION OF COMBINED WATER & SEWER COSTS



While situations will vary by city, these national trends illustrate how considering future costs can have a major impact on the financial viability of retrofits and other conservation measures.

By contrast, natural gas prices have declined since 2001 and electricity prices for commercial establishments have remained relatively flat. Based on constant 2015 dollars, both natural gas and electricity rates for commercial establishments will remain relatively flat over the next 35 years.[3] When consumer price index inflation is considered, average electric rates are projected to increase from about 10.6 cents per kilowatt hour (kWh) in 2016 to as much as 18 cents per kWh by the year 2040 and average natural gas rates are projected to rise from around $7.40 per thousand cubic feet (MCF) in 2016 to over $17 per MCF in 2040. Figure 4 shows the projected commercial energy prices with inflation.

FIGURE 4. PROJECTION OF COMMERCIAL ENERGY PRICES WITH INFLATION[4]



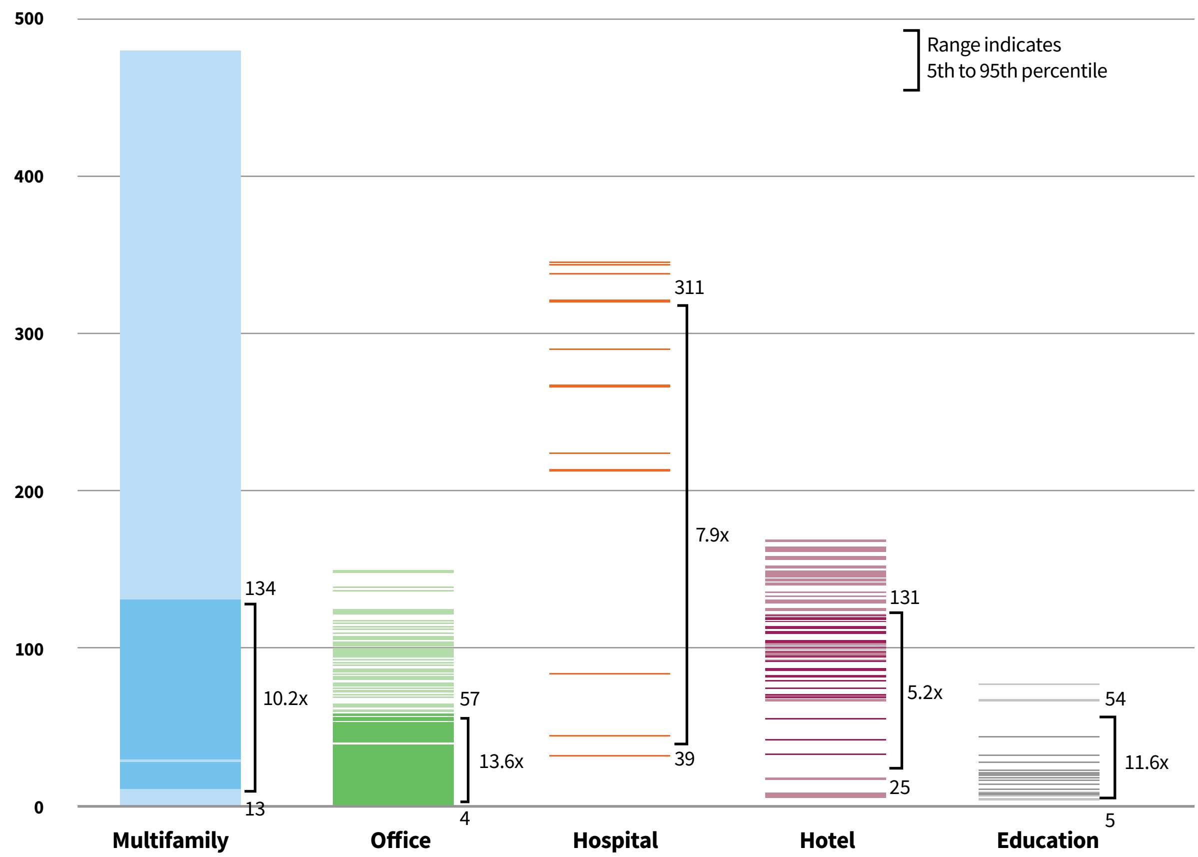
The dynamics of these price increases will have a dramatic impact on the economic viability of water and energy conservation practices. This is especially true for cases where water use may cause an increase in energy use. For example, in restaurants and food service operations hot water use throughout the kitchen simultaneously consumes energy and water. For larger facilities, cooling towers for air conditioning are often one of the largest water users. Capturing the areas where the energy-water nexus exists in any project is an important component of a thorough audit.

II. THE GROWTH OF WATER EFFICIENCY POLICIES

Water audits are the natural next step for the increasing role that local governments are now playing in regulating and improving the efficiency of their buildings. This work follows on the heels of energy efficiency policies that have changed the way we engage with energy performance in city buildings. The first policy that required benchmarking of energy performance of buildings was enacted in New York City in 2010.
Today, these policies are found in numerous cities, counties, and states.

While these benchmarking policies initially focused exclusively on energy performance, there is increasing recognition of the benefits of monitoring water performance. Results from the New York City Local Law 84 Benchmarking Report for 2014 shown in Figure 5 show that the variation in water use intensity between top and bottom performing buildings is even greater than the variation seen in energy use. The worst performing multifamily properties (those at the top fifth percentile in consumption) used 10.2x more water than those at the bottom fifth percentile in consumption, while for office buildings the spread was 13.6x. These values compare to a corresponding spread in energy use intensity (EUI) of 3.3x for multifamily properties and 7.0x for offices.

FIGURE 5. WATER USE INTENSITIES FOR NEW YORK CITY BUILDINGS

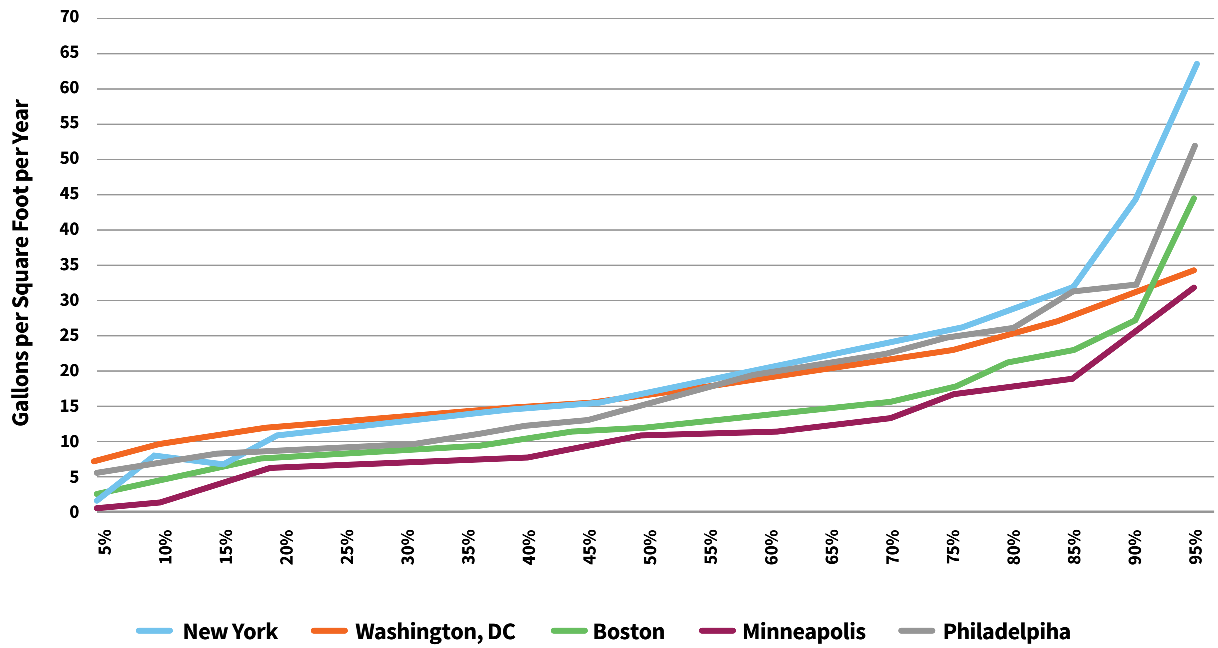


While building energy use in the United States has been benchmarked for decades, the water efficiency community has a much smaller footprint in considerations of efficiency. Australia, Canada, New Zealand, and many European countries have benchmarking water guidance for their commercial buildings, including information on what constitutes an efficient operation versus the average or median use.

To this end, it is important to point out that median and mean values are useful, but the range of water use per unit—square foot, person, room, etc.—is important in understanding the water-saving potential. Figures 6 and 7 illustrate this point.

Figure 6 shows office water use per square foot from five cities that have requirements that commercial entities use the U.S. Environmental Protection Agency's ENERGY STAR Portfolio Manager Process to benchmark both energy and water use.

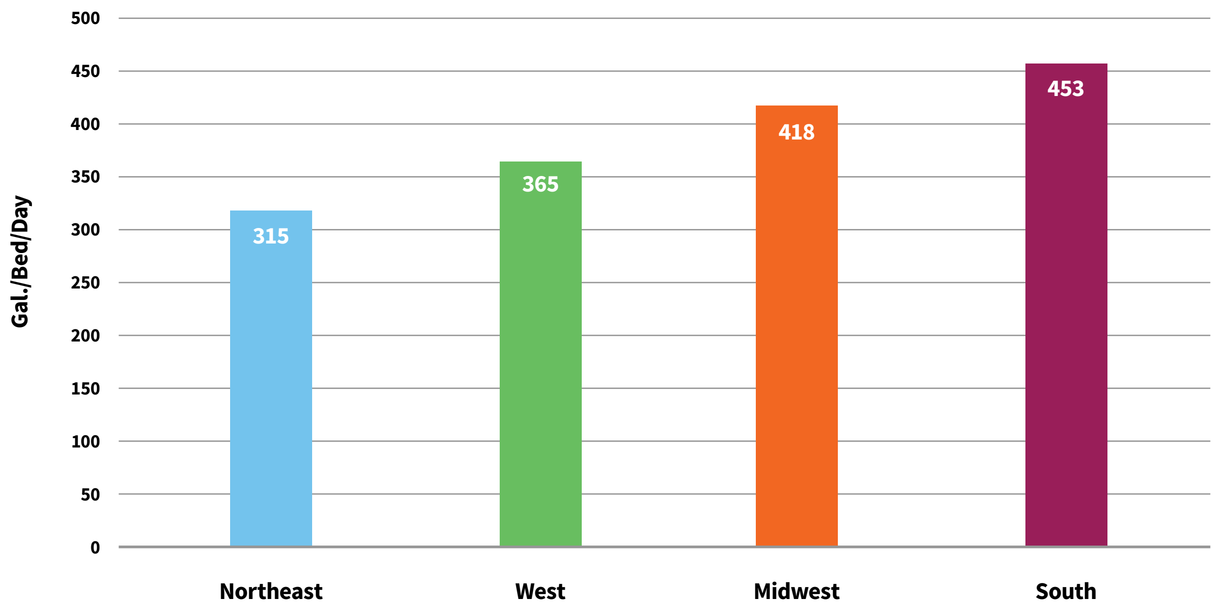
FIGURE 6. OFFICE BUILDING WATER USE BASED ON EPA PORTFOLIO MANAGER



As illustrated by Figure 6, the median value is only part of the picture. The buildings in the 85+ percent range show significantly higher water use per square foot compared to the median. This pattern is seen for most types of commercial activity.

Figure 7 illustrates water use in hospitals. The purpose of this benchmark information is to show that there is high variability in water use based on geography. For example, hospitals in the South have much higher air conditioning loads and therefore much higher cooling tower water use.

FIGURE 7. CBECS 2007 HOSPITAL USE GALLONS PER BED PER DAY [5]



Benchmarking of water performance clearly shows that there are efficiency benefits to be gained, but benchmarking alone simply quantifies the magnitude of the opportunity; it does not identify what changes should be made to reap those potential benefits. That is the role of a water audit.

III. WATER EFFICIENCY ACTIVITIES IN ATLANTA

Atlanta is a major metropolitan city making gains in addressing water conservation. This is attributable to several factors. First, the city of Atlanta currently has the highest combined water and wastewater rates of any major city in the nation. Second, the city's drinking water comes from the Chattahoochee River. This is notable because the river supplies 70 percent of the surrounding metro area's drinking water needs while also having the smallest watershed of any major metropolitan area in the country. The combination of high rates, reliance upon surface water from a small watershed, and the cyclical nature of drought in the region makes water conservation crucial for Atlanta.

In response to these circumstances, a number of water-focused initiatives have been deployed. Atlanta is a member of the Metropolitan North Georgia Water Planning District (the District), which was created in 2001 and has enacted requirements for water efficiency across the Metro area via its water management plan. The District's toilet rebate programs, for example, are responsible for savings of 2.4 million gallons of water per day across the Metro area.

The success of the Atlanta Better Buildings Challenge program, a voluntary program launched in 2011 in which building owners pledge to reduce their energy and water consumption 20 percent by 2020, has received national recognition from the U.S. Department of Energy. As of 2018, over 114 million square feet of building space from 600 properties had been committed to the Challenge. By 2017, the portfolio had achieved energy and water efficiency improvements of 17 percent, with some participating properties reducing their water consumption by as much as 50 percent.

In April of 2015, the city of Atlanta became the first city in the U.S. to require regular water audits for commercial buildings that are 25,000 square feet or larger, in accordance with its Commercial Buildings Energy Efficiency Ordinance. Following the passage of this ordinance, the city of Atlanta, in collaboration with the City Energy Project (a joint initiative of the Natural Resources Defense Council and the Institute for Market Transformation), began the process of developing a guidance document for water conservation audit professionals to use when conducting these audits.

The city of Atlanta and the City Energy Project partnered with H.W. Hoffman, Southface Energy Institute, and numerous local and national partners to develop a framework for a water efficiency assessment to be adopted as the required standard for the city of Atlanta's water audit requirement. This document is the result of that coordinated effort and is a framework for conducting audits that are both consistent in content and in depth of analysis. The framework is designed to serve as an adoptable model for cities throughout the U.S. as they enact similar building water efficiency ordinances.

OVERVIEW

I. SCOPE AND INTENT OF THE AUDIT

SCOPE

This document shall apply to existing commercial buildings, building sites, and associated systems and equipment.

Many of the procedures herein will be applicable to industrial and multifamily buildings as well, and may be adapted to meet the needs of those building types.

INTENT

To provide the facility owner with a comprehensive overview that quantifies how water is being used, what opportunities exist for reducing water use, and the potential payback for each opportunity identified. To do this, the audit report shall provide the following information:

1. List all water-using activities on a property.
2. Information on when, where, how, how much, and by whom water is used for each water-using activity on a property.
3. Quantification of costs associated with each water-using activity.
4. Identification of potential water conservation measures associated with each water-using activity.
5. Estimation of the savings volumes for each water conservation measure.
6. Estimation of return on investment (ROI) for each water conservation measure.
7. Concise summary of savings opportunities with a cost benefit analysis for each water conservation measure.

Where the audit report is required to be submitted to the city, it will also provide the city with information to derive benchmarking data, efficiency program savings estimates, and other information identified by the city as mandatory.

Information will be gathered from the local water and wastewater utilities, from the facility being audited, from benchmarking through ENERGY STAR Portfolio Manager, from public records, and from the knowledge of the auditor.

II. DESCRIPTION OF AUDIT LEVELS

Water audits, like energy audits, can vary in both detail and purpose. For energy, ASHRAE “Procedures for Commercial Building Energy Audits” defines three levels of audits. Level 1 consists of a brief facility survey to identify possible energy savings and costs for low-cost and no-cost improvements in energy efficiency. Level 2 provides a more detailed survey and analysis of opportunities, including a breakdown of all savings and costs for energy improvements and specific energy savings opportunities including estimates of ROI. Level 3 is the type of audit done prior to capital-intensive projects that provides detailed analysis and savings and cost calculations plus detailed construction information. Table 1 presents details on Level 1, Level 2, and Level 3 energy audits.

TABLE 1. TYPE OF ENERGY AUDITS

TYPE OF AUDIT	DESCRIPTION
Level 1	• Brief on-site survey of the building • Savings and cost analysis of low-cost and no-cost energy conservation measures (ECMs) • Identification of potential capital improvements meriting further consideration
Level 2	• Identification of ECMs requiring more thorough data collection and analysis • More detailed building survey • Breakdown of energy use • Savings and cost analysis of all ECMs
Level 3	• Attention to capital-intensive projects identified during the Level 2 audit • More detailed field analysis • More rigorous engineering analysis • Cost and savings calculations with a high level of accuracy

For water conservation, a similar table of audit levels is presented in Table 2. The water audit described in this document will parallel the Level 2 water audit described in Table 2, as Level 2 is recommended as the base audit level. A city, utility, or building owner can opt to amend this to achieve a Level 1 or Level 3 audit based on need.

TABLE 2. WATER CONSERVATION AUDITS

LEVEL 1	
Focus of Audit	• Brief on-site survey • Approximate estimate of savings and costs • Identify no- and low-cost measures • Identify priorities for Level 2 and 3 audits
Inputs	• Building use and square footage • Demographics • Utility bills • Submeter data • Site drawings and building floor plans • Aerial imaging • Phone interviews
Outputs	• Summary of water-using equipment and systems • Building water use intensity as compared to similar buildings • Summary of specific issues or needs • Specific water conservation measures identified • Estimate of savings and costs for water conservation measures

LEVEL 2	
Focus of Audit	• Water consumption by end use breakdown • More detailed estimate of savings potential • Practical water efficiency measures based on owner's economic criteria • Proposed changes to operations and maintenance
Inputs	• Level 1 items • Identification and description of water-using equipment models, age, condition, operational procedures, settings, and water-using characteristics • Measurement of flow rates, use estimates for all water-using equipment and systems
Outputs	• Level 1 items • Breakdown of water use by use area • Calculations for savings and costs for all water conservation measures • Benefit and cost analysis estimates including water, wastewater, water/wastewater treatment, and all associated energy costs such as heating, pumping, and treatment • List of potential capital-intensive improvements

LEVEL 3	
Focus of Audit	• Detailed analysis and monitoring to evaluate water use by subsystem • Investment-grade estimates of savings potential • Evaluation of capital-intensive measures
Inputs	• Level 2 items • Measurement of all HVAC and other non-plumbing water-using equipment Includes an as-built listing of all water-using equipment and systems
Outputs	• Level 2 items • Financial evaluation of capital investment and projected savings • Water-using equipment list and system descriptions with manufacturers' product specifications • Detailed summary report including water-using system interactions and the value of combining measures

III. AUDIT PROCESS

The purpose of the water audit is to provide facility management staff and building owners with a guide of how to reduce water and all associated costs. The audit process focuses on four main phases: data collection, site visit, analysis, and report. Each phase builds on the information from the previous, leading to a comprehensive water-use report for the city and owner to evaluate the water use and potential upgrades available to the property.

IV. REPORT FORMAT AND CONTENT

The Water Audit Report is a tool to allow building owners to understand opportunities to make decisions on capital upgrades to their facility.

Uniformity of format is important to ensure that different auditors are consistent in how they report the results of the audit. The following outline contains the elements that make up a complete audit report and should be provided by all auditors:

1. Executive summary
    - Basic building and site visit information
    - Total annual water use
    - Estimated savings from water conservation measures
    - Estimated cost and simple payback
2. Facility description
    - Property and building overview
    - Water use characteristics
    - Comparison to similar facility water use
3. Description of findings and proposed water saving measures
    - Site visit report
        - » Status of all water end-uses from site walk through
        - » Pictures where necessary
    - Water use balance
    - Proposed conservation measures
    - Cost-benefit analysis
4. Appendices
    - Data collection sheets and calculations
    - Copies of water and wastewater bills
    - Interview notes
    - All photographs from site visit

EXECUTING A WATER AUDIT

For cities that have mandated buildings must undergo a water audit, the city or its representative will maintain a list of facilities that are required to perform water audits and will provide these facilities with a timeframe in which audits must be completed. It is the facilities' responsibility to identify, contact, and choose an audit firm or qualified individual to perform a comprehensive water audit and to schedule the audit.

Each facility undergoing a water audit needs to be fully informed of the process, including specific city/utility requirements; how information gleaned from the audit will be used; and how sensitive information will be safeguarded. Facilities should also be provided with contacts at the city who can address issues such as schedules to complete work and the level of assessment to be conducted.

Auditors should be provided with the full content of this document and appendices; city/utility contact information; procedures for providing audit findings and reporting for review, privacy and confidentiality requirements; and reporting orders and methods.

I. DATA COLLECTION

Proper facility characterization is essential. This will provide the basis for comparison with similar facilities and in the breakdown of how water is used. An auditor is expected to complete the following before the site visit to be adequately familiar with the building to complete the audit.

FACILITY DESCRIPTION

The facility description is a key component to providing data and information needed to quantify potential savings and upgrade costs. This information will provide input for the demographics, physical properties, and description of water-using equipment and systems that will be needed to quantify water use, to benchmark use per unit of operation, and to provide a framework for understanding the unique features of the facility.

Building Identifying Information

This information is basic information about the building that is common to all types of buildings and should include the following at a minimum: owner, address, lot number(s), year of construction, and year of major renovation. It must be included in the audit report.

Building Areas, Dimensions and Facility Type

This section includes a narrative description of the facility's major use, as well as a listing of other uses in the facility. The auditor will provide a table showing the percent of occupied space for each activity identified by the building types provided in Table 3 for each activity occupying more than 15 percent of the occupiable floor space, plus all high water-using facility types discussed below.

Table 3 is a list of facility types to capture building type identification and water use characteristics. The nomenclature in Table 3 should be use consistently throughout the audit report.

TABLE 3. BUILDING FACILITY TYPE[6]

BUILDING TYPE	DEFINITION	SUBCATEGORIES
Education	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly."	• Elementary or middle school • High school • College or university • Preschool or daycare • Adult education • Career or vocational training • Religious education
Food Sales	Buildings used for retail or wholesale of food.	• Grocery store or food market • Gas station with a convenience store • Convenience store
Food Service	Buildings used for preparation and sale of food and beverages for consumption.	• Fast food • Restaurant or cafeteria • Bar • Catering service or reception hall • Coffee, bagel, or doughnut shop • Ice cream or frozen yogurt shop
Health Care (Inpatient)	Buildings used as diagnostic and treatment facilities for inpatient care.	• Hospital • Inpatient rehabilitation
Health Care (Outpatient)	Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building).	• Medical office (see previous column) • Clinic or other outpatient health care • Outpatient rehabilitation • Veterinarian

BUILDING TYPE	DEFINITION	SUBCATEGORIES
Lodging	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	• Motel or inn • Hotel • Dormitory, fraternity, or sorority • Retirement home • Nursing home, assisted living, or other residential care • Convent or monastery • Shelter, orphanage, or children's home • Halfway house
Mercantile	Buildings used for the sale and display of goods other than food. Shopping malls comprised of multiple connected establishments.	• Retail store • Beer, wine, or liquor store • Rental center • Dealership or showroom for vehicles or boats • Studio/gallery • Enclosed mall • Strip shopping center
Multifamily	A building or structure that is designed to permanently house several different families in separate housing units. Buildings where residents are transient or are provided services are more likely categorized as "Healthcare (Inpatient)" or "Lodging."	• Apartment building • Condominium

BUILDING TYPE	DEFINITION	SUBCATEGORIES
Office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient healthcare building).	• Administrative or professional office • Government office • Mixed-use office • Bank or other financial institution • Medical office (see previous column) • Sales office • Contractor's office (e.g. construction, plumbing, HVAC) • Non-profit or social services • City hall or city center • Religious office • Call center
Public Assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	• Social or meeting (e.g. community center, lodge, meeting hall, convention center,senior center) • Recreation (e.g. gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports) • Entertainment or culture (e.g. museum, theater, cinema, sports arena, casino, night club) • Library • Funeral home • Student activities center • Armory • Exhibition hall • Broadcasting studio • Transportation terminal
Public Order and Safety	Buildings used for the preservation of law and order or public safety.	• Police station • Fire station • Jail, reformatory, or penitentiary • Courthouse or probation office

BUILDING TYPE	DEFINITION	SUBCATEGORIES
Religious Worship	Buildings in which people gather for religious activities, (such as chapels, churches, mosques,	
Service	Buildings in which some type of service is provided, other than food service or retail sales of goods	• Vehicle service or vehicle repair shop • Vehicle storage/ maintenance (car barn) • Repair shop • Dry cleaner or laundromat • Post office or postal center • Car wash • Gas station • Photo processing shop • Beauty parlor or barber shop • Tanning salon • Copy center or printing shop • Kennel
Warehouse/Storage	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	• Refrigerated warehouse • Non-refrigerated warehouse • Distribution or shipping center
Other	Buildings that are industrial or agricultural with some retail space; buildings having several different commercial activities that, together, comprise 50 percent or more of the floorspace, but whose largest single activity is agricultural, industrial/ manufacturing, or residential; and all other miscellaneous buildings that do not fit into any other category.	• Airplane hangar • Crematorium • Laboratory • Telephone switching • Agricultural with some retail space • Manufacturing or industrial with some retail space • Data center or server farm
Vacant	Buildings in which more floorspace was vacant than was used for any single commercial activity at the time of interview. Therefore, a vacant building may have some occupied floorspace.	

In many cases, a facility contains several types of operations. Where a property contains multiple facility types, note the percent of the total occupiable space for those facilities occupying more than 15 percent of the total space. In addition, the table should include the following types of high water-use operations and the percentage of floor space they occupy.[7] High water-use intensity (WUI) operations that should always be noted even if they occupy less than 15 percent of floor space include:

- All food service operations
- All medical facilities
- Laundry operations
- Pools and spas
- All other operations using more than 1,000 gallons of water a day

Where a campus is being audited, each individual building should be accounted for and the aggregate data should also be presented.

Equivalent FTE Days of Use

Benchmarking water use per person depends on the type and function of the facility. Places that employee people in a typical hourly manner such as offices, retail of all kind, and many other types of facilities, should base their water use on equivalent full-time employee (FTE) days.

All establishments have employees, staff, and owners, so FTE analysis applies to all audits. For this effort, a FTE is defined as one person working 245 eight-hour days per year. This allows for a five-day week minus weekends, vacation, and sick leave. This equals 1,960 hours a year, or 245 days at eight hours a day, which is the equivalent to 49 weeks of work per year. If a facility has part-time employees, their time worked (total hours per year) times the number of part-time employees will need to be divided by 1,960 hours to obtain the FTE. FTE calculations should be captured in a table in the final audit report.[8]

Equations

$$\text{FTE Hours} = n \times \text{hrs/wk} \times \text{wk/yr}$$

n = number of full-time employees
hrs/wk = number of hours worked in a week
wk/yr = number of weeks worked in a calendar year

$$\text{FTEp Hours} = np \times \text{hrs/wk} \times \text{wk/yr}$$

n = number of part-time or seasonal employees
hrs/wk = number of hours worked in a week
wk/yr = number of weeks worked in a calendar year

$$\text{FTE} = \text{FTE Hours} + \text{FTEp Hours} / 1960$$

$$\text{FTE Days} = \text{FTE} \times 245$$

In addition to employees, most facilities have other types of people that use water in the building on a regular basis. Building types with additional users should account for both FTEs and other user groups. Table 4 summarizes the basic demographic types of people that use water in commercial and institutional operations.

TABLE 4. FACILITY AND OCCUPANT TYPES IN COMMERCIAL AND INSTITUTIONAL OPERATIONS

FACILITY TYPE	OCCUPANT TYPE				
	Employees	Students	Patients	Customers/ Guests/Visitors	Residents
Education	X	X			
Food Sales	X			X	
Food Service	X			X	
Healthcare (Inpatient)	X		X	X	
Healthcare (Outpatient)	X		X		
Lodging	X			X	X
Mercantile	X			X	
Multifamily					X
Office	X				
Public Assembly	X			X	
Public Order and Safety	X			X	X
Religious Worship	X			X	
Service	X			X	
Warehouse/Storage	X			X	
Other	X			X	
Vacant					

Other user groups such as students, customers, visitors, residents, and patients will not be required to be converted to equivalent FTEs. These users will be accounted for in the buildings estimated water use described in the section, Estimate Water Use.

If the auditor elects to convert students and visitors for schools to FTE equivalents the following information should be taken into consideration and will not be equivalent from school to school: hours in school day, days in school year, absentee rate for students, and after school activities and events.[9]

BUILDING PLAN REVIEW

Building owners should supply the auditor with as-built drawings, including any renovations, of the existing building. The auditor will use the drawings as a baseline to begin to identify water-using activities and create an initial count of fixtures and systems that will be verified in the field visit. Plans will be reviewed to determine water-using equipment and systems types, flush or flow rates, locations in building, and total equipment and system counts.

Develop List of Water End Uses

Fixture, equipment, and system counts should be derived from the plan review and be recorded. These counts will serve to develop a sampling plan, begin to estimate building water use, and compare water and wastewater bills. The list will be checked against the site visit data to ensure an accurate representation of the building. Areas of use commonly found in commercial buildings and typical end uses are identified in Table 5.

TABLE 5. TYPICAL END USE IN COMMERCIAL FACILITIES

AREA OF USE	TYPICAL END USES
Domestic	Water closets, urinals, bidets, trap primers, showers/tubs, lavatories, sinks, drinking fountains
Laundry	Residential clothes washers, coin & card clothes washers, all other types of commercial laundry and dry cleaning equipment
Heating and Cooling	Water heaters, hot water or steam boilers, humidification, cooling towers, single pass cooling
Food Service	Ware washing, sinks, pre-rinse spray valves, steamers and combination ovens, garbage disposers, hood washing systems, refrigeration and freezing, ice machines, food thawing, vegetable and fruit washing, floor hose
Medical/Lab Equipment	Autoclaves and sterilizers, washer-disinfectors, lab hood washers, vacuum pumps, equipment cooling, X-ray equipment, kidney dialysis, animal cage washers, animal care, hydrotherapy
Landscape Irrigation	Irrigation systems and controllers, all types of watering systems
Water Features	Pools, spas, fountains, ornamental ponds
Water Treatment	Reverse osmosis, filtration, softening, ion exchange
Outdoor Cleaning	Car and vehicle washes of all kinds, sidewalk and driveway washing, pressure washing, dust control, outdoor hose
Industrial Processes	Plating baths, washing systems, surface cooling systems, cutting surfactants, blend or dilution use, drinking or distilled water bottling
Alternate Sources	Reclaimed water, rainwater harvesting, air conditioner condensate, filter backwash water, water recycle systems of all kinds, foundation drain water
Cleaning and Other Uses	Mop sinks, floor cleaning machines, water broom, any use not mentioned above

For each of the areas of use identified within a building there are specific types of water consuming systems and equipment that will most likely be installed. Not all end uses will present a water-saving opportunity, but as part of the evaluation process all activities will need to be identified and quantified. Table 6 shows typical areas of use by facility type.

TABLE 6. TYPICAL AREAS OF USE BY FACILITY TYPE

FACILITY TYPE	AREA OF USE											
	Domestic	Laundry	Heating and Cooling	Food Service	Medical	Landscape	Water Features	Water Treatment	Outdoor Cleaning	Industrial	Alternate Sources	Cleaning and Other
Education	X		X			X						X
Food Sales	X		X	X								X
Food Service	X			X								X
Healthcare (Inpatient)	X	X		X	X	X	X	X	X			X
Healthcare (Outpatient)	X	X	X		X							X
Lodging	X	X		X		X	X		X			X
Mercantile	X								X			X
Multifamily	X	X	X			X			X			X
Office	X		X			X	X		X			X
Public Assembly	X		X			X	X		X			X
Public Order and Safety	X	X	X		X				X			X
Religious Worship	X					X						X
Service	X	X	X		X				X	X		X
Warehouse/ Storage	X		X									X
Other	X											
Vacant												

Create Schematic Drawings of Building and Building Site

A set of schematic drawings should be produced to locate the fixtures and systems that will be audited on each floor, any exterior water using activities, and locations of meter and sub-meter locations. Final locations of all audited fixtures and systems will be included in final report.

Develop Sampling Plan

Determining the number of fixtures and systems to examine during an audit is not always straight forward. Areas like employee break rooms often include kitchen faucets which differ from faucets located in restrooms and bathing and showering facilities. Additionally, access to restrooms may be limited in multifamily and hotel uses. The initial count from building plans will be used to establish a sampling protocol for the building audit.

This audit does not rely on each fixture or system being examined to determine the potential for water efficiency in the building. Sampling of repetitive and representative areas is a common practice in building inspections and commissioning and will be employed here.[10] Table 7 provides the recommended guidance on sampling rates for large buildings.

TABLE 7. SAMPLING RATES

BUILDING TYPE	SIZE CUT OFF	SAMPLE
Any Type	< 20 restrooms	100% fixtures
Any Type	> 20 restrooms	75% fixtures
Campus	> 2 buildings	50% fixtures/building
Hotel		All public access restrooms 10% guest rooms, equally distributed amongst type of room and across all floors
Multifamily		All public access restrooms 15% dwelling units, equally distributed amongst type of room and across all floors
Any Type	< 5 laundry areas	100% of appliances
	> 5 laundry areas	50% of appliances
Any Type	<10,000 sq. ft. of irrigated area	100% of systems
	>10,000 sq. ft. of irrigated area	75% of systems
	>50,000 sq. ft. of irrigated area	50% of systems

ESTIMATE WATER USE

Auditors are expected to use the information found in plan review and building overview information to estimate the amount of water that would be used by the facility. To do this, the auditor will break down water use into estimation of fixtures, hot water use, and other uses identified in the list of water end uses. Where estimates cannot be made based on plans and information obtained pre-site visit, the auditor should be sure to note what areas need closer identification during the walk-through.

Fixture Use

Building on the calculation of FTEs, the auditor will need to determine the number of uses per fixture type across the facility. Additional users such as students, customers, visitors, residents, and patients will all be taken into account to provide an estimate.

The following tables include the recommended duration and number of uses per user group by facility type. If a facility has more specific data available, that data should be used in lieu of the standard metrics defined in Tables 8 and 9.

TABLE 8. COMMERCIAL BUILDING WATER USE BY USER/DAY[11]

FIXTURE TYPE	DURATION (SECONDS)	USES/DAY			
		FTE	Guests/ Visitors	Customers	Students[3]
Water Closet (Female)	n/a	3	0.5	0.2	3
Water Closet (Male)	n/a	1	0.1	.01	1
Urinal (Male)[1]	n/a	2	0.4	0.1	2
Lavatory Use	30[2]	3	0.5	0.2	3
Shower	300	0.1	0	0	0
Kitchen Sink	15	1	0	0	0

1. If urinals are not installed for the fixture usage group, then the Water Closet (Male) usage rates are the same as the Water Closet (Female).
2. Default duration for the metering type /auto-control faucet is 15 seconds for the baseline and 12 seconds for the design case.
3 Applies to K-12 only. Other education facilities like universities should use Guests/Visitors or calculate student hours to FTE hours.

TABLE 9. RESIDENTIAL BUILDING WATER USE BY USER/DAY[12]

FIXTURE TYPE	HOTELS, HOSPITALS, MULTIFAMILY		PRISONS	
	Duration (seconds)	Uses/Day	Duration (seconds)	Uses/Day
Water Closets (Female)	n/a	5	n/a	10
Water Closets (Male)	n/a	5	n/a	10
Lavatory Faucets	60	5	30	15
Showers	480	1	400	.5
Kitchen Sink	60	4	n/a	n/a

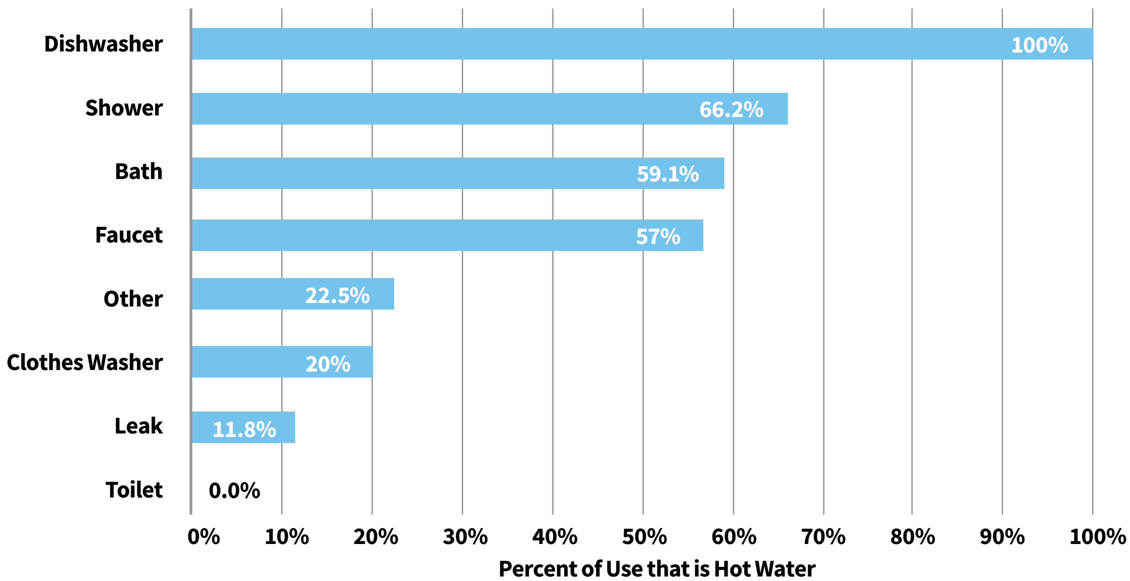
Janitorial uses for cleaning toilets also should be added to office type, hospital, hotels and all public restrooms. Assume that 90 percent of toilets and urinals are cleaned daily, requiring two flushes.

Hot Water Use

The percent of water use within a facility that is heated varies significantly. Use the information in Figure 8 for estimating all domestic type uses including:

- Hand-washing lavatories
- Showers and bathing
- Hotel and residential uses
- Residential and coin/card clothes washers

FIGURE 8. PERCENT OF INDOOR DOMESTIC USE THAT IS HOT WATER[13]



For restaurants and food service, assume that 100 percent of water that is used for dishwashing is hot water. For pre-rinse spray valves, assume that all use is hot water, unless audit information reveals other information. All other hot water uses will need to be determined at the time of the site visit. When visiting the site, special attention should be given to leaks in the hot water system.

Other Identified Uses

Where possible from the plans, all identified end uses should be given an estimate of total water use. Information for estimates may be obtained from schedules, specifications, sequences of operations and manufacturer's data. All should be verified at the site visit.

WATER AND WASTEWATER UTILITY BILL REVIEW

Obtain a minimum three-year monthly billing record, or longer record if available, for all water and wastewater sources on site. This should include information from utilities as well as any self-supplied water sources or sources purchased from other water providers, including reclaimed water sources. Where sources other than the utility provide water, they should be identified by name and source of water (e.g. well on property, rainwater harvesting, on-site recycling of water, reclaimed water from the wastewater treatment provider, etc.).

This information should be entered into a table showing the past three calendar years of monthly use by information source (e.g. utility, self-supplied, reclaimed water, private seller, etc.) and included in the final report. All volumes should be reported in gallons per month.[14] From this utility water use data, a month-by-month graph should be created that includes all three years of monthly data, and the average for each month.

If more than one water source is found on site, individual tables should be created for each water source (i.e., utility, well, rain water collection). A total water use table should also be created.

During the utility bill review, it is possible to find outlier data points. When a significant outlier point is found, additional information will need to be sought from the building owner and facility manager to understand what the issue was, and if and how it has been mitigated. A narrative explaining the root cause of the outliers and the corrective actions taken should be included in the final report. Outlier data points should not be considered in averages.

PRE-ASSESSMENT INTERVIEW

Finally, before the site visit, it is helpful to have a short interview with the building owner to understand the goals for completing the assessment. Even when an audit is required by the city, an owner will have information to share on building upgrades, concerns about water use, interest in capital improvements, and other factors that will help frame the site visit and final report.

II. SITE VISITS

Depending on their primary use, buildings can vary greatly in the types of systems that are typically installed and consuming water. When conducting the site visit, the auditor should be aware of which types of systems deserve greater attention. Although it is by no means an exhaustive list, Tables 5 and 6 summarize the most common water using activities found at commercial, multifamily residential, and institutional facilities. One of the main functions of both the walk-through and interview of staff is to discover all uses of water on site.

WALK-THROUGH

It is important that all water-using activities be examined for water conservation opportunities, and that the auditor states how the volume for each use was determined. Auditors may use a number of techniques including metered data (where available), the use of energy or other operational data from which water use can be calculated, bucket and stopwatch measurements, and a variety of other techniques. Each water-using activity identified in data collection should be verified in the site visit, and at a minimum photographs should be taken to document each area.

Fixtures and fittings

All fixtures based on the sampling plan should be examined for their condition, flush, or flow rates, and any special circumstances that would add to the cost of retrofitting should be noted. At the time of the visit, leaks and repair needs should also be noted and included in the final audit report. If this information is printed on the fixture, the rate should be recorded, but measurements should still be done to ensure that the fixtures are operating within parameters marked on them. There are several methods to determine flow rates on fixtures including:

1. Using a flow meter
2. Using a flow-rate bag or similar
3. Estimation

Metering is always the most accurate method of determining the amount of water used by fixtures. However, metering is seldom possible for large facilities. Some fixtures lend themselves better to estimation from a flow-rate bag, like shower heads and faucets. Others like toilets and urinals are best using an equation estimation.[15]

Meters and Submeters

The measurement of water use is essential to accurate auditing. Although it is not normally within the scope of the audit to test meters for accuracy, the auditors should locate and to the best of their ability, assess the potential for the meter or submeter to be accurate. The American Water Works Association's M-6 manualprovides a guide on proper meter installation, and each manufacturer has guidelines for its meters.[16] Auditors should be familiar with these requirements. For example, most guidelines recommend that at least 10 diameters of pipe length be provided on each side of the meter.

Each water meter on the property should be identified and described in a table in the final report.[17] It is the responsibility of the auditor to note any problems observed with the meters or if the audit water balance indicates that meters may not be accurate. The auditor should ask the facility manager about any metering problems. Any potential problems should be included in the final report.

Domestic Hot Water

All water heating systems should be examined for their condition, age, and temperature settings. Connections to water heaters should be carefully examined for leaks or signs of leakage, and visible piping should be checked for proper insulation, especially at joints and connections. Hot water documentation should be presented in a table in the final report.[18]

Hot water systems that operate on recirculating pumps should be noted, and control systems (aquastats and timers) should be checked and recorded. Auditors should verify time of day control settings are appropriate for building facility type.

Lavatories should be checked for the presence of thermostatic mixing valves. Temperatures of tempered water should be recorded from valve setting and tested if possible at tap. Note lavatories that are publicly accessible that do not have a mixing valve for the final report.

HVAC

The primary HVAC systems to include in a water audit are cooling towers. Where cooling towers are used, auditors should ensure proper instrumentation is both used and operating properly. Instrumentation for cooling towers includes:

- Makeup meters
- Blowdown meters
- Conductivity controllers
- High-efficiency drift eliminators

Cooling tower water systems should also have a water meter on the makeup line to determine if there is a leak in that system.

Most facilities contract with a service provider to control the water chemistry in the cooling tower. The auditor should speak with the facility manager about this contract. It should contain requirements that the cycles of concentration in the tower are maximized based on the makeup of water chemistry and the recommended maximum limits in water quality for the type of tower being used and as illustrated in Table 11.

TABLE 11. WATER CHEMISTRY LIMITS IN WATER QUALITY BY TYPE OF COOLING TOWER

Property	G-235 Galvanized Steel	Type 304 Stainless Steel	Type 315 Stainless Steel
pH	7.0–8.8	6.0–9.5	6.0–9.5
Ph During Passivation	7.0–8.0	N/A	N/A
Total Suspended Solids (ppm)[1]	< 25	< 25	< 25
Conductivity (Micro-mhos/cm)[2]	< 2,400	< 4,000	< 5,000
Alkalinity as $CaCO_3$ (ppm)	75–400	< 600	< 600
Calcium Hardness $CaCO_3$ (ppm)	50–500	< 600	< 600
Chlorides as Cl (ppm)[3]	< 300	< 500	< 2,000
Silica (ppm)	< 150	< 150	< 150
Total Bacteria (cfu/ml)	< 10,000	< 10,000	< 10,000

1. Based on standard EVAPAK M.
2. Based on clean metal surfaces. Accumulations of dirt, deposits, or sludge will increase corrosion potential.
3. Based on maximum cool fluid temperatures below 120°F (40°C).

Landscape and Water Features

Auditors should include all landscape areas and water features in their site visit. Note types of planted areas, evapotranspiration coefficient for plant types and soil, slope, and related aspects of the landscape and irrigation systems in a table. Landscape areas should be included on the schematic drawings in preparation for site visit, and verified during visit.

INTERVIEWS

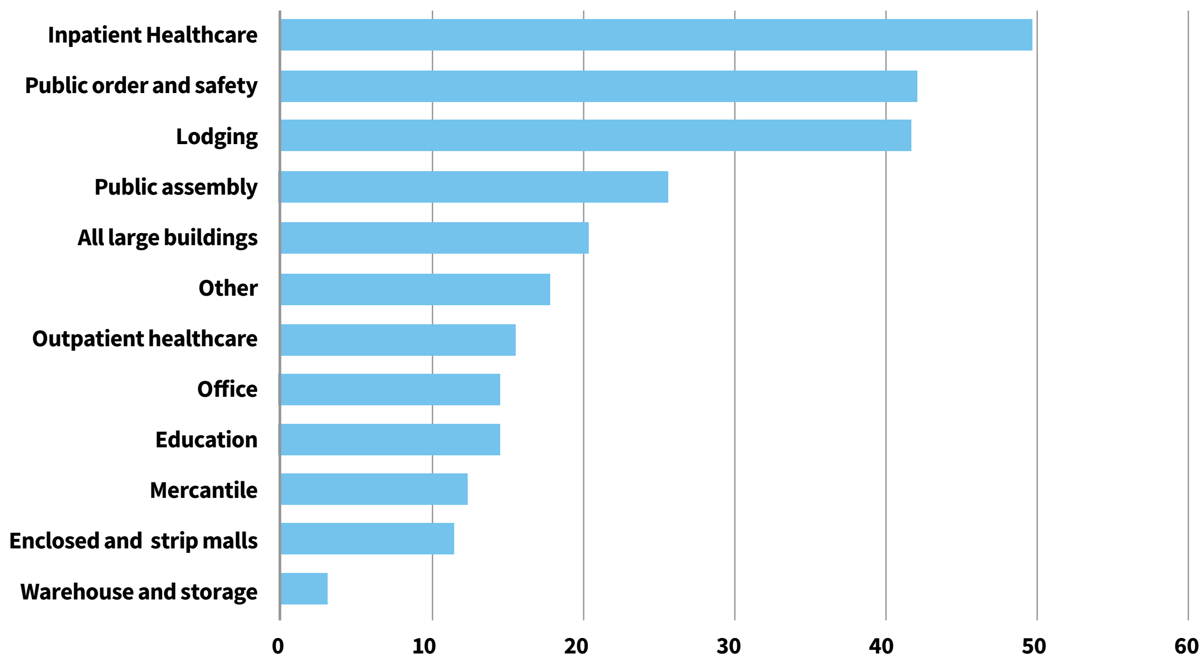
Before, during, or after the walk through the auditor should find time to interview key staff at the building site. This will likely include the facility manager, and can also include major tenants, other building staff, or frequent users and visitors. On-site interviews should focus on identifying issues in water use that may illuminate problems that would go overlooked in a one-time site visit. Users of the building will have greater insight into frequent water problems than the auditor may be able to recognize. Notes should be compiled and included as an appendix to the final report. Where warranted, after the interviews, the auditor may wish to walk through the building again to obtain additional information.

III. ANALYSIS

After all necessary data has been collected through the combination of the data collection and site visits, the auditor should review each water use measurement and estimate made to determine if that volume of use is within the range of normal parameters, and whether additional measurements or discussion with facility personnel is needed.

Normal parameters will be based on CBECS water use intensity data presented in Figure 9.[19] Water intensities within 10 percent of the water use intensity presented here will be considered normal. Figures outside of those ranges will need to be accounted for in report narrative to the best of the auditor's ability to characterize the water use at the project site.

FIGURE 9. WATER USE INTENSITY IN COMMERCIAL BUILDINGS



WATER USE BALANCE

The water use balance shows how water is used by the major use areas.[20] Where metered data is available, it should be used. Where metered data is not available, use the estimating techniques, which should be stated in the report.[21] After the data collection and site visit, the auditor should have the information and confirmation of systems needed to complete the water use balance. This will help inform the remainder of the analysis.

For each area of use, that auditor should provide an annual volume, and a percentage of use for that area.[22] For areas using greater than 15 percent of total use an additional breakdown should be made to show how each type of equipment or system uses water (Example: domestic should include water closets, urinals, bidets, trap primers, showers/tubs, lavatories, sinks, drinking fountains).[23]

The water use balance should equal at least 90 percent of the total facility water use as compared to the water bills to ensure that all major water-using equipment and systems have been identified and assessed. If accounted for use is less than 90 percent, the reason for the difference should be investigated and discussed in the report.

DETERMINE WATER CONSERVATION MEASURES

One of the most critical components of the audit report is the listing and discussion of specific measures to reduce water use. Based on areas of use and end use found on the project, the auditor should identify water conservation measures for further analysis and review. Each identified water conservation measure should include: a description of the use as it exists, a description of the potential water conservation measure(s) for that use, and potential water savings expressed in flow rate or another common metric depending on the measure.
A full analysis of annual water use and cost savings will be completed later.

Many measures will have a straightforward description and water-savings potential. Others like fire system, mop sinks, bidets, and drinking fountains, will not and it is left to the auditor's discretion to identify water-saving potential for these measures.

Fixtures and Fittings

Most modern plumbing codes have been updated to require low-flow fixtures and fittings. For fixtures that exceed the rates shown in Table 12, recommendations should be made for replacement with an analysis of costs.

TABLE 12. RECOMMENDED FLOW RATES FOR FIXTURES[24]

Showerhead	2.0 gpm
Lavatory faucet and bar sink – private	1.5 gpm
Lavatory faucet – public	0.5 gpm
Kitchen faucet	2.2 gpm
Urinal	0.5 gpf
Water closet – public and remote	1.6 gf
Water closet – public and nonremote	1.28 gpf
Water closet – private	1.28 gpf
Drinking fountains	0.7 gpm/0.25 gpc

Additionally, when recommending the replacement of domestic type fixtures, the auditor should make the owner aware of rating programs that guarantee flow rate and user satisfaction of performance such as EPA's WaterSense and map testing.[25,26]

Floor-Trap Primers

For floor-trap primers, continuous flow systems should always be recommended for removal. Where required, only the following systems are recommended in Table 13.

TABLE 13. RECOMMENDED FLOOR DRAIN P-TRAP PRIMER TYPES[27]

PRIMER TYPE	ACTUATIONS PER DAY	WATER USE
Flush Activated	Depends on Flush Valve Use	Very Low
Pressure Sensitive	Depends on Fixture Use	Very Low
Electronic	1	Very, Very Low
P-trap Primer	Depends on Fixture Use	0

Metering and Submetering

Most modern water efficiency codes require that larger water uses within a facility or campus be metered separately.[28] A water meter should be installed in buildings connected to a public water system, including municipally supplied reclaimed (recycled) water. Meters should be easily accessible for reading and monitoring. The auditor should consider recommending that separate meter or submeter be installed in the following locations:

- The water supply for irrigated landscape with an accumulative area exceeding 2,500 square feet (232 m^2).
- The makeup water supply to cooling towers, evaporative condensers, and fluid coolers.
- The makeup water supply to one or more steam boilers collectively exceeding 1,000,000 British thermal units per hour (Btu/h) (293 kW).
- The water supply to a water-using process where the consumption exceeds 1,000 gallons per day (gal/d) (0.0438 L/s), except for manufacturing processes.
- The water supply to each building on a property with multiple buildings where the water consumption exceeds 500 gal/d (0.021 L/s).
- The water supply to an individual tenant space on a property where any of the following applies:
    - » Water consumption could exceed 500 gal/d (0.021 L/s) for that tenant. The water supply to each building on a property with multiple buildings where the water consumption exceeds 1,000 gal/d (0.042 L/s).
- The water supply to an individual tenant space on a property where any of the following applies:
    - » Water consumption could exceed 1,000 gal/d (0.042 L/s) for that tenant.
    - » Tenant space is occupied by a commercial laundry, cleaning operation, restaurant, food service, medical office, dental office, laboratory, beauty salon, or barbershop.
    - » Total building area exceeds 50,000 square feet (4645 m^2).
- A makeup water supply to a swimming pool.
- The makeup water supply to an evaporative cooler having an airflow exceeding 30,000 cubic feet per minute (ft^3/min) (14,158.2 L/s).

Where daily total-building water use of either potable or reclaimed water exceeds 1,000 gallons a day or alternate sources of water exceeds 500 gallons a day, the water meters or submeters should be connected to a common monitoring site so that data can be recorded and accessible for viewing by the property manager or engineer.

HVAC
If a project contains a cooling tower that is approaching end of life, there are several considerations for water conservation balanced with energy conservation that may be taken into consideration. These considerations are often beyond the scope of most water conservation audits, but are genuine ways to reduce or eliminate water use for air conditioning. This is why an analysis of life-cycle costing of conventional cooling tower and chilled water systems versus the alternative, especially dry cooling, is warranted. For most air conditioning applications, cooling towers are not the most cost effective equipment for smaller applications below 300 tons.

The first consideration is if an alternative cooling technology such as air cooling and geothermal (ground) rejection of heat is feasible. The second is to find ways to reduce the heat load to the chillers and cooling towers in the first place by good energy efficiency.

As for alternatives to conventional cooling tower/chilled water systems include:

- Air-cooled systems
- Variable Refrigerant Flow air or geothermal cooled systems
- Geothermal (ground source) heat pumps
- Thermal absorption and desiccant systems

As for energy efficiency consideration for a building beyond the air conditioning system, reducing the total heat load on the chiller will reduce the load on the tower and thus water use. Examples range from good building design to reduce heat gain, choosing efficient lighting and equipment and good energy system controls. Technologies that increase energy efficiency for the air conditioning and cooling tower equipment should also be considered. These include:

- Air-side economizers
- Water-side economizers
- Reuse of waste heat
- Thermal storage
- Variable frequency drives

Facility managers should also consider the type of basin material that will produce the lowest future operating cost when replacing existing cooling towers.

- Life-cycle costing wet vs. dry cooling
- Towers should have:
  - Makeup meters
  - Blowdown meters
  - Conductivity controllers
  - High-efficiency drift eliminators
- No residential cooling towers

Landscaping
Recommendations following the irrigation system audit, such as those related to:

a. Shaping and contouring of landscaped areas, soil amendments, etc.
b. Possible change out of plant material to make the landscape more water efficient
c. Retrocommissioning controls or adjusting timers on existing system
d. Installing additional controls to prevent watering during or shortly after rain events
e. Replacing spray irrigation with drip irrigation systems
f. Adjusting spray heads to eliminate spray onto adjacent hardscape

QUANTIFY SAVINGS AND COSTS

Building on the work to determine water conservation measures, the auditor should fully quantify the savings the measure will bring.

To the best of ability, include the following:

- ✔ Cost of water (convert to dollars per thousand gallons)
- ✔ Cost of wastewater
- ✔ Information on evaporation credit or special rates
- ✔ Special water-related costs such as pretreatment, etc.
- ✔ Cost of electricity, natural gas, and other energy sources (specify units)
- ✔ Cost of all forms of water treatment, including chemical costs
- ✔ Cost for special analysis, such as legionella, for cooling towers
- ✔ Associated labor costs for maintenance (installation covered elsewhere)
- ✔ Electric use data for HVAC, if available
- ✔ Energy for water heating
- ✔ Any other costs

In addition, the total cost of the water conservation measure should include:[29]

- ✔ Cost of the equipment, supplies, fixtures, etc.
- ✔ Any associated shipping or delivery charges
- ✔ All associated costs for installation
- ✔ Cleanup and testing as needed
- ✔ Additional labor cost to facility to operate any new equipment
- ✔ Any other associated costs including leasing and contracting
- ✔ Quantification of full monetary benefit of measures as applicable, including reductions in water/wastewater; pretreatment; electric, gas, other fuels; chemicals; labor; and all other related costs should be included

COST-BENEFIT ANALYSIS

The cost-benefit analysis does not require a professional estimator. The auditor should be able to determine both the savings (benefit) and cost to implement the measures.

The benefits include all savings for water, wastewater, energy, chemicals, labor, and other associated costs. The costs should be total cost to implement the savings, including but not limited to:

- Cost of equipment, fixture, process, or measure
- Any associates structural or building remodeling cost
- Labor cost to maintain the equipment if different from before
- Changes in service contracts such as cooling tower treatment costs
- Chemicals and supplies costs
- Any change in insurance or liability costs
- Cost to install or implement the equipment measure
- All associated labor cost to implement the measure

The cost-benefit analysis should list and take into account all applicable rebates and tax incentives, including energy and pollution rebates and incentives for each measure.[30] In addition to those opportunities provided under local government and utility programs, the audit report should include any national energy and water rebates, tax incentives, and other forms of financial information that may help, and provide contact information for applicable local forms of financial assistance.

The following three sections will describe how to calculate water conservation measures for financial viability. These three methods are:

1. Simple Payback
2. Net Present Value (NPV)
3. Equipment Life Utility Cost Comparisons

MINIMUM REQUIREMENTS IN AUDIT REPORT

At a minimum, simple payback analysis should always be included in the audit report. Some cities require the use of net present value analysis or equipment life utility cost comparison.

Simple Payback

Determining the simple payback is an important part of the audit findings. This is calculated by simply dividing the total costs as outlined above by the total savings per year that result from implementation of the measure. At a minimum, the audit report should include a complete cost-benefit analysis with simple payback in years. The costs should indicate actual costs reflective of the area and include applicable construction, equipment, and fixtures costs, as well as the cost of installation.

Another way to express simple payback is Return on Investment (ROI). ROI is the measure of the gain (savings through conservation in this case) on an investment relative to the amount of money invested. It is the percent of the project cost that will be returned per year. To express simple payback in ROI terms, divide 1.0 by the payback in years. For example, if the payback is 2.5 years, the return on investment (ROI) would = 1.0/2.5 = 40 percent.

Net Present Value

The simple payback period is a widely deployed tool to understanding investments, especially in resource efficiency. However, it doesn't show building owners or investors the return of various efficiency measures. Two measures could have identical simple payback periods, but very different NPVs; the one with a higher NPV would likely be preferred by the party making the investment. By showing both values, the client can make a smarter decision regarding particular efficiency measures and produce a more-informed priority list. For projects over $100,000, NPV analysis can help determine the economic viability of a project.

NPV calculations are commonly used to evaluate investments in several contexts. This brief description is meant to assist auditors in presenting economic information to clients as they evaluate the appropriateness of various water-saving measures. The NPV can be calculated by using basic formulas. Additionally, NPV analysis can run from very simple to very complex, typically depending on the number of inputs used to derive ***n*** in the NPV equation. This guidance will outline an approach for an intermediate-level evaluation.

NPV calculations estimate the value of an investment over a course of years or the lifetime of an installed technology. The general form of the equation is:

$$\mathbf{NPV} = \sum n/(1+r)^{t-t_0}$$

where n is the net value of the measure in year t; r is the discount rate; and t is the year.

In Microsoft Excel, the formula is: PV= Year one value + NPV(rate [r], value year 2, value year 3,…value year t).

The net value of the measure, n, in year t, should be the difference between the benefits and the costs associated with the measure in year t. Costs and benefits incorporated into n should cover the following categories, at a minimum.

Costs

Equipment costs should include all expenditures on capital specific to the measure being reviewed. Installation costs should include all costs incurred installing the equipment, and will predominantly be comprised of labor and services required to ensure the equipment is operating efficiently and as designed. Early removal costs are additional costs incurred in removing and disposing existing operable equipment and should only be included if existing equipment is removed prior to its end of lifetime. Lastly, if operations and maintenance costs are expected to increase as a result of the use of the technology identified in the measure in question, the difference in operations and maintenance expenditures should be accounted for as a cost, and vice versa.

Benefits

Water efficiency measures produce monetary savings in several ways. Most obviously is through reduced water consumption. The current-year value of reduced water consumption should be calculated as the avoided consumption multiplied by the water rate. Additionally, there can be energy savings (primarily in the form of reduced pumping and heating loads) from water efficiency measures. The same approach as used with water should be taken in estimating the current-year benefits of reduced energy consumption. Lastly, a water efficiency measure may reduce the operations and maintenance requirements; if this occurs, these cost reductions should be accounted for as a part of the benefits as well.

Estimating future year benefit streams

In the current year, rates and consumption of water and energy, as well as O&M costs should be known. However, as these benefits likely accrue over time, a more accurate estimate of the NPV of the water efficiency measure can be produced using informed estimates of future costs.

Water and Wastewater rates

Water rates are highly variable across the United States. Current costs should be gathered from bill data and from the water utility. The water utility may make rate projections that can be integrated into an analysis of benefits from the water efficiency measure. Wastewater rates should also be obtained, which in a commercial facility can typically be based on winter water use. Wastewater in a commercial, industrial, or institutional facility can typically vary by type of business, which takes into account water quality (Biological Oxygen Demand) and suspended solids. Grocery stores, restaurants, and meat plants typically get billed at a higher rate due to their higher discharge waste load. This information, as well as water and wastewater rates for individual facilities should be available from the local water utility. Finally, if no relevant estimates of future rates are available, it is recommended to maintain the current rate structure for the analysis of future savings. Note that if prices are expected to increase, this approach undervalues the financial benefits of the water efficiency measure.

Energy rates

Energy savings would occur primarily from reduced hot water use. Energy rates also vary nationally. The process of projecting future rates should mirror that of water. The local utility provider may have produced such estimates, which can be incorporated into an analysis. However, these are frequently unavailable. In such an instance, the Energy Information Administration (EIA) produces rate estimates for the relevant fuels, by sector, as a part of its Annual Energy Outlook[31]. The most common type of energy used to heat water is natural gas. The proportion of customers using natural gas varies but is usually in the range of 70 to 80 percent.

For natural gas, the Annual Energy Outlook also provides price projections. The Natural Gas Delivered Prices by End-Use Sector and Census Division table contains the relevant price information in constant dollars for each of the nine census divisions. Future rates should be projected by using the current rate paid by the client multiplied by (1 plus the percentage change in rates) projected for the correct census division where the client is located.

For electricity, these rate estimates are provided at the Electricity Market Module (EMM) region level, which roughly corresponds to the North American Electric Reliability Corporation (NERC) sub-regions used to describe the North American electricity system and divides the country into 22 areas. The Electricity Power Projections by EMM table provides the relevant price information in constant dollars. Future rates should be projected by using the current rate paid by the client multiplied by (1 plus the percentage change in rates) projected for the correct EMM region where the client is located.

O&M Costs

Operation and maintenance (O&M) for water projects is typically not a major driver for project implementation. However, it can impact the NPV if the new replacement equipment has a lower O&M cost. New equipment should require fewer repairs, so this savings can be factored into net benefit for new equipment. For example, a new dishwasher should require fewer repairs than an old dishwasher. A new cooling tower that is automatically monitored will likely offer reduced labor costs compared to an existing cooling tower that requires manual monitoring. In both situations, there are clear benefits for equipment replacement.

Discount Rate

The discount rate is defined as the rate that determines how much money would have to be invested currently, at a given rate of return, to yield a cash flow in the future. More usefully, a discount rate allows for the comparison of costs and benefits occurring at different times, by accounting for factors such as risk and time preferences. Generally, discount rates are positive values, reflecting that investments can provide benefits that grow, risk aversion in consumers, a bias for consumption in the present, and other factors. While discount rates selected for NPV and other cost-benefit analyses can vary, the U.S. Office of Management and Budget recommends using a 3 percent discount rate for long-lived investments and a 7 percent discount rate for many private sector projects.[32]

For most water efficiency measures performing an NPV analysis, a 7 percent discount rate is recommended.

Equipment Life Utility Cost Comparison

Another method to compare the value of equipment retrofits or replacement is to look at the equipment life and compare energy and water costs over the life of the equipment. To accomplish this, three factors must be considered:

1. The price of energy over time
2. The price of water over time
3. The expected useful life of the equipment

Each city or utility will have different energy, water, and sewer cost dynamics and rates that best apply to their situation. It is the responsibility of the auditor to select the numbers that best fit the specific location.

The objective of the equipment life utility cost comparison is to look at total utility monetary savings and costs associated with each type of fixture, appliance, or equipment retrofit.

To perform this analysis, the auditor will need to gather four pieces of information:

1. Life expectancy of various types of retrofits
2. Water and sewer costs now
3. Natural gas or electric prices where applicable
4. Where inflation is to be considered, the expected future cost of utilities

For current water and sewer costs, the utilities providing these services will be the best source. They may also be able to provide insight on future rate hikes that the auditor should take into consideration.

Table 14 provides estimated ranges of life expectancy for commercial fixtures, appliances, and equipment and can be helpful in determining the useful life of all equipment.

TABLE 14. RANGE OF LIFE EXPECTANCY FOR COMMERCIAL FIXTURES, APPLIANCES AND EQUIPMENT[33]

TYPE OF EQUIPMENT	NAME OF EQUIPMENT	EXPECTED LIFE RANGE IN YEARS
Food Service	Ice makers	6–10
	Ice cream, gelato makers	8–10
	Walk-in coolers and freezers	8–15
	Combination ovens	8–12
	Food steamers	8–12
	Door & conveyor dishwashers	15–20
	Flight-type dishwashers	25+
	Food waste disposers	10
	Food waste pulpers & scrappers	15+
	Pre-rinse spray valves	1–5
Laundry Equipment	Coin/card type washers	12–15
	On-premise washer-extractors	15–20
	Tunnel washers	20+
	Home-type washers	10–14
Plumbing Fixtures	Toilets	20–30
	Urinals	20–30
HVAC Equipment	Chiller – Water-cooled	15–20
	Cooling Tower – Wood	10–20
	Cooling Tower – Galvanized	15–25
	Cooling Tower – Stainless	25–35
	Cooing Tower – Ceramic	35+
Boilers (Hot Water & Steam)	Copper core	15–20
	Steel tube boiler	20–40
	Old cast iron	25–50
	New cast iron	20–25
	Electric	10–20

IV. REPORT

The auditor should provide a report that includes all data collected along with relevant calculations, images, and charts that were part of the analysis. An executive summary should include high-level information on the audit process and the outcomes. If there are a number of recommendations, focus on presenting those with the largest savings opportunities and reference the additional recommendations in the structure of the report itself.

The city or utility department overseeing audits should determine the exact submittal procedure. Where appropriate, city or utility staff will review the report to ensure that the required content is present and that the document is legible and organized. Some common issues that should be avoided in the audit report include:

- Failure to include all possible water conservation measures for all water-using activities
- Low-cost estimates for improvements
- Failure to include all savings potential such as energy, water treatment, property tax, wastewater pre-treatment, and related savings in addition to water and sewer cost savings
- Inadequate explanation of the proposed water conservation measures
- Mistakes in billing analysis and water use estimates for each water-using area
- Inconsistent basis for benchmarking water use
- Inaccurate and incomplete description of the facility

The audit team should also provide a copy of the audit report to the facility manager and establish a time to meet with him or her to review the results. At the review meeting, the audit team representative should help the facility manager understand how the audit was conducted, how calculations were made and which potential actions will provide the most savings, and offer the largest return on investment. The main goal of the review is to answer any questions the facility manager may have, and to help him or her determine priorities.

RESOURCES AND METHODOLOGIES

- California Department of Water Resources Commercial, Industrial, and Institutional Task Force Best Management Practices Report
- EPA Water-Smart Landscapes Guide
- Federal Energy Management Program Guidelines for Estimating Unmetered Landscaping Water Use
- International Plumbing Code
- International Green Construction Code
  - Uniform Plumbing Code 2015 Green Plumbing and Mechanical Supplement
  - A summary of current green codes for plumbing fixtures and other water using equipment
- Irrigation Association Audit Procedure
- Irrigation Association's Smart Water Application Technology (SWAT) website
- Irrigation system audits should follow the ANSI/ASABE S626 SEP2016 Landscape Irrigation System Uniformity and Application Rate Testing standard, which can be purchased from the American Society of Agricultural and Biological Engineers (ASABE)
- The following websites contain information from the National Building Institute's Whole Building Design set of guidelines for federal agencies.
  - Air Force Facilities Standards
  - Air Force Water Conservation Guidebook
  - Best Management Practices Irrigation Systems
  - Existing Sustainable Federal Buildings, Guiding Principle III, Protect and Conserve Water
  - Federal Facility Criteria
  - Implementing a Water Conservation Program on Army Installations
  - Installation Water Audit Guidelines
  - Landscape Irrigation Best Practices Management
  - Procedure to Detect Water Distribution System Leaks
  - U.S. Department of Energy's Federal Energy Management Program Training Catalog
  - Water Conservation
  - Water Conservation and Water Efficiency Guidance
  - Water Efficient Installations
- South Florida Water Management District Self-Assessment Guide for Commercial and Institutional Water Efficiency Improvement
- U.S. Environmental Protection Agency's (EPA) Guidelines for Irrigation Audits on WaterSense® Labeled New Homes
- U.S. Environmental Protection Agency's WaterSense at Work

APPENDIX A: CONVERSION FACTORS

TABLE 15. WATER AND ENERGY CONVERSION FACTORS

UNIT OF MEASURE	EQUIVALENT MEASURE
WATER	
1 CCF	100 cubic feet – 748 gallons
1 cubic foot	7.48 gallons
1 million gallons (MG)	3.07 acre-feet
1 gallon (gal)	8.34 lb
1 gallon (gal)	3.7854 liters
ENERGY	
1 British thermal unit (Btu)	The energy required to raise the temperature of 1 pound of water by 1°F
1 therm	100,000 Btu
1 CCF natural gas or propane	100 cubic feet
1 MCF natural gas or propane	1,000 cubic feet
1 cubic foot natural gas	Approximately 1,000 Btu
1 cubic foot gaseous propane	2,516 Btu
1 gallon liquid propane	91,500 Btu
1 kWh	3,412 Btu
1 Ton-Hour	12,000 Btu
1 Ton	12,661 kilo-Joules per hour

APPENDIX B: EXAMPLES

I. DATA COLLECTION

FACILITY DESCRIPTION

EXAMPLE: Building Identifying Information

"The facility is located at 123 Sesame Street, Washington DC 20020. The current owner is identified as Bert and Ernie, LLC. The facility occupies two lots: 125, 126. It was constructed in 2006 and has not undergone a major renovation."

EXAMPLE: Building Facility Type

Example 1: *"The facility is an office building that has 10 floors and contains mainly insurance and financial companies. It also contains a small restaurant on the first floor. Insurance companies occupy 25 percent of the floor space and financial operations occupy the remainder."*

TABLE 16. EXAMPLE TABLE SHOWING FACILITY DESCRIPTION OF AN OFFICE BUILDING

OFFICE BUILDING	
Predominant Building Facility Type	Office
% Building under Predominant Use	98%
Total Conditioned Building Space	50,000 sq. ft.
Total Unconditioned Building Space	10,000 sq. ft.
Number of Stories	12
Number of Stories Above Grade	10
Total AC Tons	
Cooling Tower present?	Yes
Total AC using Cooling Towers	
Additional Building Facility Use	Food Service
% Building under Additional Use	2%
Total Site Area	10,000 sq. ft.
Total Landscaped Area	2,000
% Landscaped Area Irrigated	0%
Total Turf area	0 sq. ft. / N/A
% turf area irrigated	N/A
Total Green Roof area	2,500
% Green Roof Irrigated	0%
Surface Area of Water Features	N/A
Total Impervious Area	5,500

Example 2: *"The facility is a three story, multifamily condominium with one light retail establishment and one restaurant on the first floor. The retail and restaurant facilities cover less than 10 percent of the floor area."*

TABLE 17. EXAMPLE TABLE SHOWING FACILITY DESCRIPTION OF A MULTIFAMILY BUILDING

MULTIFAMILY CONDO BUILDING	
Predominant Building Facility Type	Multifamily
% Building under Predominant Use	98%
Total Conditioned Building Space	15,000 sq. ft.
Total Unconditioned Building Space	500 sq. ft.
Number of Stories	3
Number of Stories Above Grade	0
Total AC Tons	30
Cooling Tower (Yes or No)	No
Total AC Using Cooling Towers	N/A
Additional Building Facility Use	Food Service
% Building under Additional Use	5%
Additional Building Facility Use	Mercantile
% Building under Additional Use	4%
Total Site Area	10,000 sq. ft.
Total Landscaped Area	2,000
% Landscaped Area Irrigated	0%
Total Turf Area	0 sq. ft. / N/A
% Turf Area Irrigated	N/A
Total Green Roof Area	2,500
% Green Roof Irrigated	0%
Surface Area of Water Features	N/A
Total Impervious Area	5,500

Example 3: *"The facility is a mixed-use operation. Seventy-five percent is used for clothing, sporting goods, and general merchandise, and the rest is for restaurants and food service. There are two separate buildings on this campus."*

EXAMPLE: EQUIVALENT FULL-TIME EMPLOYEE (FTE) DAYS OF USE

Example FTE Calculation for Employees

A retail establishment has five full-time employees, eight that work an average of 20 hours per week for approximately 30 weeks a year, and three that work 35 hours a week for 10 weeks a year during the busy season. The FTE is calculated as follows:

For full-time employees:

- The auditor can simply record the number of FTEs as 5. However, the following is included to illustrate the calculations.
- Full-time employee hours per year = 5 employees X 245 days/year X 8 hours/day = 9,800 hours. Using 1,960 hours a year, the FTE = 9,800 1,960 = 5 FTE

For part-time and seasonal workers:

- For the eight part-time employees for 20 hours a week for 30 weeks a year = 8 employees X 20 hours/week per employee X 30 weeks/year = 4,800 hours a year. Using 1,960 hours a year, the FTE = 4,800 1,960 = 2.45 FTE
- For the three seasonal workers that work 35 hours a week for 10 weeks, similar calculations = 3 employees X 35 hours a week X 10 weeks per year = 1,050 hours a year. This is equal to 0.54 FTE.

Therefore, the total Full-Time Equivalent employees = 7.98 FTEs

TABLE 18. EXAMPLE FOR CALCULATING FULL-TIME EQUIVALENT EMPLOYEES FOR OFFICES, RETAIL, AND MOST OTHER FACILITIES

DESCRIPTION	#	HOURS/ WEEK	WEEKS/ YEAR	HOURS/ YEAR	FTES
Full-time	5	40	49	9,800	5.00
Part-time	8	20	30	4,800	2.45
Seasonal	3	35	10	1,050	0.54
			Total FTEs	**15,650**	**7.98**
			Total Equivalent FTE days per Year		**1,957**

Therefore, the total FTE days per Year = 7.98 X 245 days/year = 1,957 FTE days per Year

EXAMPLE SCHOOL AND UNIVERSITY FULL-TIME EQUIVALENT CALCULATIONS

The following is an example of a high school, using the data summarized in the table below for the number of people at the school on a daily basis, their time there, and their activities. For after-school activities and visitors, the hours that they are present should be divided by eight hours to obtain an equivalent time and included as shown in Table 19.

TABLE 19. EXAMPLE FOR CALCULATING FULL-TIME EQUIVALENT EMPLOYEES EDUCATIONAL FACILITIES (SCHOOLS, UNIVERSITIES, COLLEGES, TRADE SCHOOLS, ETC.)

DESCRIPTION	STUDENTS	STAFF/ FACULTY	AFTER-SCHOOL ACTIVITIES	VISITORS ETC.	TOTAL PER YEAR
Number of people	1,055	275	60	14	
Hours per event day	7	8	2	1	
Days per Year	185	200	60	185	
Equivalent FTE Hours per Year	1,366,225	440,000	7,200	2,590	1,816,015
				At 8 hours a day for each FTE	**227,001**
				At 245 days per year for each FTE	**926.5**

BUILDING PLAN REVIEW

EXAMPLE: List of End Uses

Project is a medium-sized sit-down restaurant.

TABLE 20. EXAMPLE TABLE FOR LIST OF END USES

AREA OF USE	END USE	NUMBER OF INSTANCES
Domestic	Water Closets	10
Domestic	Lavatories/Sinks	6
Heating and Cooling	Water Heater	3
Food Service	Ware washing	1
Food Service	Steamer	1
Food Service	Ice Machine	1
Cleaning and Other	Mop Sink	1

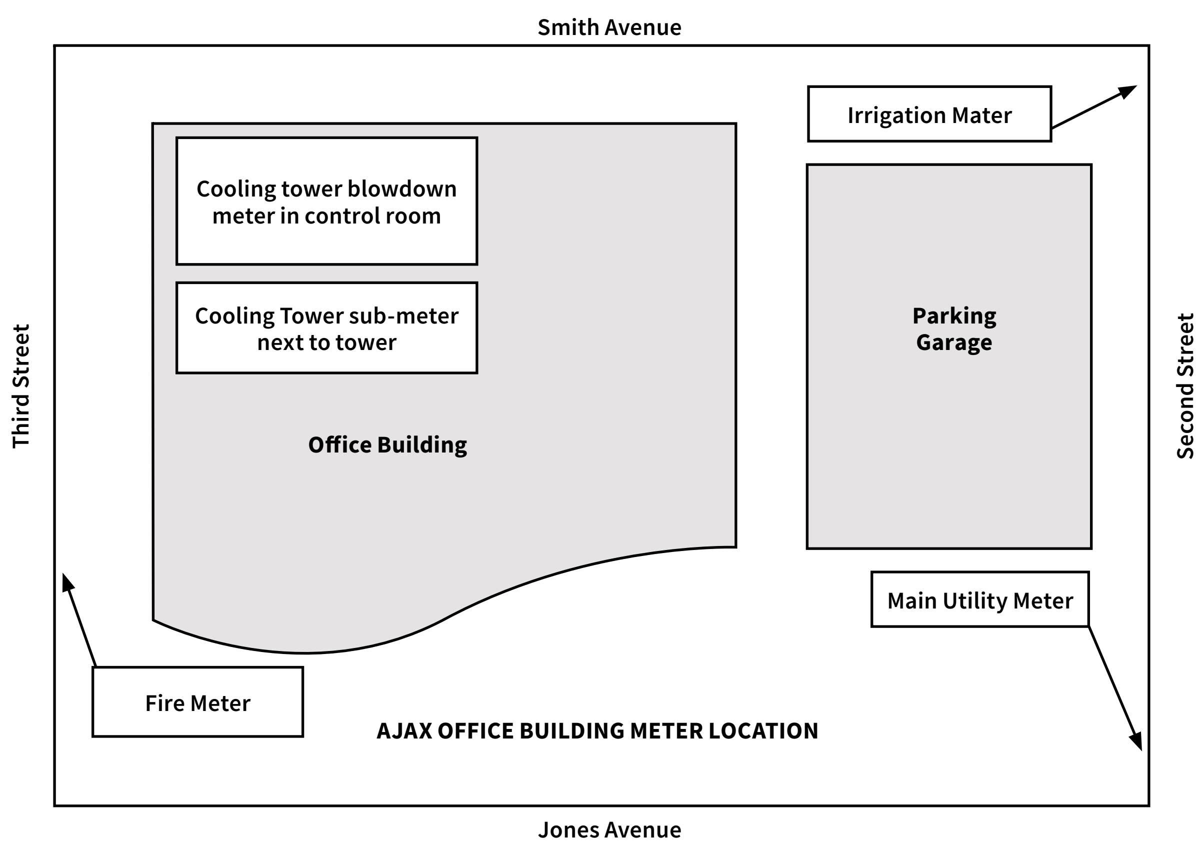
EXAMPLE: Develop Sampling Plan
Project is a multifamily building with common laundry located on every other floor.

TABLE 21. EXAMPLE TABLE FOR DEVELOPING A SAMPLE PLAN

LOCATION	TOTAL #	SAMPLE
Restrooms (not in units)	4	4
Studio Dwelling Units	25	4
1 BR Dwelling Units	40	6
2 BR Dwelling Units	25	4
Common Laundry	10	5
Landscape Irrigation	2,000	All
Green Roof Irrigation	2,000	All
Turf Irrigation	10,000	75% sprinkler heads and controls. Refer to notes on site plan.

EXAMPLE: Create Schematic Drawings

FIGURE 10. EXAMPLE SCHEMATIC DRAWING



ESTIMATE WATER USE PER DAY

EXAMPLE: Water and Wastewater Bill Review

The following is an example of a building served by both utility supplied water and well water. Tables 22 and 23 show each source and also are graphed in Figures 11 and 12. Then the three-year average for all sources is presented in Table 24.

TABLE 22. EXAMPLE HISTORICAL MONTHLY WATER USE FROM UTILITY (IN GALLONS PER MONTH)

MONTH	YEAR 2014	YEAR 2015	YEAR 2016	THREE-YEAR AVERAGE
Jan.	68,000	60,000	65,000	64,333
Feb.	80,000	78,000	79,000	79,000
March	90,000	80,000	85,000	85,000
April	100,000	85,000	400,000[1]	92,500[2]
May	180,000	150,000	170,000	166,667
June	210,000	180,000	200,000	196,667
July	220,000	190,000	210,000	206,667
Aug.	240,000	200,000	200,000	213,333
Sept.	180,000	160,000	190,000	176,667
Oct.	90,000	70,000	90,000	83,333
Nov.	70,000	60,000	80,000	70,000
Dec.	70,000	60,000	70,000	66,667
Total	**1,600,000**	**1,370,000**	**1,840,000**	**1,500,833**

Water Source: Sesame Street Municipal Water Utility
1 Outlier data point; explain reason, if known (example: Water riser leak problem was identified and remediated April 2016.")
2 Average for two years (2014 and 2015) that were not outliers.

FIGURE 11. EXAMPLE HISTORICAL MONTHLY MUNICIPAL WATER USE

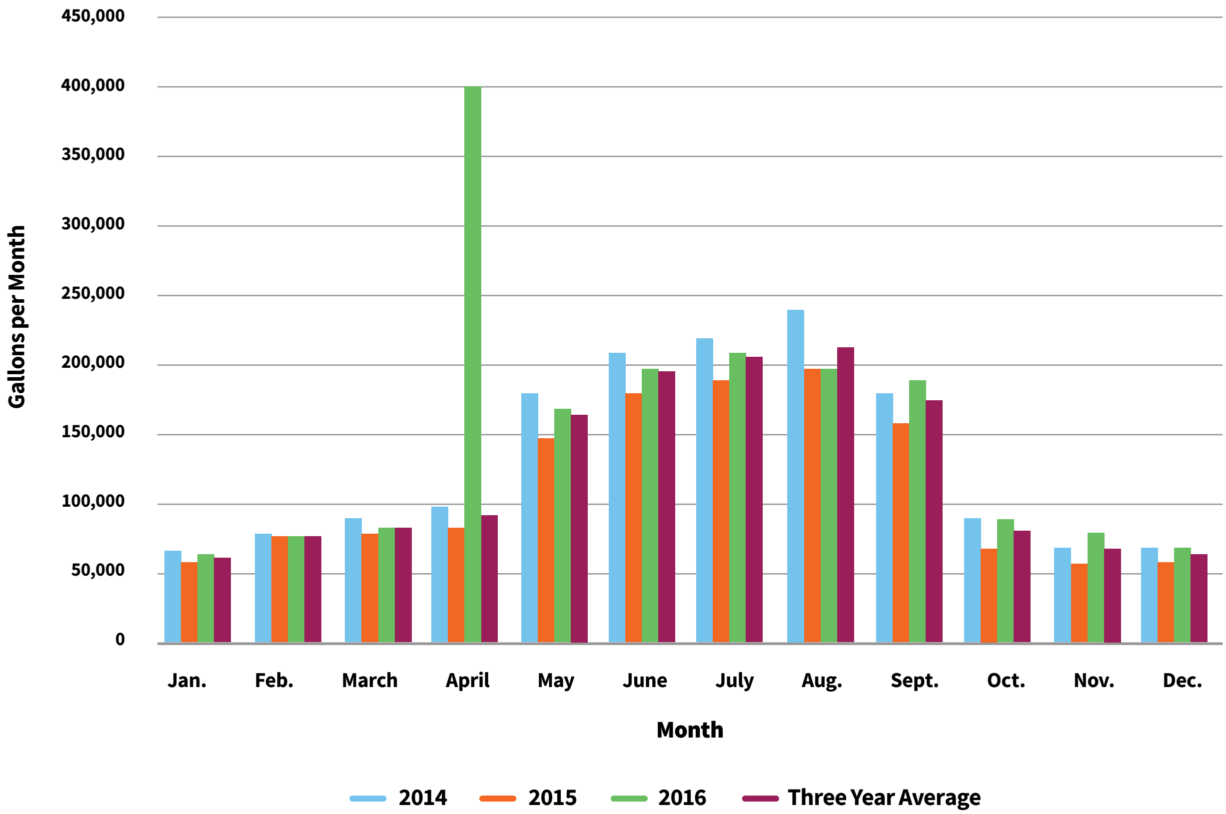


TABLE 23. EXAMPLE HISTORICAL MONTHLY WATER USE FROM WELL (IN GALLONS PER MONTH)

MONTH	YEAR 2014	YEAR 2015	YEAR 2016	THREE-YEAR AVERAGE
Jan.	3,500	3,100	2,900	3,167
Feb.	3,600	3,900	3,250	3,583
March	5,000	5,5,00	4,900	3,300
April	6,200	6,200	6,000	6,133
May	18,000	15,000	12,600	15,200
June	19,000	14,000	16,000	16,333
July	22,000	19,000	16,400	19,133
Aug.	26,000	21,000	28,000	25,000
Sept.	18,000	18,000	14,900	16,967
Oct.	9,200	9,800	9,500	9,500
Nov.	3,500	3,300	3,400	3,400
Dec.	5,000	6,000	3,000	4,667
Total	**139,000**	**119,300**	**120,850**	**126,383**

Water source: well onsite

FIGURE 12. EXAMPLE HISTORICAL WELL WATER USE

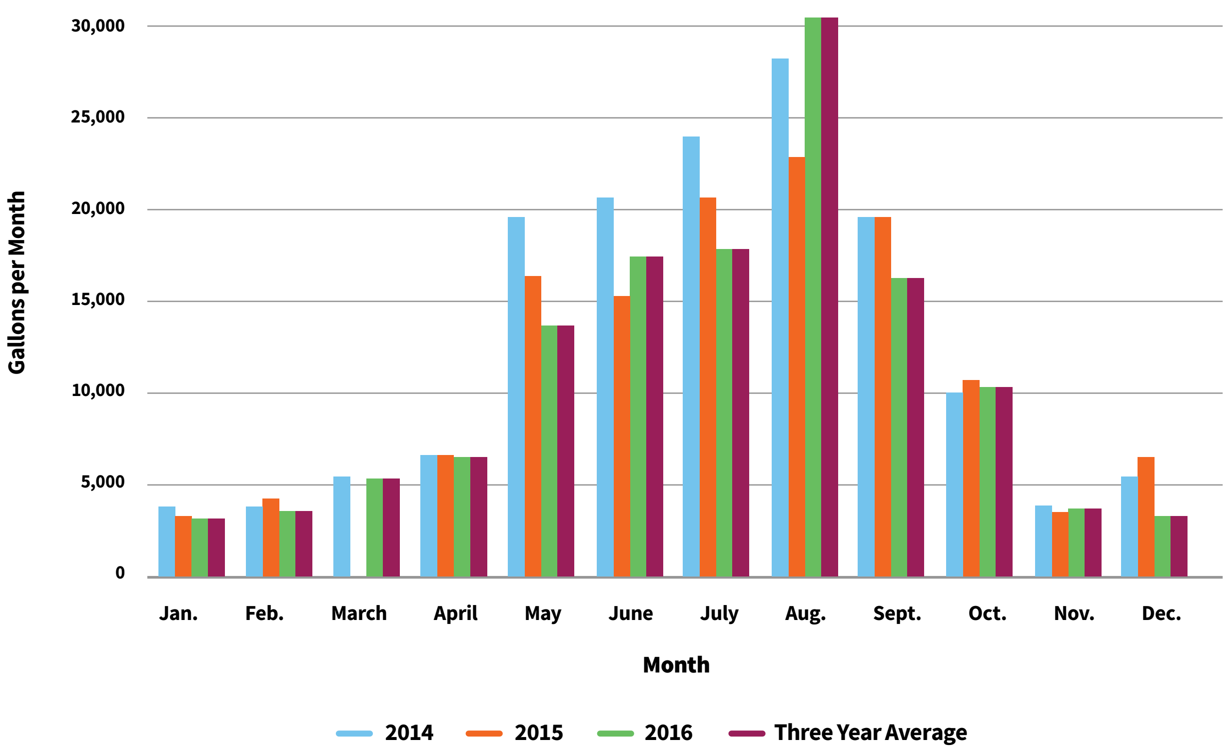


TABLE 24. EXAMPLE TOTAL WATER USE FROM ALL SOURCES (IN GALLONS PER MONTH)

MONTH	THREE YEAR AVERAGE
Jan.	67,500
Feb.	82,583
March	88,300
April	98,633
May	181,867
June	213,000
July	225,800
Aug.	238,333
Sept.	193,634
Oct.	92,833
Nov.	73,400
Dec.	71,334
Total	**1,627,216**

II. SITE VISIT

WALK THROUGH

Example: Fixtures and Fittings

The following is an example of a small restaurant. Additionally for each fixture type and location, add images.

TABLE 25. EXAMPLE TABLE FOR FIXTURES AND FITTINGS

AREA OF USE	END USE	LOCATION	WATER USE	NOTES
Domestic	Water Closet	Men's Bathroom	1.6 gpf	Running
Domestic	Water Closet	Men's Bathroom	1.6 gpf	
Domestic	Urinal	Men's Bathroom	1.0 gpf	
Domestic	Water Closet	Women's Bathroom	1.6 gpf	
Domestic	Water Closet	Women's Bathroom	1.6 gpf	
Domestic	Water Closet	Women's Bathroom	1.6 gpf	
Domestic	Lav/Sink	Men's Bathroom	2.2 gpm	
Domestic	Lav/Sink	Men's Bathroom	2.2 gpm	Leak (dripping)
Domestic	Lav/Sink	Women's Bathroom	2.2 gpm	
Domestic	Lav/Sink	Women's Bathroom	2.2 gpm	
Heating and Cooling	Water Heater	Men's Bathroom	N/A	
Heating and Cooling	Water Heater	Women's Bathroom	N/A	
Food Service	Dishwasher	Kitchen	35 gpc	
Food Service	Steamer	Kitchen		
Food Service	Ice Machine	Drink Station		
Cleaning and Other	Mop Sink	Cleaning Closet	2.2 gpm	

EXAMPLE: Meters and Submeters

TABLE 26. EXAMPLE TABLE OF WATER METERS SERVING FACILITY

METER	UTILITY OR SUBMETER	TYPE	AGE OF METER	NOTES
Main Utility	Utility	4" compound Badger	4 years	In locked utility vault at street
Irrigation	Utility	2" irrigation turbine Badger	12 years	In utility meter box at street - May need testing?
Cooling Tower Makeup	Submeter	3" compound Sensus	3 years	Next to cooling tower on room in insulated box
Cooling Tower Blowdown	Submeter	1 ½" nutating disk Sensus	New	Next to conductivity controller in control room
Fire Meter	Utility	4" Sensus	12 years	May be leaking

EXAMPLE: Domestic Hot Water

TABLE 27. EXAMPLE TABLE OF DOMESTIC HOT WATER SERVING FACILITY

WATER HEATER IDENTIFIER	AREA	TYPE	AGE	LOCATION	TEMP. SETTINGS	RECIRC CONTROLS YES/NO & DESC.	
1	Restrooms	Tank	5 yrs	Basement Mechanical Room	140	Y	Aquastat with 24/7 timer
2	Employee Break Room	On demand	1 yr	Under sink	110	N	
3	Laundry	Tank	8 yrs	Laundry Room	140	N	

EXAMPLE: Landscape Water Use

TABLE 28. EXAMPLE TABLE OF LANDSCAPE WATER USE

LOCATION OF AREA	TYPE OF AREA	TYPES OF PLANTS	TYPE OF IRRIGATION	NOTES
Front/main entry	Landscaped/mulched	Perennials, bushes, small trees	Drip	
Rear of building	Turf/grass field	Grasses	Spray time controlled	2 spray heads may be malfunctioning – areas of dead grass

III. ANALYSIS

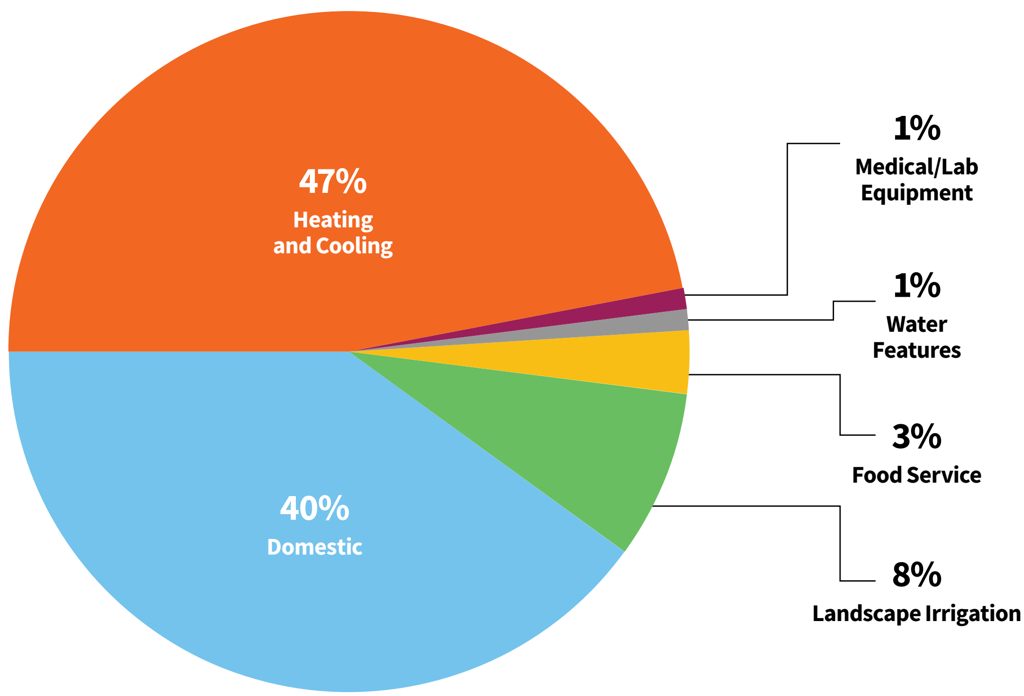
WATER USE BALANCE

EXAMPLE: Water Use Balance by Area

TABLE 29. EXAMPLE TABLE SHOWING ANNUAL USE BY TYPE

AREA OF USE	ANNUAL ESTIMATED VOLUME (GALLONS PER YEAR)	PERCENT OF USE
Medical/Lab Equipment	10,000	1%
Water Features	20,000	1%
Food Service	45,000	3%
Landscape Irrigation	125,000	8%
Domestic	600,000	40%
Heating and Cooling	700,000	47%
Total	**1,500,000**	**100%**

FIGURE 13. EXAMPLE PIE CHART OF ANNUAL WATER USE ESTIMATES



DETERMINE WATER CONSERVATION OPPORTUNITIES

EXAMPLE: Fixtures and Fittings

For example, Table 30 is showing the number and type of plumbing fixtures found and their use rates. Table 31 is the example given for faucet aerators.

TABLE 30. EXAMPLE RESTROOM WATER USE

FIXTURE	ESTIMATED GALLONS PER YEAR
Toilets	350,000
Urinals	125,000
Lavatory Faucets	115,000
Showers	10,000
Total	**600,000**

Restrooms surveyed were equipped with both manual and sensor-type faucets. There are 135 operational lavatory faucets within the facility with flow rates ranging from 0.5 gallons per minute (gpm) to 3.0 gpm shown in Table 31. The average flow rate across all fixtures is 2.2 gpm. Since this is a commercial building, code requires a 0.5 gpm aerator.

TABLE 31. EXAMPLE FAUCET AERATORS

FIXTURE TYPE	FLOW RATE IN GALLONS PER MINUTE (GPM)	QUANTITY
Lavatory Faucet	Unrestricted (3.0 GPM)	3
Lavatory Faucet	2.2 GPM	113
Lavatory Faucet	1.5 GPM	7
Lavatory Faucet	1.0 GPM	2
Lavatory Faucet	0.5 GPM	8
Average	**2.2 GPM**	**135**

COST BENEFIT ANALYSIS

TABLE 32. EXAMPLES OF COST AND BENEFITS

<table>
<tr><th>COSTS</th><th>BENEFITS</th></tr>
<tr><td>Equipment</td><td>Value of water saved</td></tr>
<tr><td>Installation</td><td>Value of energy saved</td></tr>
<tr><td>Early removal (if applicable)</td><td></td></tr>
<tr><td colspan="2">Operations and Maintenance</td></tr>
</table>

TABLE 33. EXAMPLE OF SIMPLE PAYBACK COST-BENEFIT ANALYSIS

Recommended Conservation Measure	Current Annual Water Use (Gal. /yr.)	Estimated Annual Water Savings (Gal. /yr.)	Water Use after Conservation Measures (Gal. /yr.)	Estimated Annual Dollar Savings with Conservation	Estimated Project Cost	Number of Proposed Retrofits	Simple Payback Period (yrs.)	Percent Reduction
High-efficiency 1.28 gpf toilets to replace 5.0 gpf	1,408,750	1,048,110	360,640	$11,393	$27,300	65	2.4	75%
High-efficiency 0.5 gpf urinals flushvalve to replace 1.0 gpf	254,000	127,000	127,000	$1,381	$2,200	20	1.6	50%
High-efficiency 0.3 gpm faucet aerators to replace 2.2 gpm, includes energy cost with gas heat and assumes hot water = 40% of total use	539,000	447,125	91,875	$5,580	$1,500	100	0.3	83%
Increase Cooling Tower Cycles of Concentration from 3.1 to 6.0	2,310,000	441,000	1,869,000	$4,794	$6,500	1	1.4	19%
Total	**4,511,750**	**2,063,235**	**2,448,515**	**$23,148**	**$37,500**		**1.6**	**47%**

Example: Net Present Value

Consider an Atlanta-based commercial water efficiency measure with upfront capital expenditures of $100,000 ($80,000 from equipment and installation, $20,000 from early removal of the existing equipment) that saves $32,000 in electricity, $16,000 in water, and $2,000 in O&M annually, and has a 15-year lifetime. Further, assume that the measure loses 1 percent in performance year-to-year. The client pays an average of $0.095/kWh for energy and $0.029/gal for water and wastewater (including all fees and charges). The current water rate for the City of Atlanta is generated via its bill calculator.[34] Lastly, apply a 7 percent discount rate to the analysis.

Atlanta is in the SERC-Southeastern EMM region, and EIA projects that this region will see a 0.3 percent annual increase in commercial electricity prices.

Table 34 shows the present values of the investment over the course of 15 years, along with the net present value of the investment.

TABLE 34. VALUE OF WATER EFFICIENCY MEASURE WITH A 15-YEAR LIFETIME

Year	Equipment and Installation Costs	Early Removal Costs	Total Cost	Water and Wastewater Savings	Energy Savings	O&M Savings	Total Annual Savings	Discounted Savings	Discounted Costs	Net Present Value
0	$80,000	$20,000	$100,000	$16,000	$32,000	$2,000	$50,000	$50,000	$100,000	$(50,000)
1	$-	$-	$-	$16,767	$31,775	$2,000	$50,542	$47,235	$-	$47,235
2	$-	$-	$-	$17,570	$31,552	$2,000	$51,122	$44,652	$-	$44,652
3	$-	$-	$-	$18,412	$31,330	$2,000	$51,742	$42,237	$-	$42,237
4	$-	$-	$-	$19,294	$31,110	$2,000	$52,404	$39,979	$-	$39,979
5	$-	$-	$-	$20,219	$30,891	$2,000	$53,109	$37,866	$-	$37,866
6	$-	$-	$-	$21,187	$30,674	$2,000	$53,861	$35,890	$-	$35,890
7	$-	$-	$-	$22,203	$30,458	$2,000	$54,661	$34,040	$-	$34,040
8	$-	$-	$-	$23,266	$30,244	$2,000	$55,510	$32,308	$-	$32,308
9	$-	$-	$-	$24,381	$30,031	$2,000	$56,413	$30,685	$-	$30,685
10	$-	$-	$-	$25,549	$29,820	$2,000	$57,370	$29,164	$-	$29,164
11	$-	$-	$-	$26,774	$29,611	$2,000	$58,384	$27,738	$-	$27,738
12	$-	$-	$-	$28,056	$29,402	$2,000	$59,459	$26,400	$-	$26,400
13	$-	$-	$-	$29,401	$29,196	$2,000	$60,597	$25,145	$-	$25,145
14	$-	$-	$-	$30,810	$28,991	$2,000	$61,800	$23,967	$-	$23,967
15	$-	$-	$-	$32,286	$28,787	$2,000	$63,072	$22,860	$-	$22,860
Total			**$100,000**	**$372,174**	**$485,871**	**$32,000**	**$890,045**	**$550,165**	**$100,000**	**$450,165**

Table 34 shows that the NPV (final column) of the savings in each future year is less than the simple net value method (next-to-last column). For the investment under consideration, a simple payback calculation would show just under a two-year payback, while the NPV is showing a value slightly over 2 years. The divergences become more pronounced in the later years of the analysis; the difference between the savings a simple payback calculation would produce and that of a net present value is over $560,000. The major benefit to this calculation is the presentation of the value of the investment over the 15-year lifetime, as opposed to simply assessing when the costs have been recovered; it's a more complete accounting that quantifies the return to an investment instead of focusing on the risk.

The present value portion of this calculation is the most complex piece. Year 0 is a relatively straightforward calculation (recall that the measure requires investing $100,000 and saves $50,000, so n = -$50,000):

$$PV_0 = \frac{50{,}000 - 100{,}000}{(1 + 0.07)^{0-0}} = -\$50{,}000$$

Since (2015 - 2015 = 0), and any value to the 0 power is equal to 1, the calculation simplifies to -50,000/1, which equals $-50,000, the value in Table 34.

Now, for Year 1, the measure is yielding $50,542 in savings without incurring new costs, so present value calculation would look like this:

$$PV_1 = \frac{50{,}542 - 0}{(1 + 0.07)^{1-0}} = -\$47{,}235$$

Applying that same approach to the whole monetary flow of future benefits produces a NPV of $450,165 over 15 years for this particular investment, the value shown in Table 34.

Example: Equipment Life Utility Cost Comparison

Example 1. Toilet Replacement

The simplest form of this analysis is to use current cost. For example, a 3.5 gallon per flush (gpf) toilet is replaced with a 1.28 gpf toilet. The toilet will save 2.22 gpf and the audit study shows that the fixture will be used an average of 35 times a day, 245 days a year. Based on this, the toilet will save approximately 19,036.5 gallons a year.

The average life of a toilet from Table 34 is about 25 years. Based on current rates of $11.27 per thousand gallons for combined water and sewer cost, the toilet will save $214.54 a year at current rates. This equals to $5,363.53 over the life of the fixture.

However, if future costs are assumed, the savings are more dramatic. Table 35 shows the dollar savings for the example toilet over the next 25 years if the inflation rate of the last 15 years of 5.85 percent continues.

TABLE 35. EQUIPMENT LIFE UTILITY COST COMPARISONS FOR THE TOILET REPLACEMENT EXAMPLE

YEAR	WATER & SEWER RATE PER THOUSAND GALLONS	TOILET SAVINGS PER YEAR
2016	$11.27	$214.54
2017	$11.93	$227.09
2018	$12.63	$240.38
2019	$13.37	$254.44
2020	$14.15	$269.32
2021	$14.98	$285.08
2022	$15.85	$301.76
2023	$16.78	$319.41
2024	$17.76	$338.09
2025	$18.80	$357.87
2026	$19.90	$378.81
2027	$21.06	$400.97
2028	$22.30	$424.43
2029	$23.60	$449.25
2030	$24.98	$475.54
2031	$26.44	$503.35
2032	$27.99	$532.80
2033	$29.63	$563.97
2034	$31.36	$596.96
2035	$33.19	$631.88
2036	$35.14	$668.85
2037	$37.19	$707.98
2038	$39.37	$749.39
2039	$41.67	$793.23
2040	$44.11	$839.64
25 Year Total Savings		**$11,525.04**

As the life-cycle utility cost example shows, the actual savings with inflation will be nearly double that where only current utility rates and considered.

Example 2. Commercial Ice Machine
Commercial ice machines can be either air-cooled or water cooled. With this type of equipment, once-through cooling with water is often used. Water is passed through the compressor heat exchanger, heated by about 5° F to 15° F and discharged to the sanitary sewer. However, water cooled machines are more energy efficient.

Air-cooled ice machines only use water to make ice, not cool the equipment. The machines are rated in how many 100 pounds of ice they can make a day. New equipment uses from 12 to 20 gallons of water to make 100 pounds of ice. However, water-cooled equipment uses an additional 85 gallons to 200 gallons of water to make the same amount of ice. Table 37 shows the expected life of an ice machine is around eight years.

For this example, a hypothetical air-cooled and water-cooled machine will be compared. The operating parameters for the two machines are given in Table 36.

TABLE 36. EXAMPLE ICE MACHINES

TYPE	KILOWATT HOURS PER 100 POUNDS OF ICE	GALLONS OF COOLING WATER PER 100 POUNDS OF ICE	GALLONS USED TO MAKE ICE PER 100 POUNDS OF ICE
Air-Cooled Machine	5.1	0	19
Water-Cooled Machine	3.8	105	19

It is assumed that the ice machine makes 1,000 pound of ice a day for 365 days per year. If inflation is not taken into consideration, the annual operating costs are shown in Table 37.

TABLE 37. COSTS SUMMARY AT 2016 COSTS (NO INFLATION)

TIME PERIOD	WATER & SEWER COST	WATER-COOLED ELECTRICITY COST	AIR-COOLED ELECTRICITY COST	ENERGY SAVINGS WITH WATER COOLED	COST OF WATER TO MAKE ICE
Cost for One Year	$4,443	$1,428	$1,916	$488	$782
Total Cost Over Eight Years	$35,544	$11,424	$15,328	$3,904	$6,256

When the inflation of energy and water is considered based on current inflation rates shown in Figures 3 and 4, the utility costs over the eight-year expected useful life of the water-cooled icemaker would be $35,544 for water and sewer costs and $11,424 for a total utility cost of $46,968. By contrast, the air-cooled ice machine's electricity cost would be $15,328. Water costs for making ice would be $8,926 for both machines.

In summary, using an air-cooled machine will save $31,635 over the eight-year life of the machine compared to a water-cooled type at current utility rates. When inflation is considered, these net savings grow to $42,249 over the eight-year period.

Finally, if the air-cooled ice machine is in an air-conditioned space, the rejected heat would have to be removed by the air conditioner during the cooling season, but the heat from the ice machine would reduce heating bills during the colder months.

Example 3: Air-Cooled Ice Machines in Heated and Cooled Spaces
Commercial ice machines are essentially heat pumps used to remove energy from water so that it will freeze. The heat they reject includes the electric energy used to operate the equipment, the sensible heat rejected to lower the water used to make ice to the freezing point, and the latent heat of fusion released when ice forms. When this energy is released into a heated and cooled space, it contributes to the energy needed to heat the space during the heating season but must be removed by the facility's air-conditioning system during the cooling season.

The following example show how to calculate the impacts of the rejected heat from an ice machine in a heated and cooled space. Since ice machines are rated by the hundreds of pounds of ice they can make in a day, all values are calculated on the basis of 100 pounds of ice made.

For this example, the following is assumed:

- The facility has a cube-type ice maker and needs 1,000 pounds of ice each day it is open for business.
- The facility has a rooftop heating and cooling system.
- The heating system for the building is 80 percent efficient.
- The air-conditioning system efficiency is 1.1 kilowatt hours per ton-hour.
- The facility is heated with natural gas costing $7.50 per thousand cubic feet (MCF) and each MCF has a heating value of one million Btus.
- Electricity costs $0.12 per kilowatt hour (based on Energy Information Administration national average commercial electric rates are $0.1058 cents per kilowatt hour in 2017).
- Water and wastewater combined cost $9.00 per thousand gallons (A Black and Veatch study of rates in the nation's 50 largest cities shows average commercial combined water and wastewater rates were $11.27 per thousand gallons in 2016).
- The facility operates 362 days a year, of which 211 were cooling days and were heating days. The facility is closed Thanksgiving, Christmas, and New Year's Day.
- The average temperature of the tap water used to make ice is 62°F.
- One hundred pounds of ice equals 12 gallons of water.

To begin the analysis of related costs per 100 pounds of ice, the cost per 100 pounds of ice for air- and water-cooled ice machines, without considering building and cooling loads, is calculated using the local costs of electricity and water.

Analysis of ice machines in non-heated and cooled spaces
For the *air-cooled* machine, 5.1 kilowatt hours of electricity are used per 100 pounds of ice. At 12 cents per kilowatt hour, this equals 61.2 cents per 100 pounds. For the water-cooled machine, at 3.8 kilowatt hours of electricity per 100 pound of ice, the costs are 45.6 cents per 100 pounds. This is a net difference of 15.6 cents per pound.

For making ice, both machines use 19 gallons of water to make 12 gallons (100 pounds) of ice. The remaining five gallons is used to rinse the ice cubes as they form to remove minerals that precipitate in the freezing process. This five gallons is discharged to the sewer. At $9.00 per thousand gallons, the ice making water cost for both machines is equal at 17.1 cents per 100 pounds per ice made.

The *water-cooled* machine uses 105 gallons of water per 100 pounds of ice made to cool the equipment. The water simply passes through the icemaker, cools it, and is then dumped into the sewer. At $9.00 per thousand gallons, the cost of cooling water equals 94.5 cents per 100 pounds. The net result if the air-cooled ice machine is not located in a heated and cooled space is that the water-cooled machine saves 15.6 cents per 100 pounds of ice on electric costs, but the water cost for cooling equal 94.5 cents per 100 pounds. This means that ice made by the water-cooled ice machine costs 78.9 cents more per 100 pounds than for an air-cooled machine.

Analysis of ice machines in heated and cooled spaces
If the air-cooled machine is located in a heated and cooled space, the heat rejected into that space with an air-cooled machine should be taken into account. First, the equipment uses 5.1 kilowatt hours per 100 pounds of ice. At 3,412 Btus per kilowatt hour, this is equal to 17,401 Btus of added heat per 100 pounds of ice.

The tap water used to make ice must also be cooled to 320° F, or a difference of 300° F. Water weigh 8.34 pounds per gallon and has a heat capacity of one Btu/pound/degree Fahrenheit. This represents a sensible heat load. The equipment uses 19 gallons per 100 pounds. This is equal to 4,754 Btus rejected per 100 pounds of ice (19 gal. X 8.35 lb./gal. X 1 Btu/lb./ ° F X 30 ° F increase). The latent heat of fusing for ice is 144 BTUs/pound. Therefore, for every 100 pounds made, 14,400 Btus of latent heat is released.

Total heat rejected into the heated and cooled space is equal to the sum of the electric, sensible, and latent heat per 100 pounds which equals 36,555 Btus per 100 pounds of ice.

During the heating season, this rejected heat helps to heat the building and represents a benefit. If the heating equipment is 80 percent efficient, it will use 1,250,000 Btus of energy to achieve one million BTUs of heating (1,000,000 / 0.8). At $7.50 per million Btus, it costs $9.36 ($7.50/0.8) to provide one million BTUs of heating. Since the ice machine provides 36,555 Btus of heat per 100 pounds of ice, <u>it provides a benefit equal to 34.6 cents per 100 pounds</u> during the heating season. (36,555/1,000,000 X 936 cents per million Btus)

During the *cooling season*, the 36,555 Btus of waste heat rejected into the cooled space must be removed by the air conditioner. There are 12,000 Btus per ton-hours of air conditioning. Therefore, for every 100 pounds of ice made, 3.05 ton-hours of additional cooling are needed. (36,555 Btus / 12,000 Btus per ton-hour). The air-conditioning unit uses 1.1 kilowatt hour per ton-hour so the additional electric energy use equals 3.56 kilowatt hours, which at 12 cents per kilowatt hour increases the cost for 100 pounds of ice by 40.3 cents.

Since there are 211 cooling days and 151 heating days, in one year that 100 pounds of ice will cost an additional $85.03 (211 days X 40.3 cents) in air conditioning per year. However, the heating benefit over 151 days a year will save $52.25 (151 days X 34.6 cents). The net result for making 100 pound of ice a day for 362 days a year is that an air-cooled unit in a heated and cooled space will cost an additional $32.79 a year to make 100 pounds of ice a day for 362 days a year or 36,200 pounds of ice. Based on cost normalized to 100 pounds of ice made, the additional cost per 100 pounds made will be only 9.06 cents per 100 pounds of ice.

As an extreme analysis, if it is assumed that there are 365 cooling days a year, the additional cost of air conditioning per 100 pounds of ice produced by an air-cooled ice machine in an air-conditioned space will be 40.3 cents per 100 pounds. If a chilled water loop is used, the heat is still removed by the air conditioning unit although these types of air-conditioning systems are more efficient. At an operating efficiency of 0.75 kilowatt hours per ton of air conditioning, the difference decrease to 27.5 cents per 100 pounds.

In summary, the cost of operating a water-cooled ice maker with once through cooling is always more costly than using an air-cooled unit or a chilled water loop. Also, in this example lower than average water and wastewater costs were used and higher than average electricity prices were used to emphasize that this scenario is true across the nation. Table 38 summarizes this example.

TABLE 38. EXAMPLE OF COST OF ICE PER 100 POUNDS

TYPE OF SYSTEM	ICE MAKER	WATER TO MAKE ICE	ROOM HEATING &	ONCE	TOTAL COST PER 100 POUNDS OF ICE
Air-cooled in un-air conditioned space	61.2	17.1	0	0	78.3
Air-cooled in heated & cooled space – 211 days per year with air conditioning, 151 days of heating	61.2	17.1	9.1	0	87.4
Chilled water loop – 365 air conditioning days per year	45.6	17.1	27.5	0	90.2
Air-cooled – 365 air conditioning days per year	61.2	17.1	40.3	0	118.6
Water cooled – once through	45.6	17.1	0	94.5	157.2

Costs for water and wastewater were assumed to be $9.00 per thousand gallons, natural gas was assumed to cost $7.50 per MCF and electricity was assumed to be 12 cents per kilowatt hour. Gas heating equipment was assumed to operate at 80 percent efficiency. It was assumed that the rooftop air conditioner had an energy use factor of 1.1 kilowatt hours per ton-hours and the chilled water system had an energy use factor of 0.75 kilowatt hours per ton-hour.

APPENDIX C: WATER-USING EQUIPMENT AND SYSTEMS INFORMATION

TOILETS AND URINALS

The following nomenclature shall be used for toilets and urinals.

Toilet Water Use

- Ultra High-Use Toilets: manufactured before 1985 4.5 - 5 gpf (17 liter per flush [Lpf])
- High-Use Toilets: 3.5 gpf (13.2 Lpf) (flush valve often marked with an S)
- Low-Consumption: 1.6 gpf (6.0 Lpf) (china marked with a 1.6 gpf/6 Lpf marking)
- High-Efficiency (HET): 1.28 gpf (4.5 Lpf)
- Ultra High-Efficiency (UHET): Less than 1.28 gpf

Toilet Type

- Tank Type
- Pressure Assist
- Vacuum Assist
- Flush Valve – diaphragm
- Flush Valve – piston
- Other

Urinal Water Use

- High-Use Urinals: Uses more than 1.5 gpf
- Blow Outs: 3.5 gpf (13.3 Lpf) – a type of bowl design
- Water Saver: 1.5gpf (5.7 Lpf) (flush valve often marked with an S)
- Low Consumption: 1.0 gpf (3.8 Lpf) (flush valve often marked with LC)
- New Wash Downs: 1/2 to 1 gallon (1.9 Lpf)
- High Efficiency (HEU): 1/4 gpf – 1 quart; 1/8 gpf – 1 pint
- Non-Water Use Urinals: No water use

CHOOSING THE CORRECT PARTS FOR TOILETS AND URINALS

One of the most important considerations when examining toilet and urinal plumbing fixture use is to ensure that the correct parts are chosen. The incorrect flapper valve can convert a 1.28 gpf toilet into a 5.0 gpf toilet. For most flush valve urinals and toilets, all diaphragms are interchangeable. This means that a 5.0 gpf diaphragm can fit in a 1.28 gpf toilet valve or a 0.5 gpf urinal valve. Examining what replacement parts are on hand to repair toilets and urinals and knowing how to measure flow rates in toilets and urinals is an essential part of the audit process. The following provides some guidance. However, the most important consideration is that the auditor has a working knowledge of what replacement parts are correct for each type of toilet or urinal. This especially applies to flapper valves, fill valves, and flushometer replacement parts.

Tank-type toilets

- Use the meter to determine use per flush by flushing enough times to get an accurate reading.
- Use a ruler to measure the volume of the toilet tank from the top of the water level to the bottom level of water when it is flushed. (subtract 10%-15% for bowl refill).
- If manufactured after 1998, the china at the back of the seat area and the inside of the tank will usually have a marking in it if it is a 1.6 gpf, 1.28 gpf or lower. However, measurement should still be made since flapper valves are often mismatched to the fixture.
- Use a T5 flow meter.
- Measuring can method: Turn off toilet and flush. Using a measuring cup or bucket, measure the amount of water to bring both the tank and bowl back to normal water levels.

MEASURING TOILET AND URINAL FLOW RATES

Flush Valve-Type Toilets and Urinals

The following describes ways that the volume per flush for toilets and urinals can be estimated.

Based on manufacturers' information, most flush-valve toilets have a flow rate of approximately 25 gallons per minute (25 gpm) and urinals have a flow rate of approximately 15 gallons per minute (15 gpm) at 60 pounds per square inch of pressure. This information can be used to estimate flush volumes by observing the time it takes to complete a flush cycle to estimate the volume per flush (from actuation of the flush valve to the time the valve closes). For example, if a toilet valve takes five seconds to flush, the volume of water that passes through the valve at 25 gpm would equal 5 seconds X 25 gallons per minute / 60 seconds per minute or 3.3 gallons per flush. This would mean that the valve is either a 3.5 gallons per flush (gpf) toilet or has a bad diaphragm if it is a 1.28 or 1.6 gpf toilet.

Table 39 summarizes flush volume estimates based on the number of seconds in a flush cycle. It is very difficult to determine the exact time, but it should start as soon as the toilet is flushed and end when the flush valve stops flowing. Again, this is an approximation method. There is overlap in time for 1.28 gpf and 1.6 gpf toilets.

TABLE 39. FLUSH VOLUME FLOW-RATE CALCULATOR

VALVE TYPE	NUMBER OF SECONDS IN FLUSH CYCLE	FLOW-RATE GALLONS PER MINUTE	GALLONS PER FLUSH
Toilet 1	1-3	25	1.25
Toilet 2	2-4	25	1.6
Toilet 3	6-8	25	3.5
Toilet 4	Over 8	25	4.5 +
Urinal 1	3	15	0.75
Urinal 2	4	15	1.0
Urinal 3	6	15	1.5
Urinal 4	10	15	2.5

Urinal flush volume using the timing method is also an approximation.

Flush Volume = [Flow rate (gpm) X Seconds] ÷ 60 Seconds/Minute

Another, much more time-consuming method is the bucket and bail method. With this method, a plumber packer is placed in the discharge trap in the toilet past the water inlet in the trap and is then inflated to seal the trap. All the water is pumped and sponged from the bowl and the toilet flushed. The volume caught after the flush is the amount of water actually used per flush.

TABLE 40. ESTIMATED APPROXIMATE FLUSH VOLUMES

SECONDS PER FLUSH	TOILET FLUSH VOLUME (GALLONS) AT 25 GPM	URINAL FLUSH VOLUME (GALLONS) AT 15 GPM
1	0.4	0.3
2	0.8	0.5
3	1.3	0.8
4	1.7	1.0
5	2.1	1.3
6	2.5	1.5
7	2.9	1.8
8	3.3	2.0
9	3.8	2.3
10	4.2	2.5
11	4.6	2.8
12	5.0	3.0

PISTON VS. DIAPHRAGM FLUSH VALVES

- Piston valves tend to stick closed, not open at low pressures like diaphragm valves do.
- Accuracy of flush volume +/- 5% vs. 20%–30% for diaphragm-type pistons avoid diaphragm confusion.

COOLING TOWERS

Cooling towers often represent the largest use of water in industrial and commercial applications, often comprising 20 to 70 percent or more of a facility's total water use. By optimizing operation and maintenance of cooling tower systems, however, facilities can save significant amounts of water. How much water is used depends on many factors which will be discussed. The purpose of this section is to provide insight on how to measure cooling tower water use where some form of metering is present, and how to estimate use where proper metering is not available.

Cooling towers are used in a variety of commercial, industrial, and institutional applications to remove rejected energy from air-conditioning systems and in some cases, from industrial processes. They serve commercial and institutional facility types such as office buildings, schools, supermarkets, hospitals, office complexes, and university campuses, as well as industrial operations. Cooling towers dissipate heat from recirculating water that is used to cool chillers, air-conditioning and refrigeration equipment, or other process equipment. By design, they use significant amounts of water since they dissipate this heat by evaporation.

Cooling towers work by circulating water through systems that generate heat as they function. Chiller condensers are the most common example of this in commercial and institutional operations. The warm water is then pumped to the top of the cooling tower, where it is sprayed or dripped through internal fill (or labyrinth-like packing with a large surface area). Fans pull or push air through the tower in a counter flow or crossflow to the falling water. Heat is dissipated primarily though evaporation.

The thermal efficiency and longevity of the cooling tower and its associated water loops and condenser heat exchangers depend on the proper management of water recirculated through the tower. Water leaves a cooling tower system in the following ways:

- **Evaporation:** This is the primary function of the tower and is the method that transfers heat from the cooling tower system to the environment. The quantity of evaporation is not typically targeted for water-efficiency efforts, because it controls the cooling process (although improving the energy efficiency of the systems that use the cooling water will reduce the evaporative load on the tower).
- **Blowdown or bleed-off:** When water evaporates from the tower, dissolved solids (such as calcium, magnesium, chloride, silica, and other salts and minerals) are left behind. As more water evaporates, the concentration of total dissolved solids (TDS) increases. If the concentration gets too high, the TDS can cause scales to form within the system or can lead to corrosion. The concentration of TDS is controlled by removing (i.e., bleeding or blowing down) a portion of the water in the tower basin that has high TDS concentration and replacing that water with make-up water, which has a lower concentration of TDS. Carefully monitoring and controlling the quantity of blowdown provides the most significant opportunity to conserve water in cooling tower operations. In properly instrumented cooling towers, conductivity meters determine the TDS levels in the tower and automatically discharge blowdown to the sewer to maintain proper TDS levels. In older or improperly instrumented towers, this is often accomplished through manual conductivity readings by a technician.
- **Drift:** A small quantity of water may be carried from the tower as mist or small droplets known as "drift." Drift loss is small compared to evaporation and blowdown and is controlled with baffles and drift eliminators. Drift can vary from 0.005 percent or less of the flow rate through the cooling tower with modern technology to 0.2 percent of the flow rate through the cooling tower for systems without proper drift eliminators. 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 per ton-hour. This illustrates the importance to have properly installed and functioning drift eliminator.

- **Basin leaks or overflows**: Properly operated towers should not have leaks or overflows. However, an overflow drain is provided within the tower in case of malfunction and subsequent overflow.

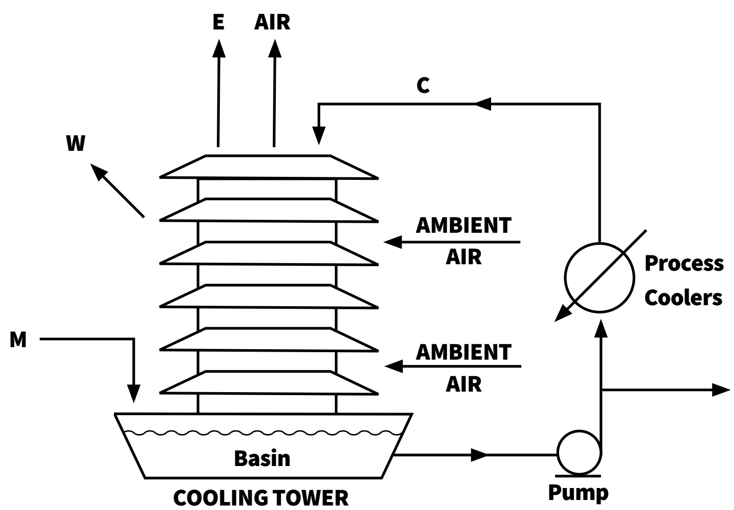
COOLING TOWER WATER USE

The water used by the cooling tower is equal to the amount of make-up water that is added to the system. The amount of make-up water needed is dictated by the amount of water that is lost from the cooling tower through evaporation, drift, blowdown, and leakage, as illustrated by Equation 1.

Equation 1

$$\text{Make-Up Water (gallons)} = \begin{array}{l}\text{Evaporation (gallons) + Drift (gallons) +} \\ \text{Blowdown (gallons) + Leaks and Overflows (gallons)}\end{array}$$

FIGURE 14. SCHEMATIC OF A COOLING TOWER WATER FLOW[35]



C= Circulating Cooling Water
E- Evaporated Water
W= Windage or Drift Loss
M= Makeup Water
D= Drawoff or Blowdown Water

All modern cooling towers should have drift eliminators that reduce drift loss to under 0.005 percent of the water recirculation rate. This makes drift loss negligible in the calculations. Likewise, good leak and overflow control makes these parameters negligible in the above equation. This means that for a well-managed and designed tower, Equation 1 can be simplified and reduced to the following.

Equation 2

Make-Up Water (gallons) = Evaporation (gallons) + Blowdown (gallons)

A key parameter used to evaluate cooling tower operation is cycles of concentration (sometimes referred to as "cycles" or "concentration ratio"). The concentration ratio is the ratio of the concentration of TDS (or conductivity) in the blowdown water divided by the conductivity of the make-up water. Since TDS enters the system in the make-up water and exits 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. See Equations 3 and 4 below.

Equation 3

$$\textbf{Cycles of Concentration} = \frac{\textbf{Conductivity of Blowdown Water (measured in Micro Siemens)}}{\textbf{Conductivity of Make-Up Water (measured in Micro Siemens)}}$$

Equation 4

$$\textbf{Cycles of Concentration} = \frac{\textbf{Make-up Water (gallons)}}{\textbf{Blowdown Water (gallons)}}$$

To use water efficiently in the *cooling tower system*, the cycles of concentration must be maximized while still protecting the integrity of the tower and condenser heat exchanger surfaces. This is accomplished by minimizing the amount of blowdown required and thereby 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 dissolved minerals and salts (TDS) remain behind and do not evaporate. As cycles of concentration increase, the danger of fouling the heat exchangers and tower increase due to one of more of the following:

- Corrosion of metal surfaces
- Biological growth since cooling towers provide an ideal bacterial and algal growth environment
- Scaling due to hardness, silica and other mineral buildup

If not controlled properly, both the tower and the condenser for the chiller are at risk of damage and significant reductions in energy efficiency.

Proper water treatment can include pH, alkalinity, conductivity, hardness, microbial growth, biocide, and corrosion inhibitor controls. Controlling these parameters allows the cycles of concentration to be increased without damaging the equipment. Controlling blowdown using an automatic scheme allows a better opportunity to maximize cycles of concentration, as the TDS concentration can be kept at a more constant set point.

All modern building and plumbing codes and standards require that cooling towers be equipped with the following:

- Makeup meter
- Blowdown meter
- Conductivity controller
- Overflow alarm

AIR CONDITIONING AND PROCESS HEAT LOAD CONSIDERATIONS

Process heat loads

Process heat loads represent heat rejection directly to the cooling water circulating through the tower. Examples include cooling for industrial processes and for commercial equipment where no chiller or refrigeration equipment is involved.

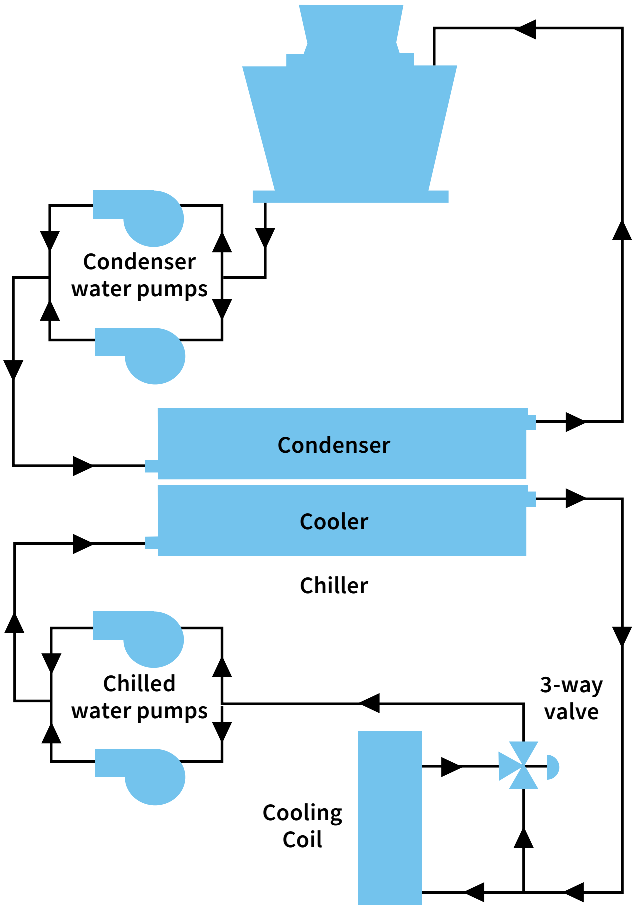
Air conditioning refrigeration heat loads

Refrigeration systems of all types operate as a "heat pump." They use mechanical energy to remove heat from a building, freezer, refrigerated storage, or similar facility. The heat is then rejected to the outside environment to either the air, ground, or water. Air-cooled systems use fans to force air over coils to reject the heat to the air. Ground-effect (geothermal) systems reject the heat to the earth through pipes buried in the ground, and water-cooled systems reject the heat to water. For most larger commercial systems, the heated water is then circulated through a cooling tower. Large power plants and industrial operations can employ cooling ponds or use once-through cooling also, but the focus of this discussion is commercial and institutional operations using cooling towers. The amount of heat that is rejected to the tower includes the heat "pumped" from the facility, as well as energy from the mechanical equipment (compressors, pumps and fans). The following discussion will provide methods to calculate water use based on the situation.

System Layout

Figure 15 shows the typical layout for a cooling tower/chilled water system. The compressor is cooled by cooling tower water loop and the chilled water (cooler) loop delivers chilled water to the air-handling systems distributed throughout the building.

FIGURE 15. CHILLED WATER/COOLING TOWER AIR-CONDITIONING SYSTEM LAYOUT



Source: Energy Design Resources: Design Brief – Chiller Plant Efficiency. https://energydesignresources.com/media/1681/edr_designbriefs_chillerplant.pdf?tracked=true

Energy Input Considerations

In the U.S. cooling loads are measured in ton-hours and air-conditioning equipment capacity in tons. The terms originated when cooling of a building was achieved using ice. One ton of ice melting to water will absorb 288,000 Btus of heat. Facilities measured their cooling load by how many tons of ice needed to be purchased each day. Dividing the 288,000 Btus by 24 hours per day gives the cooling capacity in hours. One ton-hour is therefore defined as 12,000 Btus per hour. For a cooling tower, it can be assumed that during most operating conditions, heat is dissipated through evaporation. The latent heat of evaporation for water is 971 Btus per pound of water. One pound of water weighs 8.34 pounds, therefore 1.48 gallons of water will be evaporated for every 12,000 Btus of waste heat dissipated in the cooling tower.

Chiller Tons vs. Tower Tons

Air-conditioning capacity is based on the ability of the chiller to remove heat from the interior of a building. The compressor, air moving fans, and water pumps all consume mechanical energy to accomplish this. Almost all of this expended mechanical energy ends up in the cooling tower. To account for this additional heat load, ASHRAE defines a cooling tower ton as 15,000 Btus per hour or 1.25 times that of the chiller capacity (12,000 Btus per hour). This means that for every ton-hour (12,000 Btus) of cooling, 15,000 Btus are rejected to the cooling tower. If chiller tons are known, that tonnage should be multiplied by 1.25 to obtain tower tons or if the actual additional value of the parasitic load is known it should be used.

Tower tons should be used in all calculations of water use. All chillers will have a metal "name plate" attached with the tons of capacity stamped on it. This will be an important consideration

Equation 5

$$\text{Tower Tons} = \text{Chiller Tons} \times 1.25$$

Water Use per Ton-hour of Cooling
The following provides insight on how much water is used per ton-hour of operation for a chilled water/cooling tower air-conditioning system.

Determining Cycles of Concentration
The cycles of concentration are defined in Equations 3 and 4. Cooling towers should have a conductivity controller that measures the conductivity of water in the tower basin. The conductivity is expressed in micro Siemens, which is used as a surrogate for total dissolved solids (TDS), and is expressed in parts per million of milligrams per liter. Conductivity is proportional to TDS concentration. Conductivity of the water in the tower basin can be divided by the conductivity of the make-up water to obtain cycles of concentration as illustrated in Equation 3. Where drift and leak losses are negligible, the cycles of concentration can be expressed as the ratio of makeup to blowdown as shown in Equation 4.

Gallons used per ton-hour of cooling: As described in the section above, 1.48 gallons of water will be evaporated for each ton-hour (12,000 Btus). This will calculate the evaporative loss in Equation 2. Figure 16 is based on Equation 6.

Equation 6

$$\text{Makeup (gallons)} = 1.48\ (1-1/\text{Cycles of Concentration})$$

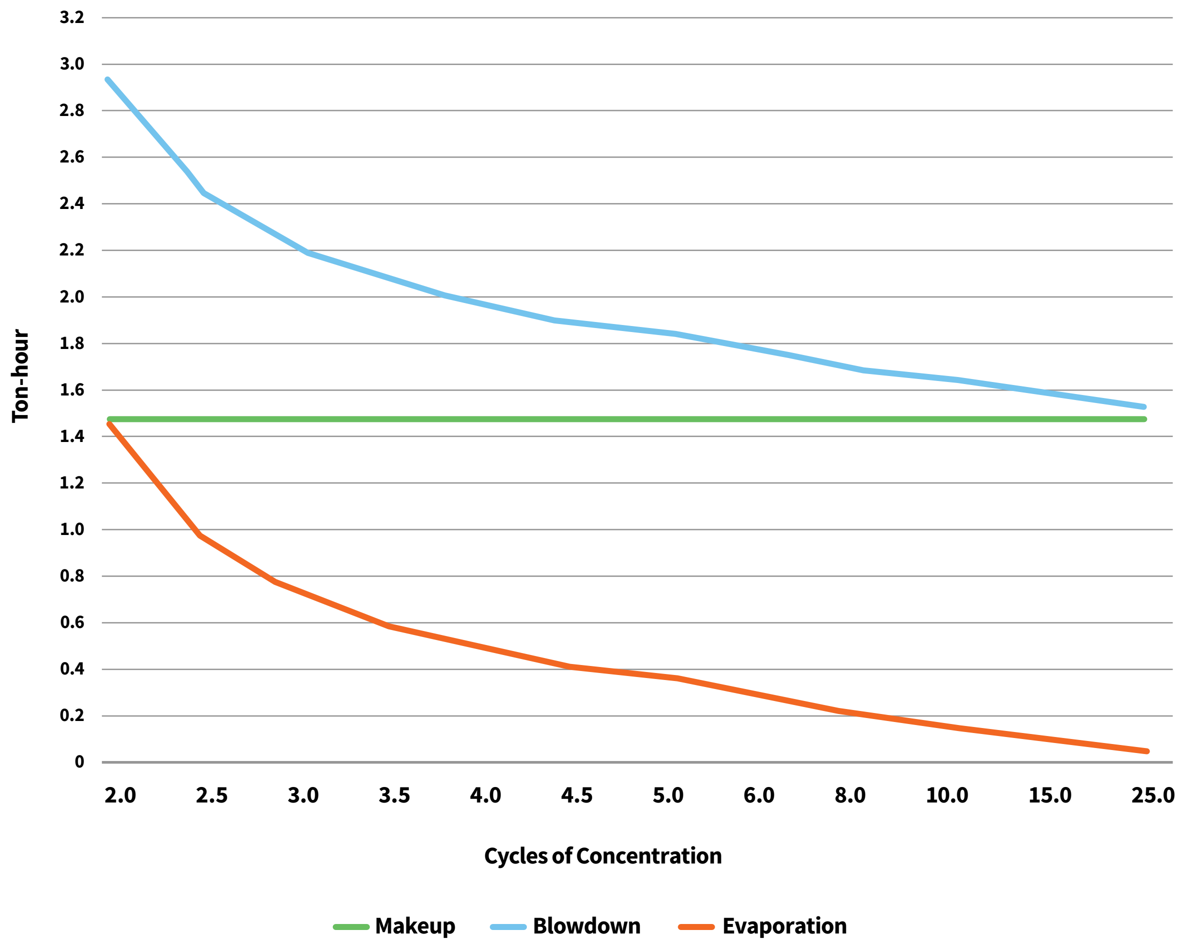
The graph should apply to tower tons for air-conditioning and refrigeration operation. It shows makeup, evaporation, and blowdown per ton-hour for various cycles of concentration. To illustrate how to use the graph, if a tower currently is operating at 3.0 cycles of concentration, makeup to the tower would be 2.22 gallons per ton-hour, evaporation would be 1.48 gallons per ton-hour and blowdown 0.74 gallons per ton-hour. If the cycles of concentration are increased to 6.0 through better water treatment, make up would be reduced to 1.78 gallons per ton-hour and blowdown to 0.30 gallons per ton-hour. However evaporation would remain the same at 1.48 gallons per ton-hour since this is a function of the waste heat dissipated by evaporation.

This would result in a savings of 0.44 gallons per ton-hour of make-up water and a reduction in blowdown of 0.44 gallons per ton-hour also. This would represent a 20 percent reduction in water use and a 59 percent reduction in blowdown. This reduction of blowdown also means that there is a significant reduction in the amount of cooling tower treatment chemicals being discharged to the sewer.

It is also important to note that the savings in water use diminish as cycles increase. For example, increasing the cycles of concentration from 3 to 5 results in 0.37 gallons per ton-hour reduction in makeup and blowdown, but increasing from 8 to 10 only reduces makeup and blowdown by only 0.05 gallons per ton-hour.

Finally, there is some convective cooling achieved in cooling towers during colder times of the year, but on an annual basis, the amount of heat rejected by convective cooling (direct heat exchange of the water film or droplets with the air as opposed to evaporation) is very small and is not considered in the above equations. Furthermore, chiller plant optimizations that vary the condenser water temperature will affect the rate of water consumption. However this is also not considered in the above equations.

FIGURE 16. WATER USE PER TON-HOUR FOR COOLING TOWERS FOR 12,000 BTUS OF HEAT REJECTED



Estimating Cooling Tower Water Use Where No Water Meter is Present

All modern plumbing codes require cooling towers to have their makeup water lines metered, but many older towers still do not have make-up meters. Where make-up and blowdown meters are present, these meters should be used to determine water use by the cooling tower. Where make-up water meters are not present, several methods can be used to develop a good estimate of water use. The following is a description of how to estimate cooling tower water use and blowdown when proper instrumentation is not available.

Estimates based on electric power use

Some systems will have a separate electric meter for the mechanical room. When such a meter is present, the first consideration for the audit or to determine what the electric meter is measuring. In many cases it only measures the energy used by the chiller system. In that case, the auditor can use the nameplate capacity on the chiller as a starting point. Care must be taken to determine if the water pumps or other equipment is also on the same meter.

Example: The electric meter for the mechanical room use shows the chiller system used 850,000 kilowatt hours in one year, and the system was rated at 0.55 kilowatt hours per ton-hour. One may have to refer to the specific model's manufacturing documentation for the chiller to determine that. If the 0.55 kilowatt hours per ton-hour is correct, then the total ton-hours per year for the system would be expressed by Equation 7.

Equation 7

Total compressor ton-hours = Kilowatt hours used / 0.55 kilowatt hours per ton-hour

Based on Equation 7, total chiller ton-hours per year would equal 1,545,456 ton-hours. To convert this to Tower ton-hours, multiply by 1.25 using Equation 6. The result is that this system rejects 1,931,818 ton-hours per year to the tower.

The annual water use can them be estimated using the cycles of concentration and Figure 16. For example, if the cycles of concentration were 3.5, the tower would use 2.07 gallons of makeup water per ton-hour, evaporate 1.48 gallons per ton-hour, and blowdown would be 0.59 gallons per ton-hour.

One can also estimate monthly, weekly, and daily use if the electric meter readings are available using Equation 7.

Estimated based on whole facility water and electric use

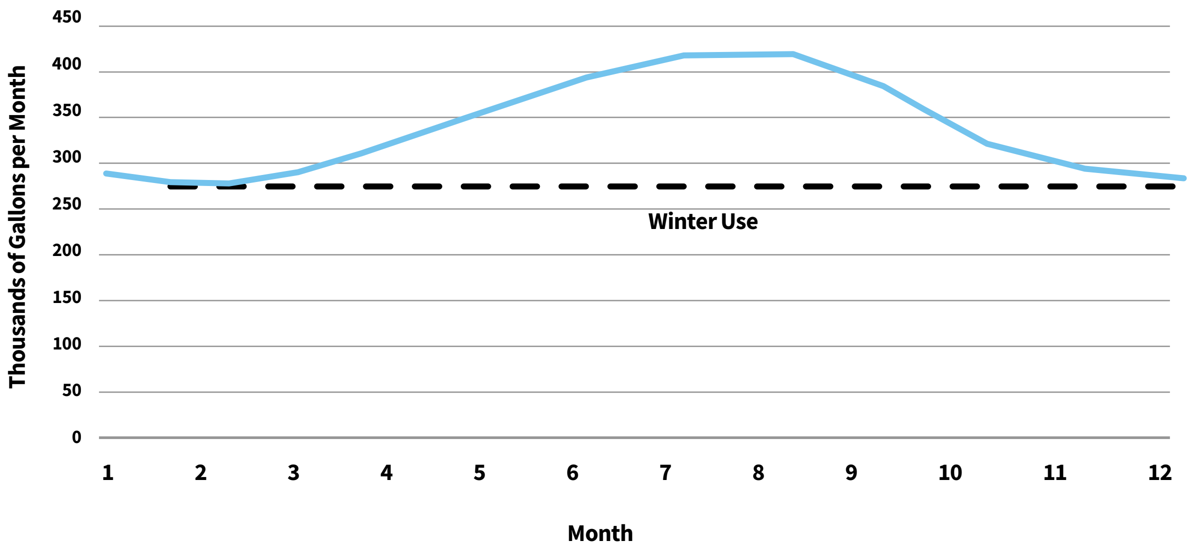
In many cases, the facility is served by only one master water and/or electric meter. Where seasonal energy or water use is primarily for air-conditioning purposes, monthly billing records can be used to estimate cooling tower use. This method is not useful where significant other seasonal loads are present. For example, if there is also significant outdoor irrigation use which is also seasonal, and that use is not metered separately, it is all but impossible to separate the two from billed water use information alone.

The following is a hypothetical example of monthly water use at an office building. The facility has a separate irrigation meter, so this graph only represents water use by the building itself. From this, water use above the base months, usually December, January and February, is primarily for makeup to the cooling tower. Figure 17 shows monthly water use by the hypothetical facility. Table 41 shows monthly and annual water use. Total annual use is 4,773,000 gallons. The winter use (December, January and February) averages 284,333 gallons per month. It can be assumed that the winter use approximates base-load (primarily indoor) water use by the facility, without cooling. Therefore, base-load use equals 3,412,000 gallons per year. Cooling tower use is estimated by taking the difference between total annual use and base load use estimates. The result is that the cooling tower uses approximately 1,361,000 gallons per year.

TABLE 41. EXAMPLE FACILITY WATER USE BY MONTH AND YEAR

MONTH	THOUSANDS OF GALLONS PER MONTH
1	288
2	280
3	330
4	400
5	450
6	490
7	510
8	500
9	480
10	420
11	340
12	285
Annual Total	**4,773**

FIGURE 17. EXAMPLE OF USING MONTHLY WATER FULL-BUILDING METERED USE TO ESTIMATE COOLING TOWER USE



This example used water building data, but the same method can be used to estimate cooling energy use. The resulting kilowatt hours per year can be converted into ton-hours using Equation 7.

Estimating cooling tower use where no metered data is available

When estimating cooling tower water use, one method of doing so where metered data or energy use data is not available is to use the ASHRAE table of Equivalent Full Load Cooling Hours/Year in Table 42. A full-load equivalent is the total hours per year that a chiller would run if at full capacity. There are 8,760 hours in a year. The full-load equivalent numbers show an estimate of the range of time a chiller would run at full load to equal the amount of time.

For example, if the chiller nameplate states that the combined capacity is 500 tons and the facility is a retail establishment in Bakersfield, California, the auditor would choose a city from the table that is close to the one where the facility is located. In this case, it would be Los Angeles.

Next, convert chiller tons to tower tons using Equation 6. In this case, that would equal *625 Tower Tons*.

Table 42 shows that the average full-load equivalent for a retail establishment in Los Angeles is 1,740–2,350 hours a year. Since Bakersfield in more inland where it is hotter, using the top number of 2,350 hours a year may more closely approximate conditions, the auditor will need to make this decision. Equation 8 will give the estimated total ton-hours per year; 1,468,750 ton-hours per year in this example.

Equation 8

Estimated Total Tower Ton-hours per Year = **Name plate capacity (Tons) X Full-Load Equivalent Hours**

Finally, the conductivity reading from the cooling tower shows that it is operating at four cycles of concentration. From Figure 17, makeup is 1.97 gallons per ton-hour and blowdown is 0.49 gallons per ton-hour.

From the above information, the facility cooling tower make-up water estimate will be in the range 2.90 million gallons a year and the blowdown will be in the range of 720,000 gallons a year. This method will only give approximate values, but where no more precise data is available, it offers a reasonable estimate of annual water use.

TABLE 42. EQUIVALENT FULL-LOAD COOLING HOURS/YEAR

LOCATION	SCHOOL	OFFICE	RETAIL	HOSPITAL
Atlanta, GA	690–830	1080–1360	1380–1860	2010–2850
Baltimore, MD	500–610	690–1080	880–1480	1350–2340
Bismarck, ND	150–250	250–540	340–780	540–1290
Boston, MA	300–510	450–970	610–1380	1020–2330
Charleston, WV	430–570	620–1140	820–1600	1260–2560
Charlotte, NC	650–730	1060–1340	1350–1830	1990–2820
Chicago, IL	280–410	420–780	550–1090	870–1780
Dallas, TX	830–890	1350–1580	1660–2090	2320–3100
Detroit, MI	230–360	390–820	530–1170	870–1950
Fairbanks, AK	26–54	64–200	110–320	210–600
Great Falls, MT	130–224	210–490	290–710	500–1210
Hilo, HI	1360–1390	2440–2580	2990–3370	4060–4910
Houston, TX	940–1000	1550–1770	1870–2290	2510–3320
Indianapolis, IN	380–560	560–1000	730–1410	1120–2250
Los Angeles, CA	780–910	1280–1670	1740–2350	2740–3770
Louisville, KY	550–670	770–1250	1000–1720	1480–2690
Madison, WI	210–310	320–640	420–900	680–1490
Memphis, TN	700–830	1090–1350	1350–1780	1910–2680
Miami, FL	1260–1300	1980–2150	2350–2740	3110–3890
Minneapolis, MN	200–300	320–610	430–870	680–1420
Montgomery, AL	840–910	1260–1510	1550–1990	2170–2950
Nashville, TN	570–740	830–1280	1030–1710	1490–2620
New Orleans, LA	920–990	1500–1720	1820–2240	2500–3280
New York, NY	360–550	540–1040	720–1480	1160–2440
Omaha, NE	310–440	480–820	610–1130	920–1780
Phoenix, AZ	950–1020	1340–1610	1630–2090	2220–3040
Pittsburgh, PA	300–530	440–920	600–1310	960–2160

LOCATION	SCHOOL	OFFICE	RETAIL	HOSPITAL
Portland, ME	190–300	310–630	410–900	700–1520
Richmond, VA	630–730	880–1310	1110–1770	1650–2760
Sacramento, CA	680–850	1080–1430	1460–2020	2250–3180
Salt Lake City, UT	410–710	510–1090	660–1520	1060–2470
Seattle, WA	260–460	440–1200	710–1860	1340–3270
St. Louis, MO	460–550	680–1100	850–1500	1260–2330
Tampa, FL	1050–1110	1800–2000	2170–2580	2910–3710
Tulsa, OK	580–770	830–1300	1030–1730	1470–2630

Note:
Data above taken from ASHRAE Applications 2007, Chapter 32, with the ranges in values determined by internal heat gains ranging between 0.6 to 2.5 Watts / Sq. Ft.
Operating with large temperature setbacks during unoccupied periods (effectively turning system off) will reduce the cooling EFLCHs by 5 percent.
Equations relating to Equivalent Full-Load Cooling Hours for cooling locations other than listed above can be found in Carlson, S. (2001) ASHRAE TRP-1120 Final Report.

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APPENDIX D: WATER COST CALCULATION

Analyzing the costs related to efficiency improvements is a complicated task. First there are the calculations of the total true cost of water based on today's costs, and then there is the analysis of cost and benefits of any proposed retrofits.

TOTAL COST OF WATER CALCULATIONS

The following information illustrates how to determine the cost of water to include water, wastewater, water and wastewater treatment, energy, and special situation cost. It then shows how to consider both the cost and benefits of water-conservation measures.

COST OF WATER CALCULATIONS EXAMPLES

Six examples are presented that demonstrate how to determine the cost of water. These include:

- Example 1. Cost for heating water
- Example 2. Cost to boost water temperature for dishwasher
- Example 3. Cost of water treatment
- Example 4. Cooling tower cost
- Example 5. Labor and service contract cost
- Example 6. Putting the cost together to determine total cost

EXAMPLE 1: COST FOR HEATING WATER

Question: The water must be heated by 80° Fahrenheit (F). How much does that cost?

Answer: If the water is to be heated, determine the type of energy used to heat the water (gas, electric, etc.) and its cost per unit (cents per kilowatt hour, or dollars per therm, or dollars per MCF [thousand cubic feet] of natural gas], etc.). One kilowatt hour equals 3,412 Btus and most electric hot water heaters are 98%+ efficient. One therm of natural gas equals approximately 100,000 Btus and one MCF equals approximately one million Btus.

The question of efficiency is more complicated. Conventional gas water heaters similar to residential heaters have efficiencies that range from 70 percent to 80 percent. In other words, one MCF of gas will deliver 700,000 to 800,000 Btus to the water. Large commercial units can have efficiencies in the 85 percent range when operating properly. Condensing water heaters operate in the 90%–95% range. For this example, it is assumed the facility is a small restaurant and that the rise in temperature will be 80° F to achieve the desired hot water temperature. A conventional water heater with an efficiency of 75 percent is used by the restaurant. The restaurant uses 1,250 gallons of hot water a day. Natural gas costs $8.25 per MCF. Water weighs 8.34 pounds per gallon and it takes one Btu to increase one pound of water by 1° F.

Question: What is the cost of heating water?

Answer: The equation showing how many MCF is used per day = gallons used X 8.34 X temperature rise divided by the efficiency X the energy in one MCF of gas.

In this example, the MCF of gas required = (1,250 X 8.34 X 80) / (75% X 1,000,000) = 1.112 MCF per day. Since gas costs $8.25 per MCF and the restaurant uses 1.112 MCF, the energy cost per day is $9.174 (917.4 cents) for heating the 1,250 gallons of water.

In other words, the energy cost per gallons = 917.4 / 1,250 = 0.734 cents per gallon. This is equal to $7.34 per thousand gallons or $5.49 per CCF.

EXAMPLE 2: COST TO BOOST WATER TEMPERATURE FOR DISHWASHER

The dishwasher requires 250 gallons per day of 180° F water. The water heater heats water to 135° F for general use in the restaurant, so the water must be heated by an additional 45° F.

Question: The restaurant must heat approximately 250 gallons of hot water by an additional 45° F for use in the dishwasher each day with an electric booster heater. Electricity costs 10 cents per kilowatt-hour (KWh). How much does that cost?

Answer: One gallon of water weighs 8.34 pounds. It takes 45 Btus to raise one pound of water by 45° F. The energy to raise 250 gallons by 45° F = 250 X 8.34 X 45 = 93,825 Btus.

There are 3,412 Btus in one kilowatt hour of electricity and the heater is 98 percent efficient. At 100 percent efficiency, the kilowatt hours needed = 93,825 Btus / 3,142 = 27.498 kWh. At 98% percent efficiency, the total use = 27.495 / 0.98 = 28.1 kWh which at $0.10 per kW costs $2.81. The cost in cents per gallon = $2.81 X 100 / 250 gallons = 1.124 cents per gallon, $11.24 per thousand gallons or $8.41 per CCF.

EXAMPLE 3: COST OF WATER TREATMENT

The restaurant softens all of its hot water: 1,250 gallons per day. The cold water has a hardness of 200 milligrams per liter (mg/l) (one mg/l = one part per million [ppm]). The softener uses a meter to recharge and it is rated at 3,000 grains of softening per pound of salt. Salt costs about $0.11 a pound based on a price for a 40-pound bag at $4.40.

Question: How much does water softening cost per gallon?

Answer: The first consideration is to calculate how much salt is needed. One grain of hardness is equal to 17.1 mg/l. Therefore, one gallon of water has 11.69 grains of hardness {200 / 17.1 = 11.69}. The facility uses (softens) 1,250 gallons a day to the total number of grains of hardness that need to be removed is 14,613 (1,250 X 11.69). One pound of salt removes 3,000 grains of hardness. Therefore, 4.87 pounds of salt are used daily (14,613 / 3,000). At $0.11 a pound, the salt costs $0.53. Since 1,250 of softened water are produced, this is equal to $0.429 per thousand gallons or $0.00043 a gallon. This equals $0.32 per CCF.

This methodology can be applied to any water treatment chemical cost. This does not include the cost of the equipment, the labor cost, or any service contract. These costs should also be included in the overall analysis of annual operating costs. The equipment cost is added to the cost of implementation and any labor cost and provided in Example 6. Service contract cost should be included in annual operating cost.

EXAMPLE 4: COOLING TOWER COST

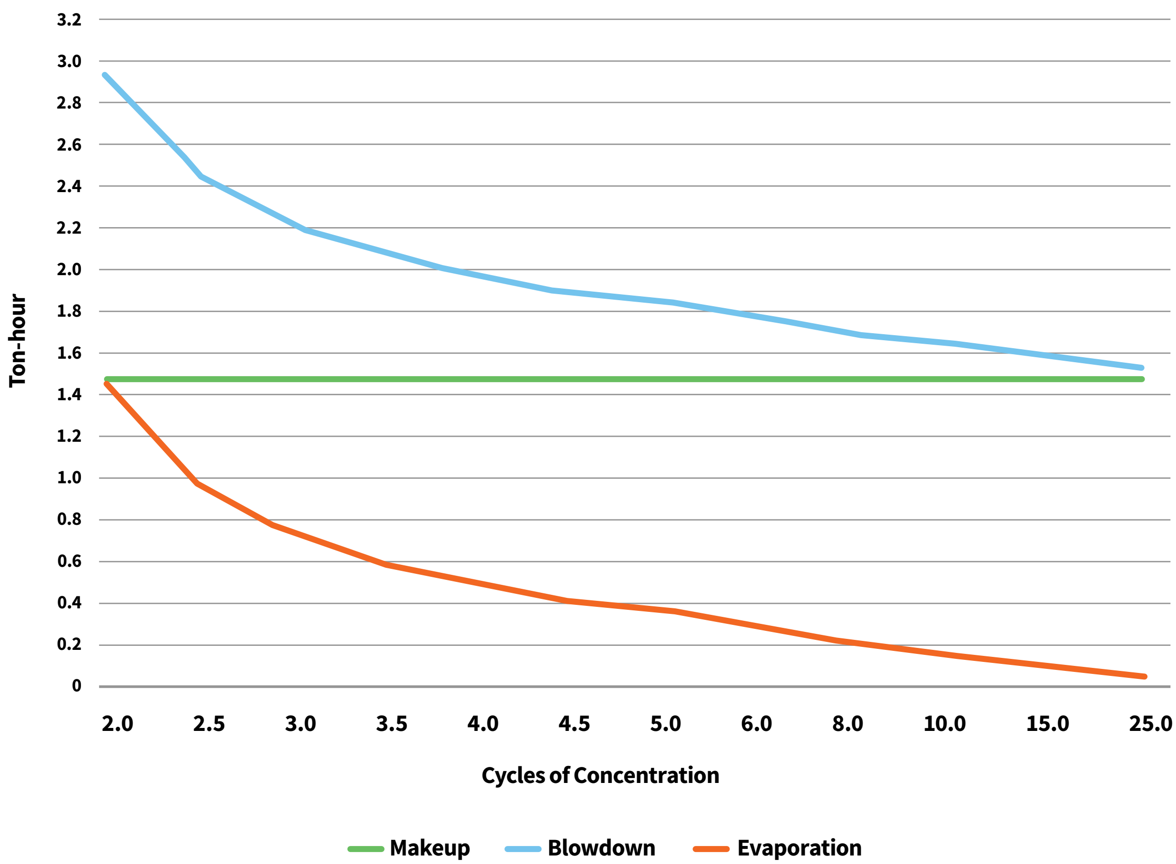
In addition to the cost of water and energy, the facility cost for the cooling tower service contract including chemicals is $5,950. The cooling tower uses approximately 2,820,000 gallons per year. The facility receives an evaporation credit from the water and wastewater utility. The audit showed that it was operating at 3.9 cycles of concentration.

Question: What is the relative cost of cooling tower operations?

Answer: Based on water-use estimates from the following graph, the tower has a makeup rate of 2.0 gallons per ton-hour. The general equation for cooling tower makeup, evaporation and blowdown, assuming minimal drift loss and leaks is: Makeup = Evaporation + Blowdown.

Based on the latent heat of evaporation for water of 971 Btu/Lb, one ton-hour = 12,000 Btus. Therefore, one ton-hour will evaporate 12.36 pounds of water and one gallon of water weighs 8.34 pounds. From this, one ton-hour will evaporate 1.48 gallons of water.

FIGURE 18. WATER USE PER TON-HOUR FOR COOLING TOWERS



The blowdown rate is 0.51 gallons per ton-hour or 25.6 percent of makeup which equals 729,600 gallons per year. The facility takes advantage of the utility's evaporation credit program. Therefore, the facility pays for 2,820,720 gallons per year and for 729,600 gallons of wastewater. Water costs $3.342 per thousand gallons and wastewater costs $6.684 per thousand gallons.

The water cost: (2,820,000 / 1,000) X $3.342 = $9,424.44 per year

The wastewater cost: (729,600 / 1,000) X$6.684 = $4,876.65

The cost for the service contract = $5,950.00

In most cases, the water treatment contract is simply used as an annual cost. It is compared to the water treatment contract cost after implementation of water efficiency measures. However, it can be incorporated into the actual water cost as illustrated in the following. This is done here to show how that can be done.

Therefore, total annual cooling tower cost for water, wastewater, and the treatment service contract = $20,251.09 for the use of 2,820,000 gallons.

The calculated cost for cooling tower water per thousand gallons therefore = $20,251.09 / (2,820,000 / 1,000) = $7.18 per thousand gallons or 0.718 cents per gallon. Another way of looking at this is to equate water cost to cents per ton-hour of cooling. The tower currently uses 2.0 gallons per ton-hour. Therefore, at a cost of 0.718 cents per gallon, it is equal to 1.436 cents per ton-hour.

Appendix C: Water-Using Equipment and Systems Information provides detailed information on estimating water use in cooling towers

EXAMPLE 5: LABOR AND SERVICE CONTRACT COST

Question: The facility installed new equipment for the first time. It will require that staff maintain and operate the equipment. How about facility staff time costs?

Answer: Labor cost for the facility staff to operate the tower should also be included. It is estimated that the routine monitoring, inspection and maintenance of the cooling tower will occupy approximately six hours of staff time a week, 52 weeks a year. The salary plus fringe benefits for the employee are $31 per hour.

Annual labor costs = 6 Hours/Week X 52 Weeks X $31 per hour = $9,670 per year.

If this is a new process and these costs were not present before the measure, these costs *should be included in the annual cost* of the measure when calculating payback. An example would be a totally new water treatment and recycle system.

If an older, less-efficient process or equipment exists and employees currently have time allocated to perform the process/operate the equipment, the net difference in time needed to operate new equipment/perform the new process v. the old process should be estimated. The result may be either a positive or negative difference in labor time and cost.

If the measure results in a reduction in staff time, *the reduction in cost should be included in the measure's benefits.*

If there is a service contract to perform the new process/operate the equipment—as is often the case for cooling tower chemical treatment, etc.—the contract cost should be included in the overall cost of the process operations.

EXAMPLE 6: PUTTING THE COST TOGETHER TO DETERMINE TOTAL COST

Question: How much does a gallon of water actually cost?

Answer: That depends on its use. In the above example, cold water costs $10.03 per thousand gallons or about one cent per gallon. Heating water by 80° F with gas costs an additional $7.39 per thousand gallons. Softening adds an extra $0.43 per thousand gallons. Heating the hot water to 180° F with electricity costs an additional $11.20 per thousand gallons.

Table 43 summarizes the types of water uses and their actual total cost. This table should be included in the audit report.

TABLE 43. ADDITIVE COST OF WATER IN EXAMPLE (INCLUDES ALL COSTS FOR WATER, INCLUDING WASTEWATER, ENERGY, CHEMICALS, AND CONTRACT COST)

TYPE OF WATER USE	DOLLARS PER THOUSAND GALLONS	CENTS PER GALLON	EXAMPLE OF USE
Cold Water	$10.03	1.003	Toilet flushing
Hot Water	$17.37	1.737	Cleaning floors
Softened Hot Water	$17.80	1.780	Restaurant cleaning
180° F Water	$29.04	2.904	Commercial dishwasher
Cooling Tower (includes water treatment cost in this example)	$7.16	0.716	Cooling tower with evaporation credit plus cost of chemical treatment contract

This table does *not* include the cost of detergent and chemicals used in the dishwasher or any pre-treatment cost for fats, oils, and greases, etc. Water efficiency measures often result in a reduction in chemical and wastewater treatment costs. These also need to be factored in an appropriate cost-benefit analysis.

The above examples illustrate how to develop water costs per gallon or thousand gallons by their intended type of use. The reasons that these costs are expressed in cents per gallon are threefold:

It is much easier for the average person to visualize a gallon of water.

Explaining to a person that replacing a 5.0 gallon per flush toilet with a 1.28 gallon per flush toilet will save 3.72 gallons—which in this case is about 3.8 cents per flush—has more meaning than expressing it in CCF per year.

Stating the total cost of water for each activity helps the facility manager understand the potential savings of each measure.

Another way to express simple payback is Return on Investment (ROI). ROI is the measure of the gain (savings through conservation in this case) on an investment relative to the amount of money invested.

It is the percent of the project cost that will be returned per year. To express simple payback in ROI terms, divide 1.0 by the payback in years. For example, if the payback is 2.5 years, the return on investment (ROI) would = 1.0/2.5 = 40 percent.

APPENDIX E: ADDITIONAL BENCHMARKING DATA AND RESEARCH

Another example of benchmarking comes from Australia. Again, it shows the range of use based on a "Fair, Efficient, and Best Practices" designation. It also illustrates the impact that the use of cooling towers has on water use in large commercial facilities.

TABLE 44. EXAMPLE OF BENCHMARKING FROM SYDNEY, AUSTRALIA FOR OFFICE BUILDING AND SHOPPING CENTERS (IN GALLONS PER SQUARE FOOT OF COOLED SPACE PER YEAR)[36]

RATINGS	BENCHMARK WITH COOLING TOWERS	BENCHMARK WITHOUT COOLING TOWERS
Best Practice	18.9	9.8
Efficient	20.7	11.6
Fair	24.8	15.7

BENCHMARKING STUDIES EXPRESSED IN GALLONS PER SQUARE FOOT PER YEAR

Table 45 contains the benchmarking information from eleven studies where the benchmark is expressed in gallons per square foot of indoor space per year. Values are median and average values as reported in the studies.

TABLE 45. SUMMARY OF 11 STUDIES REPORTING WATER USE BY GALLONS PER SQUARE FOOT OF SPACE PER YEAR MEDIAN OR MEAN AS REPORTED

Type of Facility	EPA Portfolio Manager[1]	University of Florida[2]	Santa Fe, New Mexico[3]	Colorado Water Wise - Brendle Group.[4]	Water Research Foundation End Use Study 2000[5]	Austin 2013[6]	Boston Benchmark Law 2015[7]	New York Benchmark Law[8]	Washington DC Benchmark Law[9]	Philadelphia Benchmark Law[10]	Minneapolis Benchmark Law[11]
	Gallons per Square Foot of Heated Space per Year										
Restaurants		221		173–211	130–330	215					
Senior Care Facilities	61	106		62–101				86			
Hotels	54	85		79–165	60–115	72	55	71	55	100	
Hospitals	51	31				58				68	
Grocery/ Supermarkets	24	95	36		52–64					24	
Medical Offices	19	34	49					33		35	
Offices	13	20	26		9–15		12	13	15	17	11
Banking/Financial	12	89									
Courthouse	11										
K–12 Schools	10	20		12–19	8–16			7	10	13	
Houses of Worship	7	15								11	
Retail/ Shopping Centers	5	32	20					10		16	
Unrefrigerated Warehouses	4	8						3	2	4	
Colleges/ Universities							23	14	24	75	
Residence Halls/ Dormitories							31	50	41		
Multifamily							35	54	40		

1. U.S. Environmental Protection Agency, Portfolio Manager, Data Trends, Water Use Tracking. *Retrieved from,* http://www.energystar.gov/buildings/tools-and-resources/water-use-tracking
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3. M. A. Morales, J. P. Heaney, K.R. Freidman, J.M. Martin, Estimating Commercial, Industrial, and Commercial Water Use on the Basis of Heated Building Area, AWWA Journal, June 2011
4. Planning Division, City of Santa Fe, New Mexico, Water Use in Santa Fe, 2001
5. The Brendle Group, Inc. Benchmarking Task Force - Collaboration for Industrial, Commercial & Institutional Water Conservation, 226 S. Remington St. #3 Fort Collins, CO 80524
6. Water Research Foundation, Commercial and Institutional End Uses of Water, 2001, 6666 Quincy Avenue, Denver Colorado. *Retrieved from,* http://ufdc.ufl.edu/WC13511002/00001/5j
7. M Jordan, B Hoffman, S Riesenberg, Benchmarking Commercial and Institutional Water Use in Austin, Texas, Austin Water Utility, Austin, Texas 2013
8. Energy Disclosure for City of Boston Municipal Facilities. May 15, 2015 . *Retrieved from,* https://www.cityofboston.gov/eeos/reporting
9. Energy Disclosure for City of New York . *Retrieved from,* http://www.nyc.gov/html/gbee/html/plan/ll84_scores.shtml
10. Energy Disclosure for Washington DC. *Retrieved from,* http://doee.dc.gov/page/energy-benchmarking-disclosure
11. Energy Disclosure for City of Philadelphia. *Retrieved from,* http://www.phillybuildingbenchmarking.com/wp-content/uploads/2015/09/MOS_BnchMrkRprt_R5fin_FINAL.pdf
12. Minneapolis 2014 Private and Public Building Energy Data

OTHER BENCHMARK INFORMATION FROM VARIOUS SOURCES

The following material is compiled from studies of literature by H.W. (Bill) Hoffman & Associates, LLC.

TABLE 46. SUMMARY OF HOSPITAL WATER USE COEFFICIENTS FROM VARIOUS STUDIES

STUDY	GAL/BED/DAY	GAL/SQ FT/YR	
		Average	Best
Federal Facilities		125	
Univ. of Florida Study		31	
United Kingdom-Large Teaching		41	34
UK Small Acute or Long Stay		29	22
UK Small Acute or Long Stay With Laundry		39	31
North Carolina Rule of Thumb	300		
ASHE 2002 Study	471		
Energy Star Portfolio Manager	315		
Victoria Public Health Service - Australia		39	17
Health Estate Journal - United Kingdom		87	
U.S. Energy Information Adminstration (2007)	395	68	
City of Austin's 9 Largest Medical Facilities	335	58	18

TABLE 47. SUMMARY OF SCHOOL WATER USE COEFFICIENTS FROM VARIOUS STUDIES

STUDY	DESCRIPTION	GAL./SQ.-FT/YEAR	GAL./PERSON/DAY
Brendle Group (Colorado)	High School	12	16
Brendle Group (Colorado)	Middle School	12	11
Brendle Group (Colorado)	Elementary School	11	12
USA (2000 WRF)	All Schools	8-16	3–15
British Environment Agency	All Schools		19
Austin 2000-2001	High Schools		32
	Middle Schools		22
	Elementary Schools		18
Austin 2004-2005	High Schools		34
	Middle Schools		19
	Elementary Schools		
Austin 2010-2011	High Schools		34
	Middle Schools		
	Elementary Schools		15

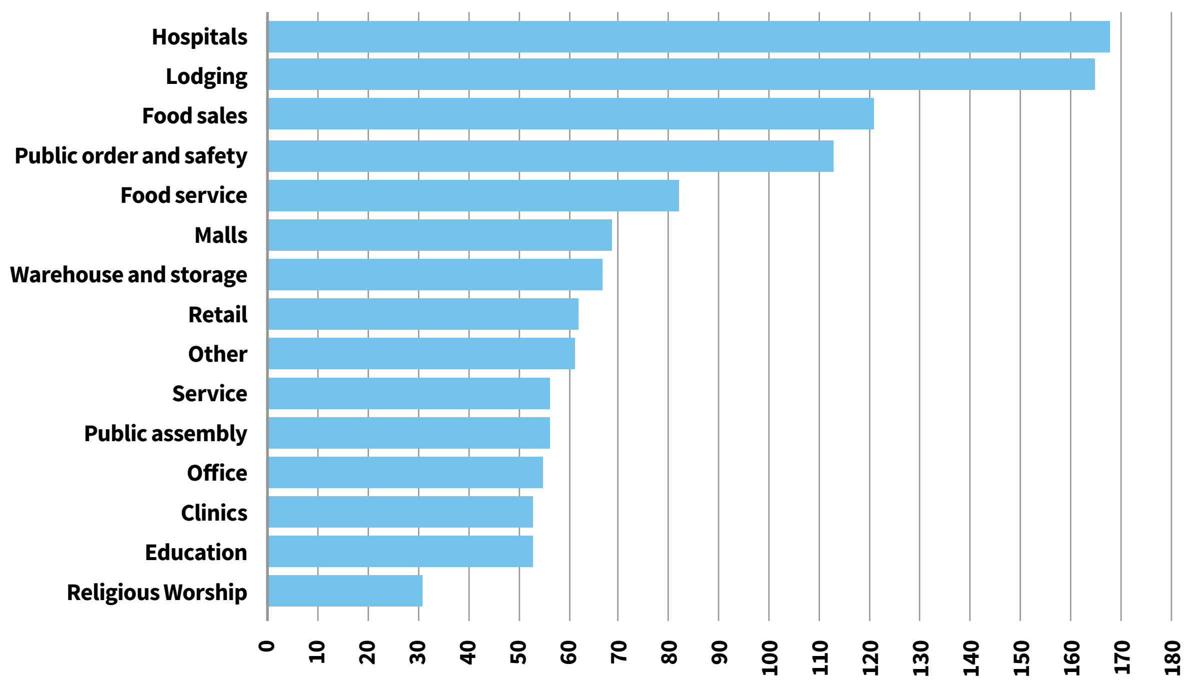
TABLE 48. SUMMARY OF HOTEL WATER USE COEFFICIENTS FROM VARIOUS STUDIES

STUDY	GAL/SQ. FT./YR	GAL./ROOM/DAY
Univ. of Florida Study	89	
Energy Star Portfolio Mgr.		102
Sydney Australia Study		99–132
USA (2000 WRF)		60–115
Colorado Study (Brendle Group)	120	95
Water Mgt. Inc. Study		75–175
2006 CIRIA London England Study		7–123
Austin Median	72	90
New York – Portfolio Manager	75	
New York – Mayors Challenge	69	129

USEFUL INFORMATION FROM CBECS STUDIES

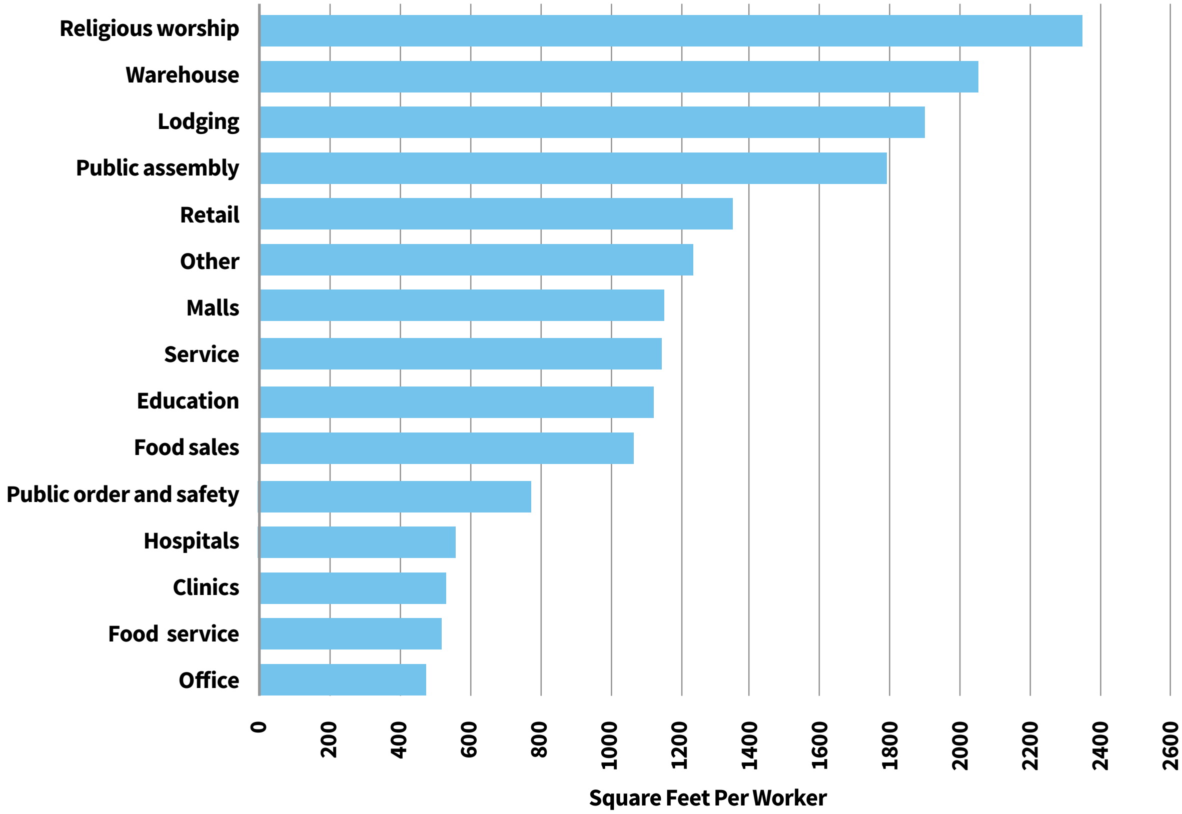
Figures 19 and 20 are based on the Commercial Buildings Energy Consumption Survey completed in 2012. They show average operating by type of facility and the number of workers per square foot of facility. Where such information is not available from the audit process, these data can be used to develop estimates.

FIGURE 19. AVERAGE OPERATING HOURS PER WEEK



Source: U.S. Department of Energy, Energy Information Administration Commercial Buildings Energy Consumption Survey (CBECS 2012). https://www.eia.gov/consumption/commercial/data/2012/bc/cfm/b1.cfm

FIGURE 20. SQUARE FEET PER WORKER



Source: U.S. Department of Energy, Energy Information Administration Commercial Buildings Energy Consumption Survey (CBECS 2012). https://www.eia.gov/consumption/commercial/data/2012/bc/cfm/b1.cfm

APPENDIX F: CODES AND STANDARDS SUMMARY

The following tables provide a summary of current plumbing codes and standards, including green supplements related to water use in commercial and institutional facilities.

TABLE 49. COMPARISON OF METERING REQUIREMENTS IN GREEN CODES[37]

	APPLICATIONS	GUIDELINES, CODE OR STANDARD?	CODE-ADOPTABLE LANGUAGE?	MINIMUM THRESHOLDS OR POINTS?	STATUS
California: CALGreen	Residential & non-residential	Code	Yes	Minimum thresholds	Became effective in 2011; continuing development & expansion
USGBC LEED-NC et.al.	All except Single-Family Residential	Guidelines	No	Prerequisites + points	LEED 2009 and v.4 mandate 20% reduction from baseline; other significant changes
USGBC LEED for Homes	Single-Family Residential (SFR)	Guidelines	No	Both	Active; being updated
Green Globes – Green Bldg Initiative 01-200XP	Residential & multi-use above 3 stories + all commercial	ANSI Standard	Yes	Points	Final standard ANSI-approved and published in April 2010; update process began 2014. New public review document to be released 2015
ASHRAE 189.1 – High Performance Buildings	Residential above 3 stories + all commercial	ANSI Standard	Yes	Minimum thresholds	Final standard ANSI-approved; published in January 2010; version 2 released 2011; now in sustaining process; addendum v for water efficiency approved in 2014

	APPLICATIONS	GUIDELINES, CODE OR STANDARD?	CODE-ADOPTABLE LANGUAGE?	MINIMUM THRESHOLDS OR POINTS?	STATUS
ASHRAE S191P – Water Efficiency	All except SFR	ANSI Standard	Yes	Minimum thresholds	First public comment period completed; revised draft to be released for second public comment period, date undetermined
ICC 700, NAHB Green Building Standard for Homes	Residential	ANSI Standard	Yes	Points	Final standard ANSI-approved; published in Jan 2009 as ICC-700
IAPMO Green Plumbing & Mechanical Code Supplement	Residential & multi-use above 3 stories + all commercial	Code	Yes	Minimum thresholds	Overlay to existing codes; version 3 programmed for 2015 publication
ICC Green Construction Code	Residential & multi-use above 3 stories + all commercial	Code	Yes	Minimum thresholds	Overlay to existing codes; final (first) version released March 2012; updated version to be published 2015
U.S. EPA WaterSense for New Homes	Residential	Guidelines	No	Minimum thresholds	Final specification issued in December 2009

TABLE 50. COMPARISON OF METERING USE STANDARDS

METERING AND SUBMETERING	CALGREEN38 (PROVISIONS EFFECTIVE JAN 1, 2014)	LEED V.4 JULY 2014	ASHRAE SS189.1 (V.2-2011, UPDATED WITH ADDENDUM V)	ASHRAE S191P (PUBLIC REVIEW DRAFT V.1)	ICC 700-2008 (WITH NAHB)	IAPMO GREEN PLUMBING & MECH CODE SUPPLEMENT (2015 VERSION)	IGCC GREEN CODE (2015 VERSION)
Metering tenant water use (usage in gallons per day)	Where non-residential tenant usage >100g + all buildings where >1000g	Metering of single family dwellings and individual multifamily units req'd as prerequisite	Tenants or buildings where >1,000 g	Tenants or buildings where >1,000 g		Where non-residential tenant use = >1,000 g/day OR high-use occupancy: all residential tenant space; all common area uses	Where usage >1,000 g/day
Meter reclaimed & potable water needed to supplement onsite water collection systems		Reclaimed				Potable and reclaimed water	
Submetering process water use – industrial/commercial (usage in gals per day)		Sub-meter at least 80% of process water, including pools	Where usage >1,000 g	Where usage >1,000 g		All where usage >1,000 g	Industrial usage >1,000 g
Submetering ornamental water features, swimming pools, in-ground spas		Sub-meter at least 80% of process water, including pools	Make-up water supply to all ornamental water features	Make-up water supply lines		Make-up water supply to ornamental water features w/ auto refill; make-up water to pools/spas	Make-up water supply lines

METERING AND SUBMETERING	CALGREEN38 (PROVISIONS EFFECTIVE JAN 1, 2014)	LEED V.4 JULY 2014	ASHRAE SS189.1 (V.2-2011, UPDATED WITH ADDENDUM V)	ASHRAE S191P (PUBLIC REVIEW DRAFT V.1)	ICC 700-2008 (WITH NAHB)	IAPMO GREEN PLUMBING & MECH CODE SUPPLEMENT (2015 VERSION)	IGCC GREEN CODE (2015 VERSION)
Submetering cooling towers			Towers of >500 gpm flow (thru-put): make-up & blow-down water supply lines	Towers of >500 gpm flow (through-put)		Make-up water supply	Towers of 100 tons or greater: make-up and blow-down water supply lines
Submetering evaporative coolers			Where use in excess of 0.6 gpm: meter make-up water supply	Where use in excess of 0.6 gpm: meter make-up water supply		Make-up water supply where cooler has air flow in excess of 30K cfm	Where use in excess of 0.6 gpm: meter make-up water supply
Submetering hydronic cooling systems						Make-up water supply when >50 tons of cooling	
Submetering fluid coolers & chillers						Make-up water supply where no closed-loop recirc	
Submetering roof spray systems						Where vegetated roof or thermal conditioning of >300 sq. ft.	
Submetering boilers		Make-up water supply to boilers: drawing more than 100K gallons annually or rated at 500K Btu/hr or more	Steam & hot water boilers rated at 500K Btu/hr or more	Steam & hot water boilers rated at 500K Btu/hr or more		Make-up water supply to boilers collectively exceeding 1 mil Btu/hr	Make-up water supply to boilers: drawing more than 100K gallons annually or rated at 500K Btu/hr or more

METERING AND SUBMETERING	CALGREEN38 (PROVISIONS EFFECTIVE JAN 1, 2014)	LEED V.4 JULY 2014	ASHRAE SS189.1 (V.2-2011, UPDATED WITH ADDENDUM V)	ASHRAE S191P (PUBLIC REVIEW DRAFT V.1)	ICC 700-2008 (WITH NAHB)	IAPMO GREEN PLUMBING & MECH CODE SUPPLEMENT (2015 VERSION)	IGCC GREEN CODE (2015 VERSION)
Submeter indoor plumbing fixtures & fittings		Required. Alternate path of calculated use is provided.					
Submeter domestic hot water		Meter at least 80% of domestic hot water					
Submeter health care processes		Meter process water systems, e.g. purified water, dietary dept., laundry, labs, physio-therapy/ hydrotherapy, surgical & hydronics					
Submetering landscape irrigation	Where non-residential landscape >1,000 sq. ft.**	Meter at least 80% of irrigated landscape, excluding Xeriscaping and native vegetation	Where total irrigated landscape >25,000 sq. ft.	Where total irrigated landscape >5,000 sq. ft.		Where >2,500 sq. ft. irrigated landscape	Yes, all irrig systems that are automatic

METERING AND SUBMETERING	CALGREEN38 (PROVISIONS EFFECTIVE JAN 1, 2014)	LEED V.4 JULY 2014	ASHRAE SS189.1 (V.2-2011, UPDATED WITH ADDENDUM V)	ASHRAE S191P (PUBLIC REVIEW DRAFT V.1)	ICC 700-2008 (WITH NAHB)	IAPMO GREEN PLUMBING & MECH CODE SUPPLEMENT (2015 VERSION)	IGCC GREEN CODE (2015 VERSION)
Building Meter Data Management System			Require remote data communication to central system, recording hourly consumption data			Requires remote data collection & transfer capability where more than10 non-utility-owned meters are installed	Meters must be capable of con-necting & communi-cating water use data; direct connec-tion to central bldg system not req'd

TABLE 51. COMPARISON OF FIXTURE FLOW RATES UNDER CODES AND STANDARDS

Fixtures and Appliances	Federal Standard: from EPAct 1992, EPAct 2005, "Energy Independence and Security Act of 2007", NAECA updates, other sources		WaterSense® or ENERGY STAR®		Consortium for Energy Efficiency (CEE)
	Current Standard	Proposed/ Future Standard	Current Requirements	Proposed/ Future Requirements	Current Specification
Residential Toilets **(Water Closets)**	≤ 1.6 gpf[39]	≤ 1.28 gpf/ 4.8 Lpf informally proposed by efficiency advocates (tank-type only)	Tank-type toilets: WaterSense v.1.2 = ≤ 1.28 gpf (4.8L) with at least 350 gram bulk waste removal Flushometer valve/bowl combinations: WaterSense v.1.0 = ≤ 1.28 gpf (4.8L) with at least 350 gram bulk waste removal	No changes to existing specifications are planned	No specification
Residential Lavatory (Bathroom) Faucets	≤ 2.2 gpm at 60 psi[40]	≤ 1.5 gpm/ 5.7 Lpm informally proposed by efficiency advocates	WaterSense v.1.0: ≤ 1.5 gpm & 0.8 gpm minimum at 20 psi	No change to existing specification is planned	No specification
Residential Kitchen Faucets			WaterSense: No specification	No specification proposed at this time	No specification
Residential Showerheads	≤ 2.5 gpm at 80 psi		WaterSense v.1.0: ≤ 2.0 gpm with special spray force & coverage requirements	No change to existing specification is planned	No specification

Fixtures and Appliances	Federal Standard: from EPAct 1992, EPAct 2005, "Energy Independence and Security Act of 2007", NAECA updates, other sources		WaterSense® or ENERGY STAR®		Consortium for Energy Efficiency (CEE)
	Current Standard	Proposed/ Future Standard	Current Requirements	Proposed/ Future Requirements	Current Specification
Residential Clothes Washers	Top-loading standard models: MEF ≥ 1.29 ft3/kWh/cycle (after Jan 1, 2018, the MEF[41] increases to 1.57) Integrated WF ≤ 8.4 gal/cycle/ft³ (NOTE: after Jan 1, 2018, the IWF decreases to 6.5) Front-loading standard models: MEF ≥ 1.84 ft³/kWh/cycle Integrated WF ≤ 4.7 gal/cycle/ Top-loading compact models: MEF ≥ 0.86 ft3/kWh/cycle (after Jan 1, 2018, the MEF increases to 1.15) Integrated WF ≤ 14.4 gal/cycle/ft³ ft3 (NOTE: after Jan 1, 2018, the IWF decreases to 12.0) Front-loading compact models: MEF ≥ 1.13 ft³/kWh/cycle Integrated WF ≤ 8.3 gal/cycle/		ENERGY STAR: Effective March 7, 2015 for 1.6 to 6.0 cubic feet Top-loading models (> 2.5 cu. ft.): MEF ≥ 2.06 ft3/kWh/cycle. Integrated WF ≤ 4.3 gal/cycle/ Front-loading models (> 2.5 cu. ft.): IMEF ≥ 2.38 ft3/kWh/cycle Integrated WF ≤ 3.7 gal/cycle/ Compact models (≤ 2.5 cu. ft.): IMEF ≥ 2.07 ft³/kWh/cycle Integrated WF ≤ 4.2 gal/cycle/		Effective March 7, 2015 Tier 1: MEF ≥ 2.38 ft3/kWh/cycle; WF ≤ 3.7 gal/cycle/ft³ Tier 2: MEF ≥ 2.74 ft³/kWh/cycle; WF ≤ 3.2 gal/cycle/ft³ Tier 3: MEF ≥ 2.92 ft³/kWh/cycle; WF ≤ 3.2 gal/cycle/ft³

Fixtures and Appliances	Federal Standard: from EPAct 1992, EPAct 2005, "Energy Independence and Security Act of 2007", NAECA updates, other sources		WaterSense® or ENERGY STAR®		Consortium for Energy Efficiency (CEE)
	Current Standard	Proposed/ Future Standard	Current Requirements	Proposed/ Future Requirements	Current Specification
Standard Size and Compact Residential Dishwashers[42]	Final Rule of DOE, effective 5/30/2013 STANDARD Size Models: Energy: ≤ 307 KWh/year WF ≤ 5.0 gallons/cycle COMPACT Models: Energy: ≤ 222 kWh/yr WF ≤ 3.5 gallons/cycle		Energy Star Effective Jan 29, 2016 STANDARD Size Models: Energy: ≤ 270 kWh/year WF ≤ 3.5 gallons/cycle COMPACT Models: Energy: ≤ 203 kWh/year WF ≤ 3.1 gallons/cycle		Effective Jan. 29, 2016 STANDARD Size Models (8 place settings or more): 270 max kWh/ year; WF ≤ 3.5 gallons/ cycle Compact Size Models (hold fewer than 8 place settings): 203 max kWh/ year; WF ≤ 3.1 gallons/ cycle

TABLE 52. COMPARISON OF FIXTURE FLOW RATES UNDER CODES AND STANDARDS

PLUMBING: TOILETS & URINALS	CalGREEN[43] (provisions effective Jan 1, 2014)	LEED V.4 July 2014	ASHRAE 189.11 (v.2-2011, updated with addendum v-2014)	ASHRAE S191P (Public review draft v.1)	ICC 700-2008 (with NAHB)	IAPMO Green Plumbing & Mech Code Supplement (2015 version)	International Green Construction Code (2015 version)
Residential toilets OR "private" setting in commercial – FLUSHOMETER TYPE (gals per flush)	HET: 1.28g[2]	*No individual maximums specified, except requires WaterSense products where available[44].* *Mandatory to reduce aggregate water consump-tion by at least 20% from "baseline"[45]*	HET: 1.28g[2]	HET: 1.28g[2]	HET: 1.28g	HET: 1.28g[46]	HET: 1.28g[2]
Residential toilets – TANK TYPE (gallons per flush)	HET: 1.28g[2] + WaterSense		HET: 1.28g[47] + WaterSense	HET: 1.28g[2] + WaterSense		HET: 1.28g[2] + WaterSense	HET: 1.28g[2] + WaterSense
Commercial toilets "public" setting and remote[48] (gals/flush)	HET: 1.28g[2] Tank-type must comply with WaterSense		HET: 1.28g[49] Tank-type must comply with WaterSense	HET: 1.28g[2] Tank-type must comply with WaterSense		1.6g[4,6]	1.6g[4],[50]
Commercial toilets – "public" setting and non-remote (gallons/flush)						HET: 1.28g[2,4]	HET: 1.28g[2,4,]
Flushing urinals (gallons per flush)	HEU: 0.5 gpf		HEU: 0.5g + WaterSense	HEU: 0.5g + WaterSense	HEU: 0.5 gpf	HEU: 0.5g + WaterSense	HEU: 0.5g + WaterSense
Non-water urinals	Permitted		Permitted	Permitted		Permitted; requires upstream discharges to drain from other fixtures or fittings	

PLUMBING: FAUCETS & SHOWERS	CalGREEN[51] (provisions effective Jan 1, 2014)	LEED V.4 July 2014	ASHRAE 189.11 (v.2-2011, updated with addendum v-2014)	ASHRAE S191P (Public review draft v.1)	ICC 700-2008 (with NAHB)	IAPMO Green Plumbing & Mech Code Supplement (2015 version)	International Green Construction Code (2015 version)
Residential & commercial "private" lavatory faucets (gallons/ minute)	1.2 gpm[52]	*No individual maximums specified, except requires WaterSense products where available[53].* *Mandatory to reduce aggregate water consump-tion by at least 20% from "baseline"[3]*	1.5 gpm + WaterSense[54]	1.5 gpm + Water- Sense[9]	1.5 gpm	1.5 gpm + WaterSense9	1.5 gpm7
Commercial & non-residential "public" lavatory faucets (gals/ min.)	0.5 gpm[55]		0.5 gpm	0.5 gpm		0.5 gpm	0.5 gpm
Commercial kitchen & bar sink faucets (gallons per minute)	1.8 gpm[56]		Hands-free in food prep area & in dish room of comm'l kitchen				2.2 gpm[57]
Commercial metering faucets (gallons per cycle[58])	0.25 gpc		0.25 gpc	0.25 gpc		0.25 gpc	0.25 gpc
Residential kitchen faucets (gallons per minute)	1.8 gpm; allows temporary override to 2.2 gpm		1.8 gpm; allows temporary override to 2.2 gpm	2.2 gpm		1.8 gpm; allows temporary override to 2.2 gpm	1.8 gpm; allows temporary over- ride to 2.2 gpm for pot filling
Residential showerheads (gallons per minute)	2.0 gpm + WaterSense		2.0 gpm + WaterSense	2.0 gpm	2.5 gpm	2.0 gpm + WaterSense; shower valve must scald-protect at showerhead flow rate	2.0 gpm + WaterSense
Non-residential showerheads (gal/min)	2.0 gpm + WaterSense						

APPLIANCES, EQUIPMENT, IRRIGATION & ALTERNATE WATER	CalGREEN[59] (provisions effective Jan 1, 2014)	LEED V.4 July 2014	ASHRAE 189.11 (v.2-2011, updated with addendum v-2014)	ASHRAE S191P (Public review draft v.1)	ICC 700-2008 (with NAHB)	IAPMO Green Plumbing & Mech Code Supplement (2015 version)	International Green Construction Code (2015 version)
Residential dishwashers (total water per full cycle)	(defers to California Energy Commission)	ENERGY STAR (or equiva-lent)	ENERGY STAR & 3.8 gal – 14.3L	ENERGY STAR & 5.8 gal – 22L	ENERGY STAR	ENERGY STAR	ENERGY STAR
Residential clothes washers (water factor maximum)			ENERGY STAR & WF of 5.4 gal – 20L	ENERGY STAR & WF of 6.0 gal – 23L	ENERGY STAR	ENERGY STAR	ENERGY STAR& WF of 5.4 gal – 20L
On-site reclaimed water (incl. graywater) treatment systems	(future)	Metered	Encouraged through the treatment and use of alternate (non-potable) sources of water		Points available for use of alternate sources	Specific provisions for equipment installation & water treatment	NSF 350 listed
Rainwater capture	(future)						Included
Landscape irrigation	Weather-based or soil moisture sensor-based irrigation con-troller req'd for landscape >1,000 sf	30% - 50% reduction from base-line calcu-lated via WaterSense water budget tool	ET-based; smart technology; restrictions on turf		Non-mandatory provisions; some turf restrictions	75% of irrigation needs satisfied with water from alternate sources; if controller used, smart controller req'd; other specific landscape provisions	If automatic irrigation controller is used, smart controller req'd; alternate non-potable water sources encouraged; other specific landscape provisions
Water features (fountains, etc.)		Metered	Use alternate water sources (non-potable) where available; recirculation required			Use alternate water sources (non-potable) where available	Use alternate (non-potable) water source; potable water use OK for small features.
Commercial clothes washers with public access[60] (water factor max.)		CEE Tier 3A	ENERGY STAR & WF of 4.0 gal (.53 kL/m3)	ENERGY STAR& WF of 7.5 gal (1 kL/ m3)		ENERGY STAR where applicable	
Commercial clothes washers – all others without public access (water use maximum)		1.8 gal per pound (on-premise)	WF of 8.0 gal				

APPLIANCES, EQUIPMENT, IRRIGATION & ALTERNATE WATER	CalGREEN (provisions effective Jan 1, 2014)	LEED V.4 July 2014	ASHRAE SS189.1 (v.2-2011, updated with addendum v)	ASHRAE S191P (Public review draft v.1)	ICC 700-2008 (with NAHB)	IAPMO Green Plumbing & Mech Code Supplement (2015 version)	IgCC Green Code (2015 version)
Residential water softeners						Permitted where water hardness[3] 8 grains/gallon; demand-initiated regeneration reqd; max water use 5 gal (19L) per 1K grains of hardness removed; salt efficiency exceeding 3400 grains of total hardness removed per pound of salt; NSF 44 listed	Demand-initiated regeneration reqd; max water use 4.0 gal (15L) per 1K grains of hardness removed; salt efficiency no less than 4000 grains of total hardness removed per pound of salt; NSF 44 listed; brine may not discharge to a reclaimed water collection system
Reverse osmosis water treatment system		75% recovery req'd				NSF 58 listed; auto shut-off	
						Water-powered sump pumps prohibited, except for emergency; emergency pumps shall be at least 58% efficient	Water-powered sump pumps prohibited, except for emergency; emergency pumps shall be at least 67% efficient
Automated vehicle wash facilities						Make-up water restrictions: In-bay-40gal/vehicle; Conveyor & express type-35gal/vehicle; spray wands & foamy brushes-3.0 gpm	50% water reuse; other water restricted as follows: In-bay-40gal/vehicle; Conveyor & express type-35gal/vehicle
Self-service vehicle wash facilities							Spray wands: 3.0 gpm

COMMERCIAL FOOD SERVICE	CalGREEN (provisions effective Jan 1, 2014)	LEED V.4 July 2014	ASHRAE SS189.1 (v.2-2011, updated with addendum v)	ASHRAE S191P (Public review draft v.1)	ICC 700-2008 (with NAHB)	IAPMO Green Plumbing & Mech Code Supplement (2015 version)	IgCC Green Code (2015 version)
Cubed ice makers			ENERGY STAR (air-cooled)	ENERGY STAR (air-cooled)		ENERGY STAR (air-cooled) + 20 g per 100 lbs. of ice	ENERGY STAR (air-cooled)
Nugget & flaked ice makers		ENERGY STAR (or equiv.)				ENERGY STAR (air-cooled) + 14 g per 100 lbs. of ice	
All other ice makers not covered by Energy Star							25 gal per 100 lbs. of ice produced; air cooled
Connectionless steam cooker (gal per hour)		2.0 to 6.0 g per pan (cook-to-order = 5 to 10g per pan max)	2.0 g	2.0 g per pan		2.0 g per compartment	2.0 g per pan
Connected steam cooker (max gals per hour)	(defers to Calif Energy Commission on food service appliances)					1.5 g per pan; tempering water not required for discharges (per UPC)	5.0 g per pan
Dishwashers (max gallons)		ENERGY STAR + 0.9 to 1.6 gal per rack depending on type; Rackless flight-type DWs = 180 gal/hr max	ENERGY STAR, version 2 requiremnts	Energy Star where applicable; Rackless flight-type DWs = 160 gal/hr maximum		ENERGY STAR	ENERGY STAROR 2.2 gal/rack OR 2.2 gpm for rackless
Combination ovens (max gallons/hr)		1.5 to 3.5 g per pan	10g	3.5 g per pan		1.5 g per pan in steamer mode; no water use allowed in convection mode; tempering water not required for discharges (per UPC)	3.5 g per pan

COMMERCIAL FOOD SERVICE	CalGREEN (provisions effective Jan 1, 2014)	LEED V.4 July 2014	ASHRAE SS189.1 (v.2-2011, updated with addendum v)	ASHRAE S191P (Public review draft v.1)	ICC 700-2008 (with NAHB)	IAPMO Green Plumbing & Mech Code Supplement (2015 version)	IgCC Green Code (2015 version)
Dipper wells (gallons per minute)				Max flow per minute equal to the capacity of the DW, not to exceed 1.0 gpm		Max flow per minute equal to the capacity of the DW, not to exceed 0.2 gpm	1.0 gpm
Food waste disposers (max gals per minute)		No load: 1.0g Full load: 3.0g to 8.0g				No load: 1.0g Full load: 8.0g	No load: 1.0g Full load: 8.0g
Food scrap collector or pulper (max gallons/ minute)		2.0g				2.0g with auto shut-off	
Pre-rinse spray valve (max gallons per minute)		1.3g + WaterSense[61]	1.3g	1.3g + WaterSense[3]		1.3g with auto shut-off + WaterSense[3]	1.3g with auto shut-off + WaterSense[3]
Kitchen faucets (gpm - gallons per minute)	1.8 gpm; allows temporary override to 2.2 gpm		Hands-free in food prep area & in dish room of comm'l kitchen	Hands-free in food prep area & in dish room of comm'l kitchen			2.2 gpm

APPENDIX G: REBATES

NATIONAL WEBSITES

- DSIRE energy rebates that may be applicable to water conservation
- U.S. Environmental Protection Agency ENERGY STAR Rebate Finder
- U.S. Environmental Protection Agency Watersense Rebate Finder

LOCAL WEBSITES

- The City of Atlanta Department of Watershed Management (DWM)
- Georgia Power Rebates
- Georgia Power Commercial Applications program
- Metropolitan North Georgia Water Planning District
- U.S. Energy Efficiency Administration listing for Georgia

ENDNOTES

1. According to Black and Veatch (which provides multiple reports on the water and sewer rates for the largest 50 cities in the United States) and Dr. Janice Beecher, Director of the Institute of Public Utilities at Michigan State University.
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3. Beecher, Janice (Black & Veatch). 2016. 50 Largest Cities Report. Retrieved from, https://pages.bv.com/Whitepaper-ManagementConsulting-50LargestCitiesRateSurvey_01-RegistrationPage.html
4. U.S. Department of Energy. Energy Information Administration.
5. U.S. Department of Energy. 2016. Energy Information Administration. Annual Energy Outlook – 2016. *Retrieved from,* http://www.eia.gov/outlooks/aeo/pdf/0383(2016).pdf
6. U.S. Department of Energy. Energy Information Administration Commercial Buildings Energy Consumption Survey (CBECS) for 2012. *Retrieved from,* https://www.eia.gov/consumption/commercial/.
7. U.S. Department of Energy. Energy Information Administration CBECS Building Types Definitions. *Retrieved from,* https://www.eia.gov/consumption/commercial/building-type-definitions.php with addition of Multifamily
8. See Appendix B.
9. See Appendix B.
10. See Appendix B.
11. Each building owner, city, or utility participating will need to determine the specifics of the number of restrooms actually entered and audited.
12. Adopted from U.S. Green Building Council Water Use Reduction, Additional Guidance for Commercial Buildings, 2014. *Retrieved from,* http://www.usgbc.org/Docs/Archive/General/Docs6493.pdf
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14. American Water Works Association. 2019. Technical Resources on the topic of Water Conservation. *Retrieved from,* https://www.awwa.org/Resources-Tools/Resources/Water-Conservation#7485310-awwa-technical-resources
15. See Appendix B.
16. See Appendix C for calculation methods.
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18. See Appendix B.
19. See Appendix B.
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21. U.S. Department of Energy. Energy Information Administration. *Retrieved from,* https://www.eia.gov/consumption/commercial/reports/2012/water/
22. See Appendix B.
23. See Site Visit Section, Appendix B, and Appendix C.
24. See Table 5.

25. See Table 5 for end uses by area.
26. International Green Construction Code. 2012. *Retrieved from,* https://up.codes/code/international-green-construction-code-igcc-2012
27. U.S. Environmental Protection Agency. Watersense. Retrieved from, https://www.epa.gov/watersense
28. https://www.map-testing.com/
29. H.W.(Bill) Hoffman & Associates. 2018. Research across various references and resources.
30. These recommendations are based on the green plumbing guides found under Resources and Methodologies.
31. See Appendix D.
32. See Appendix G.
33. This information can be accessed rapidly through the EIA AEO Data Browser. *Retrieved from,* http://www.eia.gov/outlooks/aeo/data/browser.
34. For more information, visit https://www.whitehouse.gov/omb/circulars_a004_a-4.
35. Multiple sources referenced.
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39. The document was taken from "A Comparison of 'Green'," is provided courtesy of John Koeller, Koeller and Company. This can be found at the Map Testing Web Site at, http://www.map-testing.com/assets/files/2015-april-comparison_of_green.pdf.
40. Prescriptive option only.
41. EPAct 1992 standard for toilets applies to both commercial and residential models.
42. EPAct 1992 standard for faucets applies to both commercial and residential models.
43. MEF measures energy consumption of the total laundry cycle (wash + dry). The higher the number, the greater the energy efficiency.
44. Standard models capacity is greater than or equal to eight place settings and six serving pieces; Compact models capacity is less than eight place settings and six serving pieces.
45. Prescriptive option only.

46. Watersense product maximums are toilets, 1.28 gpf; flushing urinals, 0.5 gpf; residential lavatory faucets, 1.5 gpm; residential showerheads, 2.0 gpm; pre-rinse spray valves, 1.28 gpm.
47. Baseline established as EPAct 1992 (fixtures/fittings), EPAct 2005 (pre-rinse spray valves), ANSI standard ASME A112.18.1/CSA B125.1 & model plumbing codes (public lavatory faucets).
48. For dual-flush fixture, "effective" flush volume defined as average of 2 reduced flushes and 1 full flush.
49. Maximum full flush volume on dual flush fixtures is 1.28 gallons per flush; calculation of "effective flush volume" is no longer required.
50. "Remote" definition: toilet is one located 30 feet or more upstream of other drainline connections or fixtures AND where that connection is served by less than 1.5 drainage fixture units.
51. For dual-flush fixture in this category, maximum full flush volume is 1.28 gallons per flush; calculation of 'effective flush volume' is not required.
52. 1.6 g permitted only when toilet location meets code definition of "remote."
53. Prescriptive option only.
54. Also a minimum flow rate of 0.8 gpm at 20 psi (WaterSense not specified); maximum flow rate as set by California Energy Commission & incorporated into CalGREEN.
55. Today, WS product maximums are: toilets, 1.28 gpf; flushing urinals, 0.5 gpf; residential lavatory faucets, 1.5 gpm; residential showerheads, 2.0 gpm; pre-rinse spray valves, 1.28 gpm.
56. WaterSense also provides for minimum flow rate of 0.8 gpm at 20 psi .
57. Table 5.303.2.2 (Baseline - Nonresidential Mandatory Measures); CalGREEN also specifies a maximum flow rate of 0.5 gpm in Section 4.303.1.4.2 (Residential Mandatory Measures).
58. CalGREEN (Table 5.303.2.3) generically defines "kitchen faucets" for "Nonresidential Mandatory Measures" without specifying if the requirements specifically apply to commercial kitchens; CalGREEN includes no requirements for bar sink faucets.
59. Handwashing faucets in food service must be self-closing.
60. Metering faucets have no flow rate maximum.
61. Prescriptive option only.
62. Includes common area laundry rooms, hotels, laundromats.
63. WaterSense requirement is 1.28 gpm maximum.

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