Related Commercial Resources

CHAPTER 37. ENERGY AND WATER USE AND MANAGEMENT

ENERGY and water management in buildings is the control of energy and water use and cost while maintaining indoor environmental conditions to provide comfort and to fully meet functional needs. This chapter provides guidance on establishing an effective, ongoing energy and water management program, as well as information on planning and implementing energy and water management projects. The energy manager or other similarly tasked champion should understand how energy and water resources are used in the building to manage them effectively. There are opportunities for savings by reducing waste and improving efficiency in energy- and water-consuming systems, optimizing energy and water supply, and reducing the unit price of the purchased utility.

Water costs may include, but not be limited to, sewer, potable water, and reclaimed water costs, and may be included in the energy management activity.

1. ENERGY AND WATER USE MANAGEMENT

There are many different processes by which building owners and operators control energy and water consumption and costs typically vary by building types. For example, small buildings, such as residences and small commercial businesses, usually involve the efforts of one person, whereas larger buildings may require teams or third-party organizations to help manage. Energy and water management procedures should be as simple, specific, and direct as possible. General energy and water management advice, such as from utility surveys or state, provincial, or local offices, can provide ideas, but the recommendations must be evaluated to determine whether they apply to the target building. Owners and operators of smaller buildings may only need advice on specific energy and water projects (e.g., boiler replacement, lighting retrofit). On the other hand, large or complex facilities, such as hospital or university campuses, industrial complexes, or large office buildings, usually require an integrated team and a well-defined process, as represented in Figure 1. which is adapted from the ENERGY STAR® website (www.energystar.gov).

In general, energy and water management for existing buildings has these basic steps, which may vary based on the size of the building and respective team:

1. With support from senior management, appoint an energy manager or resource manager to oversee the energy and water management system and to ensure that someone is dedicated to the initiatives and accountable to the organization.
2. Initiate early communication to solicit feedback for other steps of the process.
3. Establish an accounting system that records energy and water consumption and associated costs. It should include comparisons with similar buildings, to benchmark and set performance goals.
4. Validate and analyze current and historical energy and water use data to help identify energy- and water-efficiency measures
5. Carry out energy and water surveys and walk-through audits to identify low-cost/no-cost operations, maintenance, and energy- and water-efficiency measures. Having qualified professionals, such as energy engineers and energy and water auditors, do this is recommended.
6. Using the survey and audit results, optimize building operating procedures to eliminate energy and water waste.
7. Evaluate energy- and water-efficiency measures for expected savings, estimated implementation costs, risks, and non-energy and water benefits. Recommend a number of prioritized energy- and water-efficiency projects for implementation.
8. Implement approved energy-efficiency measures (EEMs) or energy-conservation measures (ECMs) and water use reduction measures. Tender projects that must be outsourced.
9. Track results using the energy accounting system for overall performance, supplemented as needed by energy and water monitoring related to specific projects.
10. Compare results to past goals, revise as necessary, and develop new goals. Report to senior management and tenants. Return to step 7 and continue the process to maintain and continually improve building performance.

Each of these energy and water management program components is discussed in detail in the following sections.

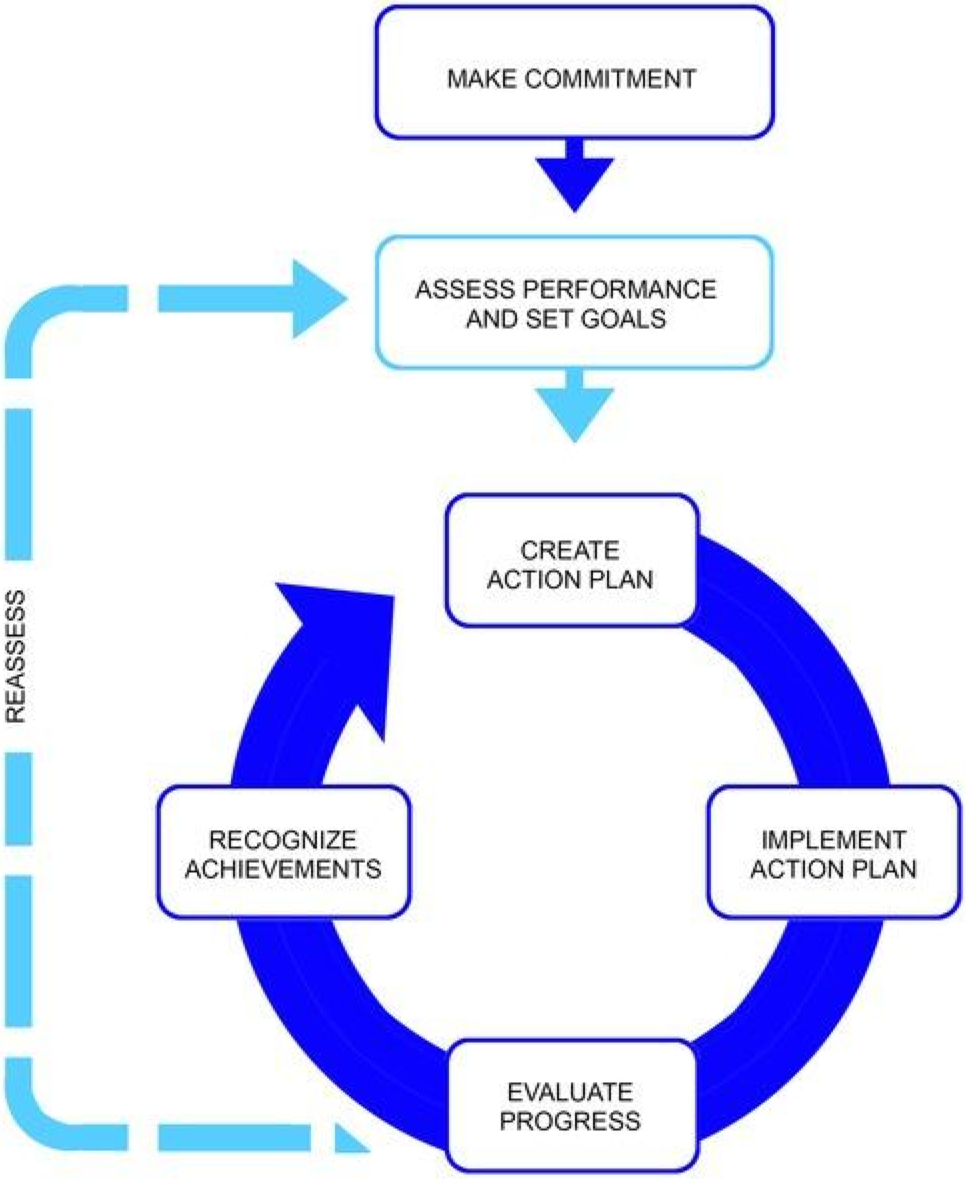


Figure 1. An Energy and Water Management Process (Adapted from www.energystar.gov)

ASHRAE *Standard* 100 gives details useful in energy management planning in existing buildings. Information on energy efficiency in new design can be found in all volumes of the *ASHRAE Handbook* and in ASHRAE *Standards* 90.1 and 90.2. Protocols for energy and indoor environmental quality performance and best practices are presented in ASHRAE (2010, 2012). The area most likely to be overlooked in new design is the ability to measure and monitor energy and water consumption and trends for each energy and water use category given in Chapter 42. Additional guidelines for this area can be found in Chapter 34 of the 2021 *ASHRAE Handbook—Fundamentals*.

Organizing for Energy and Water Management

To be effective, energy and water management must be given the same emphasis as management of any other cost/profit center. Top management should

- Establish the energy and water cost/profit center
- Assign management responsibility for the program
- Assign an energy manager and provide training
- Allocate resources
- Clearly communicate the energy and water management program to all departments and personnel
- Set clear program goals
- Encourage ownership of the program by all levels of the organization

- Set up an ongoing reporting and analysis procedure to monitor results
- Develop a feedback mechanism to allow timely revisions

It is common for a facility to allocate 3 to 10% of the annual energy and water cost for administration of an energy and water management program. The budget should include funds for continuing education of the energy manager and staff.

Energy Managers

The functions of an energy manager fall into four broad categories: technical, policy-related, planning and purchasing, and public relations. A list of specific tasks and a plan for their implementation must be documented and communicated to building occupants to ensure realization of any energy savings. An energy manager in a large commercial complex may perform most of the following functions; one in a smaller facility may have only a few from each category to consider.

Technical functions.

- Establish an energy and water accounting system
- Establish a baseline against which energy- and water-saving improvements can be measured
- Conduct, or arrange for a qualified consultant to conduct, energy audits and recommissioning studies to identify energy- and water-efficiency measures
- Act as an in-house technical consultant on new energy and water conservation technologies, alternative fuel sources, and energy- and water-efficient practices
- Evaluate energy and water efficiency of proposed new construction, building expansion, remodeling, and new equipment purchases
- Set performance standards for efficient operation and maintenance of equipment and facilities
- Review state-of-the-art energy and water management hardware
- Review building operation and maintenance procedures for optimal energy and water management
- Implement energy-efficiency measures (EEMs) and water use reduction measures
- Measure and maintain the effectiveness of EEMs and water use reduction measures
- Measure energy and water use in the field to verify the design and operating conditions

Policy-related functions.

- Fulfill energy policy established by top management
- Monitor federal and state (provincial) legislation and regulatory activities, and recommend policy/response
- Adhere to energy management building codes and water use restrictions established by local or state (provincial) authorities
- Represent the organization in energy associations
- Administer government-mandated reporting programs

Planning and purchasing functions.

- Evaluate fuel-switching and load management opportunities
- Purchase equipment based on life-cycle cost
- Take advantage of energy- and water-efficiency programs offered by utilities and agencies
- Negotiate or advise on major utility contracts
- Develop contingency plans for supply interruptions or shortages
- Forecast and budget for short- and long-term energy and water requirements and costs

- Report regularly to top management and other stakeholders

Public relations functions.

- Make occupants aware of the benefits of efficient energy and water use
- Establish a mechanism to elicit and evaluate suggestions from building occupants
- Recognize and communicate successful energy projects
- Establish an energy and water communications network
- Increase community awareness with press releases and appearances at civic group meetings

The energy manager should have the following qualifications.

General qualifications.

- A technical background, preferably in engineering
- Experience in energy- and water-efficient design of building systems and processes
- Practical, hands-on experience with systems and equipment
- Goal-oriented management style
- Ability to work with people at all levels
- Technical report-writing and verbal communication skills

Desirable educational and professional qualifications.

- Bachelor of science degree, preferably in mechanical, electrical, architectural, industrial, or chemical engineering
- Thorough knowledge of energy resource planning and conservation
- Ability to analyze and compile technical and statistical information and reports, and interpret plans and specifications for building facilities
- Knowledge of
  - Utility rates, energy efficiency, and planning
  - Automatic controls and systems instrumentation
  - Energy-related metering equipment and practices
  - Project management

If it is not possible to add a full-time manager, an existing employee with a technical background should be considered and trained. Energy and water management should not be a collateral duty of an employee who is already fully occupied. Another option is to hire a professional energy management consultant. Energy services companies (ESCOs) provide energy and water services as part of a contract, with payments based on realized savings. Other companies charge a fee to perform a variety of energy and water management functions.

2. COMMUNICATIONS

Energy and water management requires careful planning and help from personnel that operate and use the facility. A communication plan should be regularly reviewed by both the energy manager and senior management. The initial communiqué should introduce the plan and express the support of top management for high-level goals. Providing early information to tenants and staff is important, because it takes time to change behaviors. Once the communication plan is launched, the energy manager should be prepared to answer a variety of questions from different areas of the company.

An effective communication strategy may include

- Produce a regular newsletter
- Post energy- and water-saving tips or reminders

- Hold annual seminars with maintenance and cleaning staff
- Meet with operations staff for training and feedback
- Report regularly to management and operations staff

Message content should be tailored to the specific audience. The more successful and accessible the communication is, the more quickly the energy and water management activities will become integrated into occupants' daily routine. Diligent reporting by the energy manager promotes accountability and persistence of performance.

3. ENERGY AND WATER ACCOUNTING SYSTEMS

An energy and water accounting system that tracks consumption and costs on a continuing basis is essential. It provides energy and water use data needed to identify areas of concern, allowing for focused efforts, and to confirm savings from energy- and water-efficiency projects. An effective energy manager uses an accounting system that can be used in ongoing energy monitoring and building performance measurement. The primary data source is utility bills, but other sources include

- Time-of-use meter data and submeter energy and water usage data
- Combustion efficiency
- Water quality test results
- Recordings of indoor temperature and relative humidity
- Weather data: hourly temperature and relative humidity, wind, percent cloud cover
- Power failure event recordings
- Occupancy data: schedules, people counts, occupant activity levels, special events and holidays
- Water and energy benchmarking data from similar buildings in similar climates
- Equipment service and shutdown logs
- Facility drawing plans and specifications
- Benchmarking data: building location, size, monthly energy and water use, energy use intensity (EUI), and cost utilization index (CUI) (see the section on Analyzing Energy and Water Data for use of proper metrics)
- Computer modeling results

Energy and Water Accounting Process

The energy manager establishes procedures for meter reading, monitoring, and tabulating facility energy and water use and profiles. The energy manager also periodically reviews utility rates, rate structures, and trends, and monitors changes to the rate tariffs for their facility. The energy manager provides periodic reports to management, summarizing the work accomplished, its cost effectiveness, plans for future work, and projections of utility costs. Utility bill analysis software or a spreadsheet system can be used to track avoided costs. If energy- and water-efficiency measures are to be cost effective, continued monitoring and periodic re-auditing are necessary to ensure persistence of the efficiency measures. The procedures in ASHRAE *Guideline* 14 can be used to measure and verify energy and water savings.

Energy and Water Accounting

Energy and water accounting is the tracking of energy and water usage and demand on a consistent basis to provide a current picture of building energy performance and to identify instances and trends of excess use. The energy manager should establish which metrics to measure and what units each metric should have. Typically, in buildings, energy is tracked in units of kilowatt-hours (kWh) or kilo-British Thermal Units (kBtu) and water is tracked in litres or cubic metres (m^3). Peak electric demand is often also tracked in kilowatts. Tracking these metrics consistently and regularly is important to ensure reporting accuracy and easy of communication.

The method by which these metrics are recorded can vary greatly depending on the technical expertise of the manager, the level of technology in the facility, and the number of buildings for which the manager is responsible. For many users, a simple spreadsheet will suffice. If more sophistication is needed, software with dashboard and graphics features is available. There are also web-based accounting systems and subscriptions. For example, Portfolio Manager, available through ENERGY STAR, is a free web-based portal that allows users to enter monthly energy data. The

Portfolio Manager can calculate the facility's energy usage intensity (EUI) and provide a normalized ENERGY STAR rating (www.energystar.gov/benchmark). Portfolio Manager normalizes by building type for weather, facilitates setting goals, helps compare multiple buildings in a portfolio, and is useful for numerous building types. If sharing information across different platforms is needed, the U.S. Department of Energy's Standard Energy Efficiency Data (SEED) platform allows users to manage energy datasets across multiple buildings while using ENERGY STAR.

Utility Rates

Because most energy and water management activities are dictated by economics, the energy manager must understand the utility rates that apply to each facility. Electricity rates are more complex than gas or water rates, and some rate structures make cost calculations difficult. In addition to general commercial or institutional electricity rates, special rates may exist, such as time of day, interruptible service, on peak/off peak, summer/winter, and peak demand. Electricity rate schedules vary widely in North America; Chapters 38 and 57 discuss these in detail. Energy managers should work with local utility companies to identify the most favorable rates for their buildings and must understand how demand is computed as well as the distinction between marginal and average costs (see the section on Improving Discretionary Operations). The utility representative can help develop the most cost-effective methods of metering and billing.

4. ANALYZING ENERGY AND WATER DATA

Preparing for Cost and Efficiency Improvements

Opportunities for savings come in reducing (1) the cost per unit of energy and then (2) energy and water consumption. Historically, energy users had little choice in selecting energy suppliers, and regulated tariffs applied based on certain customer characteristics. In recent years, there has been a move in North America and other parts of the world to deregulate energy markets, and there is more flexibility in supply and pricing. Electricity rate structures vary widely in North America; Chapter 38 discusses these in detail.

Electricity and water utilities commonly meter both consumption and demand. **Demand** is the peak rate of consumption, typically averaged over a 15 or 30 min period. Electricity and water utilities may also use a ratchet billing procedure based on demand. Contact the local utility to fully understand the demand component.

Some utilities use **real-time pricing (RTP)**, in which the utility calculates the marginal cost of power per hour for the next day, determines the price, and sends this hourly price to customers. The customer can then determine the power consumption at different times of the day. A variation on RTP was introduced in some areas: **demand exchange and active load management** pays customers to shed loads during periods of high utility demand. Also called **demand reduction** or **demand response**, the utilities ask participating customers to reduce their consumption for a period of time on as little as a few hours' notice.

Caution is advised in designing or installing systems that take advantage of utility rate provisions, because the structure or provisions of utility rates cannot be guaranteed for the life of the system. Provisions that change include on-peak times, declining block rates, and demand ratchets. Chapter 57 has additional information on billing rates,

Analyzing Energy and Water Use Data

Any reliable utility data should be examined.Utilities often provide metered data with measurement intervals as short as 15 min. Data from shorter time intervals make anomalies more apparent. High consumption at certain periods may reveal opportunities for cost reduction (Haberl and Komor 1990a, 1990b). If monthly data are used, they should be analyzed over several years.

A base year should be established as a reference point. Record the dates of meter readings so that energy use can be normalized for the number of days in a billing period. Any periods in which consumption was estimated rather than measured should be noted.

If energy data are available for more than one building or department, each should be tabulated separately. Initial tabulations should include both energy and cost per unit area (in an industrial facility, this may be energy and cost per unit of goods produced). Document variables such as heating or cooling degree-days, percent occupancy, quantity of goods produced, building occupancy, hours of operation, and daily weather conditions (see Chapter 14 in the 2021 *ASHRAE Handbook—Fundamentals*). Because these variables may not be directly proportional to energy use, it is best to plot information separately or to superimpose one plot over another. Examples of ways to normalize energy consumption for temperature and other variations are provided in ASHRAE *Guideline* 14.

Potential savings areas can be identified by separating base energy consumption from weather-dependent energy consumption. **Base-load energy use** is the amount of energy consumed independent of weather, such as for lighting, motors, domestic hot water, and miscellaneous office equipment. When a building has electric cooling and no electric heating, the base-load electric energy use is normally the energy consumed during the winter. The annual base-load energy use may also be estimated by taking the average monthly use during nonheating or noncooling months and multiplying by 12. For many buildings, subtracting the base-load energy use from total annual energy use yields a good estimate of heating or cooling energy consumption. This approach is not valid when building operation differs from summer to winter, when cooling operates year-round, or when space heating is used during summer (e.g., for reheat). Base-load analysis can be improved by using hourly load data. **Electric load factors (ELFs)** and occupancy factors can also be used instead of hourly energy profiles (Haberl and Komor 1990a, 1990b).

Although it can be difficult to relate heating and cooling energy directly to weather, several authors, including Fels (1986) and Spielvogel (1984), suggest that this is possible using a curve-fitting method to calculate the balance point of a building (as discussed in Chapter 19 of the 2021 *ASHRAE Handbook—Fundamentals*). For this method, building use must be regular, and actual rather than estimated data must be used, along with accurate dates and weather data.

Relating energy and water consumption, as well as energy consumption and wastewater treatment, can provide useful information to building owners when making sense of how certain energy conservation measures can result in water conservation. These relations and ratios are mostly based on information from utility bills. Although experience and observations with facility types may be informative, this information should augment utility bills and, in some respects, provide a reality check of realistic energy and water consumption and wastewater treatment based on facility type. In unpublished observations, for example, Haberl notes for university facilities at Bryan College Station, Texas, that 1 Wh is consumed in order to provide 3.79 L of pressurized potable water, and 3 to 4 Wh is consumed to treat 3.79 L of wastewater.

More detailed breakdown of energy use requires that some metered data be collected daily (winter versus summer days, weekdays versus weekends) and that some hourly information be collected to develop profiles for night (unoccupied), morning warm-up, day (occupied), and shutdown. That detailed breakdown may also include metering specific systems to measure their respective energy and water consumption (submetering). Submetering of energy end uses is recommended for optimal energy management. For more information, see Chapter 42.

An example spreadsheet using three years of electricity bill data for a two-story office building in Atlanta, Georgia, is presented in Table 1. (Chapter 18 of the 2021 *ASHRAE Handbook—Fundamentals* has floor plans and elevations of the building available for download on ASHRAE Handbook Online.)

Table 1 Electricity Consumption for Atlanta Example Building

		Occupancy Factor		**32.7%**			**Building Area: 30,700 ft^2**					
		Summer ELF 2002		**82.5%**	**Summer ELF 2003**		**37.4%**	**Summer ELF 2004**		**54.7%**		
Year	**Month**	**Bill Start**	**Bill End**	**Billing Period**	**Billed Use, kWh**	**Actual Demand, kW**	**Billed Demand, kW**	**LF**	**Daily Use, kWh**	**Daily Base Use, kWh**	**Monthly Base Use, kWh**	**Percent Excess Use, kWh**
2002	Jan-02	1/2/2002	1/31/2002	29	54,600	166	166	47.3%	1883	1665	48,285	11.6%
2002	Feb-02	1/31/2002	2/28/2002	28	46,620	148	166	46.9%	1665[a]	1665	46,620	0.0%
2002	Mar-02	2/28/2002	4/1/2002	32	60,900	140[b,c]	166	56.6%	1903	1665	53,280	12.5%
2002	Apr-02	4/1/2002	4/29/2002	28	56,340	166	166	50.5%	2012	1665	46,620	17.3%
2002	May-02	4/29/2002	5/31/2002	32	65,520	159	166	53.7%	2048	1665	53,280	18.7%
2002	Jun-02	5/31/2002	6/28/2002	28	63,540	180	180	52.5%	2269	1665	46,620	26.6%
2002	Jul-02	6/28/2002	7/31/2002	33	76,860	158	171	61.4%	2329	1665	54,945	28.5%
2002	Aug-02	7/31/2002	8/30/2002	30	82,620	192	192	59.8%	2754[a]	1665	49,950	39.5%
2002	Sep-02	8/30/2002	9/30/2002	31	66,780	195[b]	195[b]	46.0%	2154	1665	51,615	22.7%
2002	Oct-02	9/30/2002	10/29/2002	29	60,720	193	185	45.2%	2094	1665	48,285	20.5%
2002	Nov-02	10/29/2002	12/2/2002	34	62,100	151	185	50.4%	1826	1665	56,610	8.8%
2002	Dec-02	12/2/2002	1/2/2003	31	60,180	166	185	48.7%	1941	1665	51,615	14.2%
2003	Jan-03	1/2/2003	1/31/2003	29	57,120	178	185	46.1%	1970	1704	49,429	13.5%
2003	Feb-03	1/31/2003	3/3/2003	31	61,920	145	185	57.4%	1997	1704	52,838	14.7%
2003	Mar-03	3/3/2003	4/1/2003	29	60,060	140	185	61.6%	2071	1704	49,429	17.7%
2003	Apr-03	4/1/2003	4/30/2003	29	62,640	154	185	58.4%	2160	1704	49,429	21.1%
2003	May-03	4/30/2003	6/2/2003	33	73,440	161	185	57.6%	2225[a]	1704	56,247	23.4%
2003	Jun-03	6/2/2003	6/28/2003	26	53,100	171	185	49.8%	2042	1704	44,316	16.5%
2003	Jul-03	6/28/2003	7/30/2003	32	67,320	180[b]	185[b]	48.7%	2104	1704	54,542	19.0%
2003	Aug-03	7/30/2003	8/29/2003	30	66,000	170	185	53.9%	2200	1704	51,133	22.5%
2003	Sep-03	8/29/2003	9/30/2003	32	63,960	149	171	55.9%	1999	1704	54,542	14.7%
2003	Oct-03	9/30/2003	10/30/2003	30	55,260	122	171	62.9%	1842	1704	51,133	7.5%

2003	Nov-03	10/30/2003	11/26/2003	27	46,020	140	171	50.7%	1704[a]	1704	46,020	0.0%
2003	Dec-03	11/26/2003	12/30/2003	34	61,260	141	171	53.2%	1802	1704	57,951	5.4%
2004	Jan-04	12/30/2003	1/30/2004	31	59,040	145	171	54.7%	1905	1676	51,960	12.0%
2004	Feb-04	1/30/2004	2/28/2004	29	54,240	159	171	49.0%	1870	1676	48,608	10.4%
2004	Mar-04	2/28/2004	3/19/2004	20	37,080	122	171	63.3%	1854	1676	33,523	9.6%
2004	Apr-04	3/19/2004	3/31/2004	12	22,140	133	171	57.8%	1845	1676	20,114	9.2%
2004	May-04	3/31/2004	5/4/2004	34	64,260	148	171	53.2%	1890	1676	56,988	11.3%
2004	Jun-04	5/4/2004	6/2/2004	29	63,720	148	171	61.9%	2197	1676	48,608	23.7%
2004	Jul-04	6/2/2004	7/2/2004	30	69,120	169	169	56.8%	2304	1676	50,284	27.3%
2004	Aug-04	7/2/2004	8/3/2004	32	73,800	170[b]	170[b]	56.5%	2306[a]	1676	53,636	27.3%
2004	Sep-04	8/3/2004	9/1/2004	29	64,500	166[b]	166[b]	55.8%	2224	1676	48,608	24.6%
2004	Oct-04	9/1/2004	10/1/2004	30	60,060	152	161	54.9%	2002	1676	50,284	16.3%
2004	Nov-04	10/1/2004	11/2/2004	32	65,760	128	161	66.9%	2055	1676	53,636	18.4%
2004	Dec-04	11/2/2004	12/3/2004	31	51,960	132	161	52.9%	1676[a]	1676	51,960	0.0%

	kWh/y·ft^2	Days	Total kWh	Peak kW	Billed kW	Avg LF	Daily Base Use, kWh	Total Base Use, kWh
2002	24.65	365	756,780	195	195	51.6%	1665	607,725
2003	23.72	362	728,100	180	185	51.5%	1704	617,009
2004	22.33	339	685,680	170	171	52.4%	1676	568,208

[a] Maximum or minimum value for year.

[b] Peak demand for year.

[c] Minimum demand used in seasonal ELF calculation.

Electrical Use Profile

The **electrical use profile (EUP)** report, shown in Figure 2, divides electrical consumption into base and weather-dependent consumption. The average daily consumption for each month appears in the daily use column in Table 1 and is plotted in the EUP graph. The average daily consumption is calculated by dividing the consumption for a particular month by its billing days.

The lowest value in the daily-use column of Table 1 is used to plot the facility's base electrical consumption (shown as the base use line in Figure 2). Where a facility uses electricity only for cooling or heating, or in an all-electric facility where there is no overlap between cooling and heating, the difference between these two lines represents the weather-dependent electrical consumption.

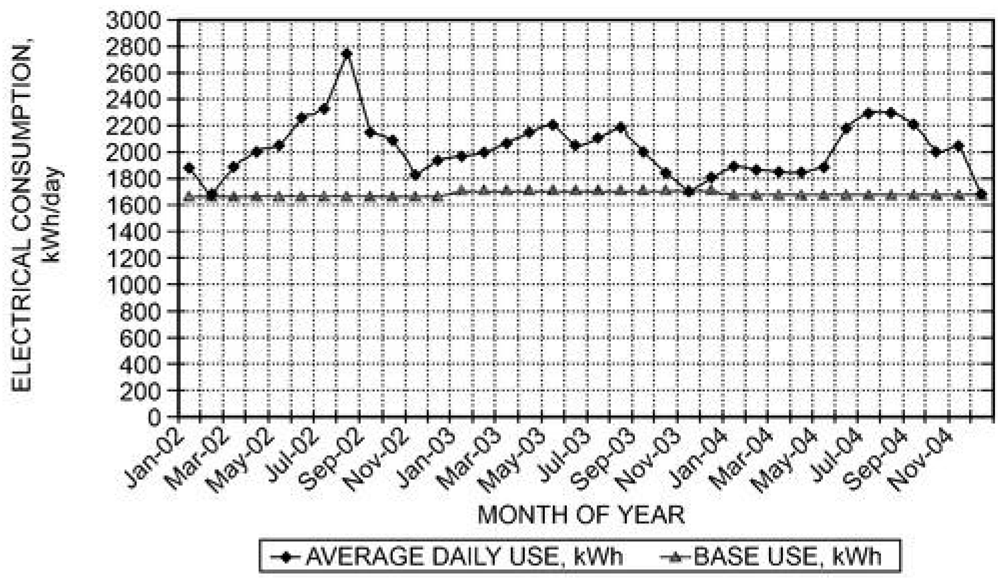


Figure 2. Electrical Use Profile for Atlanta Example Building

Weather-dependent energy consumption (either electricity or other fuels) may then be compared to the **cooling degree-days (CDD)** or **heating degree-days (HDD)** totals for the same time period (see Chapter 14 of the 2021 *ASHRAE Handbook—Fundamentals*). This comparison shows how the building performs from month to month or year to year. The HDDs stop and CDDs start at the balance point, defined as the outdoor temperature at which, for a specified interior temperature, the total heat loss is equal to the heat gain from the sun, occupants, lights, etc. Note that all-electric buildings may have periods of overlap between heating and cooling, causing the base load to be overestimated and the heating and cooling estimates to be conservative.

Examine the average daily use line to see whether it follows the expected seasonal curve. For example, the shoulders of the curve for an electrically cooled, gas-heated hospital should closely follow the base electrical use line in the winter. As summer approaches, this curve should rise steadily to reflect the increased cooling load. Errors in meter readings, reading dates, or consumption variances appear as unusual peaks or valleys. Reexamine the data and correct errors as necessary.

If an unusual profile remains after correcting any errors, an area of potential energy savings may exist. For example, if the average daily use line for the facility is running near summer levels during March, April, May, October, and November, simultaneous heating and cooling may be occurring. This situation is shown in Figure 2 and often occurs with dual-duct systems.

Simultaneous heating and cooling is also indicated in the percent excess use column of Table 1. The values show the percent difference between the value appearing in the monthly base use column and the billed consumption for the month. In Figure 2, note how the excess consumption for spring and fall months runs close to the summer percentages. The monthly base use is the lowest value from the daily use column multiplied by the number of billing days for each month.

For electrically cooled, gas-heated facilities, weather-dependent consumption is the difference between the totals of the monthly base use column and the billed use column.

For an all-electric facility, subtract the total monthly consumption from total billed use for the cooling months, then do the same calculations for heating months to determine the electric cooling and heating loads, respectively.

Calculating Electrical Load and Occupancy Factors

Another method for detecting potential energy savings is to compare the facility's electrical load factor to its occupancy factor. An ELF exceeding its occupancy factor indicates a higher-than-expected electric use occurring outside normal occupancy (e.g., lights or fans are left on or air conditioning is not shut off as early in the day as possible in summer). Setback thermostats, direct digital control (DDC) strategies, time-of-day scheduling, and lighting controls can address this.

The ELF is the ratio of the average daily use and the maximum possible use if peak demand operated for a 24 h period. The occupancy factor is the ratio of the hours a building actually is occupied and 24 h/day occupancy.

To calculate the ELF, find the month with the lowest demand on the utility data analysis spreadsheet. This value represents the base monthly peak demand, and is usually found in the same or adjacent month as the month with the lowest consumption. From the EUP report, find the lowest value in the daily use column. For example, the lowest average daily use for the office building in Table 1 is 1704 kWh (in November 2003), and the lowest monthly demand from the spreadsheet is 122 kW (in October 2003). The ELF is calculated as follows:

$$\text{ELF} = \frac{\text{Lowest average daily use}}{\text{Lowest monthly demand} \times 24} = \frac{1704}{122 \times 24} = 0.58 \text{ or } 58\%$$

The office is normally occupied from 7:30 am to 6:30 pm, Monday to Friday. Therefore, the occupancy factor is calculated as

$$\begin{array}{c}\text{Occupancy}\\ \text{factor}\end{array} = \frac{\text{Actual weekly occupied hours}}{24 \text{ h} \times 7 \text{ days}} = \frac{55}{168}$$
$$\approx 0.327 \text{ or } 33\%$$

Calculating Seasonal ELFs

ELFs can also be calculated for cooling and heating seasons. Typical defaults are May to August as cooling months, and the rest of the year as heating months, but these change based on climate.

The steps for calculating a seasonal ELF are as follows:

1. The daily base consumption is determined from the daily use column of the EUP report. Subtract the lowest value of the year from the highest value of the season.

2. The base demand is determined by subtracting the lowest monthly demand for the year from the demand recorded for the month with the highest daily use. These calculations can be refined further if on- and off-peak

data are available.

For example, because the electrically cooled Atlanta example building operates year-round, the summer ELF must also be calculated. The daily base consumption (1089 kWh) is determined by subtracting the lowest value (1665 kWh) from the highest cooling-season value (2754 kWh) in the daily use column of the EUP report.

From the spreadsheet, take the demand from September 2002 (the month with the peak cooling-season actual demand) and subtract the lowest monthly demand from the spreadsheet (195 – 140) to determine the cooling-season base demand (55 kW). Thus, the summer ELF is

$$\text{Summer ELF} = \frac{1089}{55 \times 24} = 0.825 \text{ or } 82.5\% \text{ (for 2002)}$$

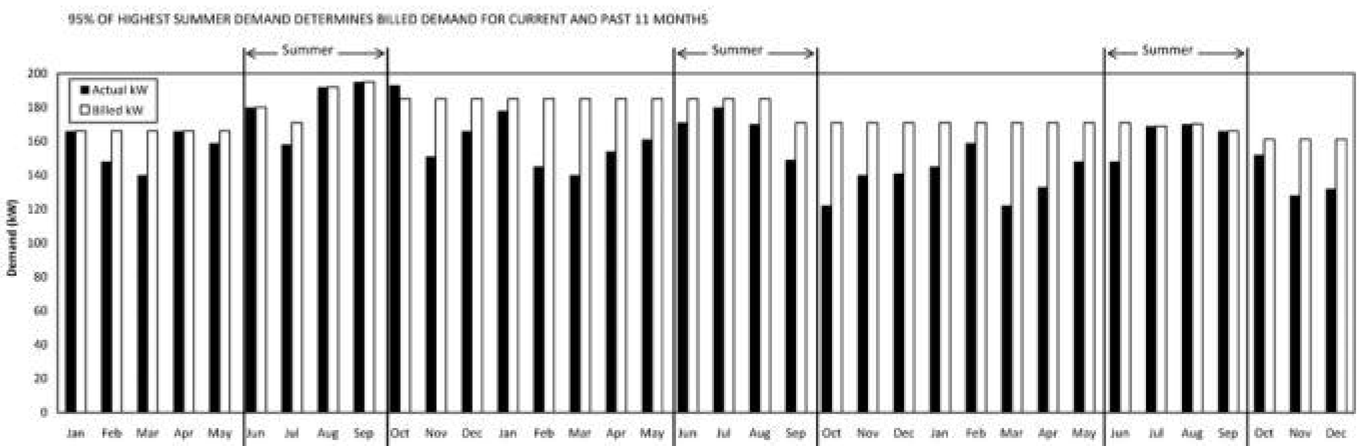
These calculations show that the cooling equipment is operating beyond building occupancy (82.5% versus 32.7%) Therefore, excessive equipment run times should be investigated. Note that comparing the ELF to the occupancy factor is meaningless for buildings occupied 24 h a day, such as hospitals.

Similar tables and charts may be created for natural gas, water, and other utilities.

Electricity Demand Billing

The Atlanta example building has a ratchet-type demand rate (see Chapter 57), and billed demand is determined as a percentage of actual demand in the summer months. The ratchet is illustrated in Figure 3, where billed demand is the greater of the measured demand or 95% of the highest measured demand within the past 12 months. The billed demand for January of the third year was 171 kW (171 = 0.95 × 180), or 95% of the actual demand from July of year 2.

In Table 1, the actual demand in the first six months of 2003 had no effect on the billed demand, and therefore no effect on the dollar amount of the bill; the same is true for the last three months of the year. Because of the demand ratchet, the billed demand in January 2004 (171 kW) was set in July 2003. This means that any conservation measures that reduce peak demand will not affect billed demand until the following summer (e.g., June to September 2004); however, consumption savings begin at the next billing cycle. The effect of demand ratchet rates is that any conservation measures implemented have a longer initial payback period simply because of the utility rate structure. The energy manager should investigate other rate structures, such as time-of-use (TOU) or seasonal rates. Rate structures for smaller buildings may not include demand charges.



Year 1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Actual kW	166	148	140	166	159	180	158	192	195	193	151	166
Billed kW	166	166	166	166	166	180	171	192	195	185	185	185

Year 2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Actual kW	178	145	140	154	161	171	180	170	149	122	140	141
Billed kW	185	185	185	185	185	185	185	185	171	171	171	171

Year 3

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Actual kW	145	159	122	133	148	148	169	170	166	152	128	132
Billed kW	171	171	171	171	171	171	169	170	166	161	161	161

Figure 3. Comparison Between Actual and Billed Demand for Atlanta Example Building

Benchmarking Energy Use

Benchmarking (comparing a building's normalized energy consumption to that of similar buildings) can be a useful first measure of energy efficiency. Relative energy use is commonly expressed in **energy utilization index (EUI**; energy use per unit area per year) and **cost utilization index (CUI**; energy cost per unit area per year). The Atlanta example building is 2852 m^2 in size, so its 2004 EUI is 866 MJ/m^2 per year and its CUI is $15.82/$m^2$ per year.

Commercial Buildings. Two sources of benchmarking data for U.S. buildings are ENERGY STAR (www.energystar.gov) and performance metrics developed using data from the U.S. Department of Energy's Energy Information Administration (DOE/EIA; www.eia.gov). Tables 2 to 5 present commercial building performance metrics (benchmarks) developed from the 2012 DOE/EIA Commercial Building Energy Consumption Survey (CBECS) using a methodology similar to that described by Sharp (2014) and used in the development of building energy performance targets for ASHRAE *Standard* 100. Table 2 lists population metrics and total EUI distributional values derived for each building type (in both SI and I-P units). Table 3 provides the same metrics but on a source- or primary-energy-use basis that can be useful when the user wants to account for energy-generation-related efficiencies. Table 4 lists distributional values derived for building electricity use, and Table 5 shows similar values for building energy costs. As an example of how to interpret and use these percentiles using Table 2, an administrative office with a total EUI of 588 MJ/(m^2·yr) is a typical performer (in the middle or 50th percentile of the distribution of office buildings). It is in the top-performing quartile (25th percentile) if it has an EUI of 361 MJ/(m^2·yr) or less, and it is in the worst-performing 10% of office buildings if it has an EUI of 1388 MJ/(m^2·yr) or higher. When referring to these tables, keep in mind a facility's operating or occupied hours (which affect energy intensity) and current utility rates. Additional information on CBECS data and surveys is available at www.eia.gov/consumption/commercial.

Residential Buildings. In addition to data for commercial buildings, DOE/EIA also has data for residential buildings through the Residential Energy Consumption Survey (RECS). Compared to commercial buildings, there are fewer types of residential buildings, and residential buildings tend to have more variability in EUI and CUI based on geographic location. The residential EUI and CUI data are presented in this section for the following five building types and four major geographic United States Census regions, as illustrated in Figure 4 (U.S. Census Bureau 2021):

- Mobile home
- Single-family detached home
- Single-family attached home
- Apartment in a building with two to four units
- Apartment in a building with five or more units

The EUI and CUI residential data are derived directly from the DOE/EIA 2015 RECS specifically for this Chapter, using the RECS data directly with no screening or deletions. The RECS survey weights were applied to obtain the calculated values. The RECS floor area value (TOTSQFT_EN = Total square footage) used for RECS published data was used as the floor area for each home in the database. The 2015 RECS data do not include wood, coal, district steam, or solar thermal energy use, although this lack of coverage is expected to have little to no discernible impact on the calculated values shown.

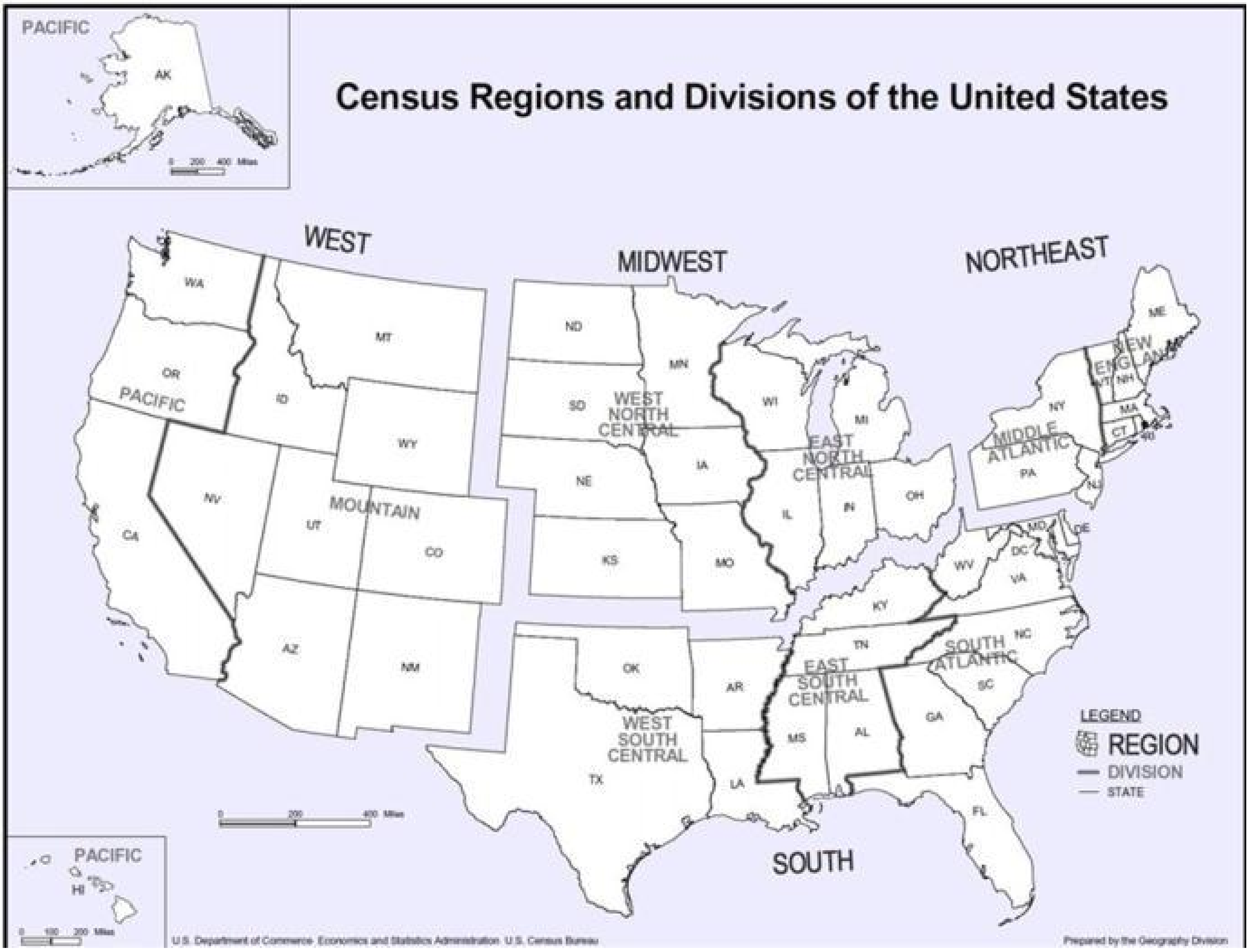


Figure 4. United States Census Regions Map

Calculation of EUI for a home, just as for a commercial building, requires adding up all energy used over a 365-day period, and then dividing by the appropriate floor area value. DOE/EIA has an entire document on floor area, *2015 RECS Square Footage Methodology* (www.eia.gov/consumption/residential/reports/2015/squarefootage). Figure 5 shows what floor areas of a single-family house are included typically for total home floor area (TOTSQFT_EN). Basement floor area in large apartment buildings is typically not included, and the most useful value for larger apartment buildings is likely to be the average of all homes (dwellings) in the building.

The calculated total number of RECS U.S. housing units (homes) for the 2015 data equals 118 million, about 95% of the census total for July 1, 2015, but the census total includes seasonally occupied units. Detailed RECS microdata can be obtained from www.eia.gov/consumption/data.php.

Figure 5. Floor Areas Included in Total Home Floor Area of RECS EUI Calculations

Tables 6 to 8 present residential building performance metrics (benchmarks) developed from the 2015 DOE/EIA RECS. Table 6 lists housing population data and total site energy EUI distributional values derived for each housing type and Census region. Site energy is the value tabulated by RECS of energy used in the home and does not include energy losses incurred for production and distribution of energy to individual homes. Table 7 provides the same metrics but on a source- or primary-energy-use basis that can be useful when the user wants to account for energy-distribution-related efficiencies. Source energy is calculated here by multiplying the energy used at the home by a national average adjustment factor to cover energy production and distribution losses. The factors used here are electricity (3.34); natural gas (1.047); and fuel oil-kerosene-propane (1.01). Table 8 shows a similar breakout of CUI values for home energy costs.

Databases. Compiling a database of past energy use and cost is important. All reliable utility data should be examined. ASHRAE *Standard* 105 contains information that allows for uniform, consistent expressions of energy consumption in new and existing buildings.

The energy use database for a new building may consist solely of typical data for similar buildings, as in Table 2. This may be supplemented by energy simulation data developed during design. A new building should be commissioned to ensure proper operation of all systems, including any energy-efficiency features (see ASHRAE *Guideline* 1.1 and Chapter 44).

All the data presented in these tables come from detailed reports of consumption patterns, and it is important to understand how they were derived. When using the data, verify correct use with the original EIA documents.

Mazzucchi (1992) lists data elements useful for normalizing and comparing utility billing information. Metered energy consumption and cost data are also published by trade associations, such as the Building Owners and Managers Association International (BOMA), the National Restaurant Association (NRA), and the American Hotel and Lodging Association (AH&LA). In some cases, local energy consumption data may be available from local utility companies or state or provincial energy offices.

Additional energy use information for homes and commercial buildings in Canada can be found at the Office of Energy Efficiency at www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/publications.cfm. In Europe, benchmarking data are defined on a national basis in the frame of the European Directive on the Energy Performance of Buildings (EPBD) (EC 2010) and the Energy Efficiency Directive (EED) (EC 2012), where the emphasis is on performance of member states and includes performance of major end-use-sector components such as buildings. Under the EPBD, building energy benchmarking information is provided in the form of an energy performance certificate (EPC). EPCs must provide the energy consumption of a building, including reference benchmark values to allow assessment of relative energy performance. EPCs must also include recommendations for cost-effective improvement options for the building. In most countries, performance is expressed on a letter scale (e.g., A to G, where A is very efficient and G is very inefficient). The EPBD-EED framework provides room for member states to detail the mechanisms and manner of implementation. An assessment of EPCs provides more information on use and how they fit into the framework (EC 2013). The overall framework continues to be improved as needed (EC 2018a, 2018b, 2019a).

Table 2 2012 Commercial Sector Floor Area and EUI Percentiles

Building Use	Calculated, Weighted		Actual Number of Buildings, *N*	Calculated, Weighted Energy Use Index (EUI) Values Site Energy, MJ/yr per gross square metre					
				Percentiles					
	Number of Buildings, Thousand	Floor Area, 10^9 m^2		10th	25th	50th	75th	90th	Mean
Administrative/professional office	558	0.84	766	218	361	588	828	1390	728
Bank/other financial	91	0.08	79	516	673	1002	1299	1723	1059
Bar/pub/lounge	71	0.03	60	493	772	1435	2618	3791	1909
Clinic/other health	87	0.12	135	279	497	718	1049	1726	900
College/university*	27	0.17	104	299	656	998	1449	1811	1231
Convenience store	79	0.03	47	707	1289	2486	4048	5154	2769
Convenience store with gas station	52	0.02	32	1402	2469	2802	3981	5287	3261
Courthouse/probation office	6	0.04	26	598	836	1056	1190	1461	1049
Distribution/shipping center	151	0.53	307	80	181	328	514	811	403
Dormitory/fraternity/sorority*	25	0.07	48	116	270	657	966	1379	681
Elementary/middle school	189	0.57	397	233	342	528	801	1238	647
Enclosed mall	1	0.08	34	306	489	707	805	1045	671
Entertainment/culture*	51	0.12	89	56	263	506	832	1362	682
Fast food	92	0.03	94	1088	2219	4671	7842	9585	5127
Fire station/police station	69	0.05	53	235	364	642	966	1591	746
Government office	113	0.25	205	243	450	654	927	1487	778
Grocery store/food market	45	0.07	48	1176	1518	2253	2657	3418	2219
High school	43	0.28	142	265	481	721	1048	1428	828
Hospital/inpatient health*	10	0.22	409	1075	1829	2348	3107	3622	2430
Hotel	30	0.24	159	482	645	747	1203	1876	1017
Laboratory*	16	0.04	41	507	841	1771	2924	7118	2425
Library*	24	0.07	37	321	509	793	972	1122	787
Medical office (diagnostic)	60	0.05	62	203	381	643	847	1164	692
Medical office (non-diagnostic)	50	0.03	42	262	337	580	725	1021	600
Mixed-use office	125	0.25	212	161	287	519	785	1305	635
Motel or inn	61	0.06	61	502	562	677	1313	1552	898
Non-refrigerated warehouse	427	0.50	350	23	72	197	452	849	305
Nursing home/assisted living	30	0.12	94	573	889	1255	1800	2196	1448
Other	109	0.14	87	14	186	450	1366	2641	1122
Other classroom education	62	0.07	62	157	267	446	1002	1311	646
Other food sales	1	0.00	2	2075	2470	2470	2470	2470	2381
Other food service	37	0.01	27	56	479	1155	2578	3649	1597

Other lodging	13	0.04	27	426	637	808	1446	1804	978
Other office	74	0.04	52	137	276	493	893	1484	684
Other public assembly	41	0.06	63	221	431	637	889	2083	848
Other public safety	9	0.04	22	855	1207	1345	1625	1625	1321
Other retail	59	0.03	41	265	451	807	1443	1912	951
Other service	114	0.06	83	154	276	545	1274	3887	1507
Post office/postal	30	0.04	26	337	515	717	878	1008	698
Preschool/daycare	68	0.04	50	320	441	736	1024	1387	844
Recreation	100	0.18	127	199	287	577	1114	1814	793
Refrigerated warehouse	8	0.04	21	285	401	955	2623	3446	1454
Religious worship	412	0.42	352	99	191	319	576	933	493
Repair shop	84	0.05	53	94	162	387	849	1315	566
Restaurant/cafeteria	179	0.10	180	680	1414	3218	5442	7391	3665
Retail store	336	0.42	294	126	259	574	939	1428	689
Self-storage	209	0.15	81	23	44	143	383	789	327
Social/meeting	135	0.09	98	90	201	418	1002	1400	630
Strip shopping mall	163	0.47	296	440	672	1175	2004	3011	1596
Vacant	296	0.30	247	8	45	127	343	573	240
Vehicle dealership/showroom	43	0.05	34	246	393	693	1143	1615	869
Vehicle service/repair	214	0.15	149	128	246	505	1011	1832	810
Vehicle storage/maintenance	176	0.12	113	64	188	368	836	1507	697
SUM or Mean for sector	5557	8.09	6720	101	262	563	1046	2182	982

Source: Oak Ridge National Laboratory, T. R. Sharp, calculated from U.S. DOE/EIA 2012 CBECS microdata.

NOTE: Metrics will not exactly match those in CBECS Table PBA3 as shown on the CBECS website due to including propane and wood as energy sources and because EIA uses a database to generate Table PBA3 that is slightly different from the database they make available to the public.

* District chilled water use and cost are not reflected in building EUIs and cost metrics because they were not reported in the CBECS public database. Analysis showed there was potential this could significantly impact some EUIs for these building use types: college/university, dormitory/fraternity/sorority, entertainment/culture, library, hospital/inpatient health, and laboratory. Commentary in this chapter will explain the impact of chilled water systems on these categories.

Table 3 2012 Commercial Sector Floor Area and Source EUI Percentiles

Building Use	Calculated, Weighted: Number of Buildings, Thousand	Calculated, Weighted: Floor Area, 10^9 m^2	Actual Number of Buildings, *N*	Calculated, Weighted Energy Use Index (EUI) Values — Source Energy, MJ/yr per gross square metre — Percentiles: 10th	25th	50th	75th	90th	Mean
Administrative/professional office	558	0.84	766	554	880	1395	2061	3517	1797
Bank/other financial	91	0.08	79	1285	1663	2653	3409	4193	2708
Bar/pub/lounge	71	0.03	60	1228	1920	3454	6073	7906	4274
Clinic/other health	87	0.12	135	742	1207	1785	2622	4703	2233
College/university	27	0.17	104	886	1582	2436	2981	4349	2824
Convenience store	79	0.03	47	2120	3924	7469	12750	15798	8143
Convenience store with gas station	52	0.02	32	3797	7396	8692	12091	16134	9365
Courthouse/probation office	6	0.04	26	1483	1822	2532	2757	3622	2442
Distribution/shipping center	151	0.53	307	207	431	797	1315	1822	928
Dormitory/fraternity/sorority	25	0.07	48	365	801	1341	2189	2370	1529

Elementary/middle school	189	0.57	397	612	907	1263	1758	2683	1514
Enclosed mall	1	0.08	34	404	1479	2121	2438	3030	1887
Entertainment/culture	51	0.12	89	170	550	893	1961	3604	1641
Fast food	92	0.03	94	2732	6277	11451	17338	21630	12082
Fire station/police station	69	0.05	53	510	731	1263	2236	2861	1621
Government office	113	0.25	205	653	1159	1755	2631	3337	1976
Grocery store/food market	45	0.07	48	3092	4749	5627	7478	8789	6002
High school	43	0.28	142	756	1095	1701	2340	3258	1899
Hospital/inpatient health	10	0.22	409	2560	3977	5533	6720	7790	5358
Hotel	30	0.24	159	1207	1472	2060	2623	4362	2452
Laboratory	16	0.04	41	1488	2040	4066	5857	13045	5872
Library	24	0.07	37	1012	1602	1861	2436	2562	1952
Medical office (diagnostic)	60	0.05	62	431	912	1541	2295	2871	1793
Medical office (non-diagnostic)	50	0.03	42	711	989	1524	1832	2259	1532
Mixed-use office	125	0.25	212	391	735	1316	1978	2858	1549
Motel or inn	61	0.06	61	1007	1531	1841	2952	4311	2310
Non-refrigerated warehouse	427	0.50	350	67	215	538	1102	1737	739
Nursing home/assisted living	30	0.12	94	1109	1902	2667	4321	5488	3106
Other	109	0.14	87	44	548	1017	2686	6977	2461
Other classroom education	62	0.07	62	447	669	1033	1858	2332	1316
Other food sales	1	0.00	2	5123	5976	5976	5976	5976	5784
Other food service	37	0.01	27	177	1425	3114	7032	11496	4493
Other lodging	13	0.04	27	925	990	1791	3051	3947	2011
Other office	74	0.04	52	433	758	1155	2138	2891	1537
Other public assembly	41	0.06	63	689	912	1201	1807	3805	1838
Other public safety	9	0.04	22	1879	2771	3464	4183	4786	3523
Other retail	59	0.03	41	427	1047	2040	3433	5314	2477
Other service	114	0.06	83	388	707	1273	2387	8343	2745
Post office/postal	30	0.04	26	724	1279	1644	1835	2231	1587
Preschool/daycare	68	0.04	50	802	1115	1606	2351	3269	2077
Recreation	100	0.18	127	453	654	1357	2507	4117	1887
Refrigerated warehouse	8	0.04	21	541	1264	3009	5597	10856	4389
Religious worship	412	0.42	352	224	431	667	1073	1849	938
Repair shop	84	0.05	53	298	447	932	1794	2676	1164
Restaurant/cafeteria	179	0.10	180	1875	3174	6698	11094	14522	7691
Retail store	336	0.42	294	385	654	1478	2447	3750	1755
Self-storage	209	0.15	81	71	137	449	1035	2486	981
Social/meeting	135	0.09	98	319	581	1195	1945	3740	1508
Strip shopping mall	163	0.47	296	1171	1934	2947	4726	6053	3678
Vacant	296	0.30	247	26	114	274	711	1251	545
Vehicle dealership/showroom	43	0.05	34	516	1009	1522	2963	3990	2081
Vehicle service/repair	214	0.15	149	350	675	1247	2069	3361	1617
Vehicle storage/maintenance	176	0.12	113	182	471	861	1416	3278	1485
SUM or Mean for sector	5557	8.09	6720	300	669	1351	2536	5225	2336

*

Source: Oak Ridge National Laboratory, T. R. Sharp, calculated from U.S. DOE/EIA 2012 CBECS microdata.

* District chilled water use and cost are not reflected in building EUIs and cost metrics because they were not reported in the CBECS public database. Analysis showed there was potential this could significantly impact some EUIs for these building use

types: college/university, dormitory/fraternity/sorority, entertainment/culture, library, hospital/inpatient health, and laboratory. Commentary in this chapter will explain the impact of chilled water systems on these categories.

Table 4 Electricity Index Percentiles from 2012 Commercial Survey

	Weighted Electricity Use Index Values, kWh/yr per gross square metre					
	Percentiles					
Building Use	**10th**	**25th**	**50th**	**75th**	**90th**	**Mean**
Administrative/professional office	35	59	104	164	264	135
Bank/other financial	94	118	204	260	357	209
Bar/pub/lounge	96	122	272	412	494	294
Clinic/other health	52	77	141	201	329	169
College/university	66	100	158	214	300	189
Convenience store	177	317	531	1119	1301	691
Convenience store with gas station	302	611	735	1021	1233	783
Courthouse/probation office	85	142	185	197	258	172
Distribution/shipping center	11	25	54	90	136	66
Dormitory/fraternity/sorority	32	54	91	139	185	102
Elementary/middle school	47	61	87	127	199	109
Enclosed mall	9	120	174	215	247	155
Entertainment/culture	10	19	72	142	274	120
Fast food	182	463	794	1289	1637	876
Fire station/police station	21	42	84	157	243	108
Government office	51	84	128	182	273	151
Grocery store/food market	244	375	465	588	693	483
High school	43	67	113	168	260	133
Hospital/inpatient health	179	218	347	475	489	356
Hotel	79	102	147	195	313	181
Laboratory	126	152	356	433	713	433
Library	89	113	156	167	195	145
Medical office (diagnostic)	34	51	123	179	247	140
Medical office (non-diagnostic)	43	71	97	155	168	118
Mixed-use office	23	47	93	143	204	115
Motel or inn	61	130	160	228	364	179
Non-refrigerated warehouse	5	15	38	72	126	55
Nursing home/assisted living	55	115	187	296	382	205
Other	3	22	53	180	547	163
Other classroom education	13	28	74	116	159	82
Other food sales	386	443	443	443	443	430
Other food service	16	95	234	612	1014	370
Other lodging	30	33	94	162	267	127
Other office	35	43	80	105	182	106
Other public assembly	39	51	76	135	318	121
Other public safety	111	172	289	366	407	278
Other retail	29	69	153	241	469	194
Other service	23	46	79	165	315	148
Post office/postal	48	80	111	143	153	111
Preschool/daycare	30	83	122	178	256	155

Recreation	16	41	80	193	357	136
Refrigerated warehouse	31	111	265	494	957	378
Religious worship	13	23	38	63	119	54
Repair shop	19	33	56	109	141	72
Restaurant/cafeteria	116	209	414	730	929	493
Retail store	26	48	99	192	291	134
Self-storage	6	12	34	91	219	84
Social/meeting	16	31	68	118	307	105
Strip shopping mall	102	149	215	300	433	261
Vacant	1	9	18	40	101	38
Vehicle dealership/showroom	18	57	95	232	324	151
Vehicle service/repair	21	49	80	125	182	96
Vehicle storage/maintenance	5	22	53	97	214	95
Mean for sector	18	41	94	184	385	168

Source: Oak Ridge National Laboratory, T. R. Sharp, calculated from U.S. DOE/EIA 2012 CBECS microdata.

Table 5 Energy Cost Percentiles from 2012 Commercial Survey

	Weighted Energy Cost Values, $/yr per gross square metre					
	Percentiles					
Building Use	**10th**	**25th**	**50th**	**75th**	**90th**	**Mean**
Administrative/professional office	5.70	9.25	14.10	21.30	33.46	17.86
Bank/other financial	10.65	13.88	22.92	32.50	40.35	23.67
Bar/pub/lounge	12.91	17.54	27.65	48.31	87.48	38.09
Clinic/other health	5.60	10.22	19.05	23.67	34.86	20.01
College/university	8.93	12.91	20.55	26.58	45.41	23.03
Convenience store	17.00	30.34	52.19	88.55	170.65	73.92
Convenience store with gas station	34.75	44.22	67.36	98.56	107.71	76.07
Courthouse/probation office	11.19	13.77	26.15	37.98	51.11	28.62
Distribution/shipping center	2.26	3.66	6.99	11.73	18.94	8.82
Dormitory/fraternity/sorority	5.27	6.35	11.94	18.61	25.39	13.02
Elementary/middle school	6.03	8.61	12.16	17.00	24.86	14.31
Enclosed mall	3.23	10.11	16.89	20.98	26.15	15.39
Entertainment/culture	2.04	5.60	11.62	17.86	29.37	15.49
Fast food	31.85	62.73	98.35	139.56	175.28	102.33
Fire station/police station	4.20	5.60	10.33	17.43	28.94	13.99
Government office	5.70	8.82	14.53	22.17	30.99	17.86
Grocery store/food market	23.35	40.03	50.25	69.51	75.54	52.83
High school	6.56	9.58	14.20	19.26	28.08	17.54
Hospital/inpatient health	21.09	29.81	39.27	51.43	67.57	42.39
Hotel	9.25	11.94	15.17	23.03	35.08	20.12
Laboratory	17.97	24.86	36.15	56.38	118.58	52.19
Library	8.72	15.17	17.97	24.32	33.57	19.48
Medical office (diagnostic)	6.78	10.11	16.46	22.27	35.40	18.18
Medical office (non-diagnostic)	6.03	9.04	13.67	17.22	30.34	14.96
Mixed-use office	3.77	7.42	13.45	20.87	30.24	15.60
Motel or inn	6.99	12.27	18.83	23.03	33.03	19.05

Non-refrigerated warehouse	0.75	2.47	5.81	9.79	16.25	7.42
Nursing home/assisted living	10.65	14.31	22.06	37.44	62.52	27.65
Other	0.97	4.84	7.85	23.24	60.47	25.39
Other classroom education	2.37	5.49	10.76	17.32	24.75	11.73
Other food sales	38.20	38.20	38.20	38.20	43.79	39.38
Other food service	1.29	10.01	31.85	82.64	92.97	46.05
Other lodging	8.50	8.72	14.10	20.34	24.53	16.03
Other office	3.55	6.99	12.37	16.89	26.04	15.60
Other public assembly	6.03	8.29	10.65	14.42	31.74	15.60
Other public safety	14.63	18.83	21.95	31.53	31.53	23.03
Other retail	5.49	10.11	16.89	35.40	54.23	24.32
Other service	3.44	6.13	11.19	24.75	59.18	23.03
Post office/postal	7.64	10.11	13.45	17.32	21.74	14.10
Preschool/daycare	9.04	12.05	15.71	21.63	36.26	18.61
Recreation	4.09	7.42	11.94	27.01	46.81	19.15
Refrigerated warehouse	8.18	9.68	25.29	41.00	95.33	37.44
Religious worship	2.15	3.87	6.35	10.11	15.28	8.39
Repair shop	2.37	4.73	9.68	14.31	26.68	11.41
Restaurant/cafeteria	15.17	28.73	53.80	84.04	118.79	61.76
Retail store	4.20	7.32	12.48	21.52	34.11	16.79
Self-storage	0.65	1.40	3.34	8.61	27.44	9.68
Social/meeting	2.80	5.06	9.15	16.03	32.06	12.91
Strip shopping mall	9.58	15.60	24.10	37.66	52.19	30.02
Vacant	0.65	1.40	3.23	7.32	13.34	5.38
Vehicle dealership/showroom	4.30	9.36	13.56	26.36	42.18	20.12
Vehicle service/repair	3.44	7.64	12.48	17.00	35.51	15.92
Vehicle storage/maintenance	1.83	4.52	9.36	17.11	26.68	14.53
Mean for sector	3.12	6.56	12.70	22.92	46.59	21.09

*

Source: Oak Ridge National Laboratory, T. R. Sharp, calculated from U.S. DOE/EIA 2012 CBECS microdata.

* District chilled water use and cost are not reflected in building EUIs and cost metrics because they were not reported in the CBECS public database. Analysis showed there was potential this could significantly impact some EUIs for these building use types: college/university, dormitory/fraternity/sorority, entertainment/culture, library, hospital/inpatient health, and laboratory. Commentary in this chapter will explain the impact of chilled water systems on these categories.

Table 6 Residential Site Energy EUIs from RECs 2015 Data

Home Type and Regional Breakout				Site EUI kBtu/yr per m^2, weighted					
				Percentiles					
Type	REGION	*N*	Homes	10th	25th	50th	75th	90th	Mean
Mobile home	Northeast	18	490,107	518	653	749	989	1407	874
	Midwest	33	980,335	339	475	822	1027	1341	795
	South	161	3,881,942	202	376	516	707	884	561
	West	74	1,434,659	321	391	524	662	1180	636
Single-family detached	Northeast	475	10,804,083	252	362	476	632	884	527
	Midwest	913	18,159,251	260	349	475	632	836	520
	South	1369	28,696,793	201	284	414	564	748	454
	West	995	16,210,914	182	264	387	544	711	434
Single-family attached	Northeast	76	1,866,750	262	355	528	765	969	565

	Midwest	93	1,279,769	260	337	503	681	1067	562
	South	169	2,278,327	194	282	387	538	755	427
	West	141	1,585,286	181	281	401	513	729	426
Multifamily, 2-4 units	Northeast	77	3,159,585	310	500	684	976	1312	755
	Midwest	73	1,962,091	202	429	605	847	1095	655
	South	95	2,408,501	210	315	415	694	934	528
	West	66	1,862,065	235	332	452	594	789	487
Multifamily, 5+ units	Northeast	148	4,686,013	251	404	602	769	950	612
	Midwest	215	3,990,289	222	325	479	649	821	512
	South	216	7,176,411	195	276	408	544	695	425
	West	279	5,295,079	166	270	355	501	665	399
United States		5686	118,208,250						

Table 7 Residential Source Energy EUIs from RECS 2015 Data

Home Type and Regional Breakout				Source EUI MJ/yr per m^2, weighted					
				Percentiles					
Type	**REGION**	***N***	**Homes**	**10th**	**25th**	**50th**	**75th**	**90th**	**Mean**
Mobile home	Northeast	18	490,107	1011	1317	1772	2271	2498	1794
	Midwest	33	980,335	1056	1420	1783	2487	2748	1840
	South	161	3,881,942	602	1124	1579	2169	2816	1703
	West	74	1,434,659	625	829	1192	1897	2862	1510
Single-family detached	Northeast	475	10,804,083	466	625	818	1090	1454	909
	Midwest	913	18,159,251	500	625	829	1124	1533	943
	South	1369	28,696,793	568	761	1056	1465	1987	1181
	West	995	16,210,914	375	545	829	1158	1579	931
Single-family attached	Northeast	76	1,866,750	466	591	965	1170	1442	954
	Midwest	93	1,279,769	545	670	909	1249	1851	1011
	South	169	2,278,327	579	772	1022	1408	1999	1147
	West	141	1,585,286	409	602	806	1090	1715	931
Multifamily, 2-4 units	Northeast	77	3,159,585	681	829	1215	1772	2419	1351
	Midwest	73	1,962,091	591	874	1226	1624	1772	1249
	South	95	2,408,501	579	897	1226	1772	2578	1431
	West	66	1,862,065	534	693	920	1192	1579	1045
Multifamily, 5+ units	Northeast	148	4,686,013	636	818	1022	1306	1703	1102
	Midwest	215	3,990,289	579	806	1079	1317	1715	1136
	South	216	7,176,411	647	863	1136	1613	2112	1283
	West	279	5,295,079	432	613	886	1192	1522	943
United States		5686	118,208,250						

Table 8 Residential Energy CUIs from RECS 2015 Data

Home Type and Regional Breakout				Energy Cost Index $/yr per m^2, weighted					
				Percentiles					
Type	**REGION**	***N***	**Homes**	**10th**	**25th**	**50th**	**75th**	**90th**	**Mean**
Mobile home	Northeast	18	490,107	$13	$16	$19	$23	$31	$20
	Midwest	33	980,335	$10	$12	$17	$22	$26	$17

	South	161	3,881,942	$6	$12	$15	$22	$29	$17
	West	74	1,434,659	$8	$10	$13	$20	$26	$16
Single-family detached	Northeast	475	10,804,083	$6	$8	$10	$14	$19	$12
	Midwest	913	18,159,251	$5	$6	$8	$11	$15	$9
	South	1369	28,696,793	$6	$8	$11	$15	$19	$12
	West	995	16,210,914	$4	$6	$9	$13	$17	$10
Single-family attached	Northeast	76	1,866,750	$5	$8	$11	$15	$17	$12
	Midwest	93	1,279,769	$5	$6	$9	$12	$18	$10
	South	169	2,278,327	$6	$8	$11	$14	$18	$12
	West	141	1,585,286	$4	$6	$9	$12	$17	$11
Multifamily, 2-4 units	Northeast	77	3,159,585	$8	$11	$16	$23	$33	$18
	Midwest	73	1,962,091	$7	$9	$13	$17	$19	$13
	South	95	2,408,501	$6	$9	$12	$17	$28	$14
	West	66	1,862,065	$6	$7	$10	$15	$22	$12
Multifamily, 5+ units	Northeast	148	4,686,013	$9	$12	$18	$23	$29	$18
	Midwest	215	3,990,289	$6	$8	$11	$14	$18	$12
	South	216	7,176,411	$7	$9	$12	$16	$21	$13
	West	279	5,295,079	$5	$7	$10	$14	$19	$12
United States		5686	118,208,250						

Benchmarking Water Use

As with energy, benchmarking a building's water use to established norms can be a quick, first indicator of an opportunity for improving water efficiency. Building water performance metrics are becoming more ubiquitous. The DOE/EIA collected building water use data as part of its national 2012 CBECS survey. In 2017, the EIA used these data to generate national average water consumption metrics for 10 building types (not counting the "other" category). Their results can be found at www.eia.gov/consumption/commercial/reports/2012/water/. This is informed by a statistically based national sampling. The EPA WaterSense and ENERGY STAR programs collaborated to generate national median water consumptions for 14 building types based on the data collected through the ENERGY STAR program. The EPA's sample is based on users submitting data through their ENERGY STAR Portfolio Manager application, so it is not entirely random.

Commentary: Based on the analysis done by Sharp to develop Tables 2 to 5 in this chapter, district chilled water provides cooling to nearly half of the college and university buildings in the CBECS database used to develop the values in Tables 2, 3, and 5 in this chapter. However, chilled-water consumption and cost are unreported by CBECS, so the total energy use and cost computed for these buildings are not exactly correct. As a result, actions considered were to either drop college/university EUIs from the tables, calculate EUIs using all college/university buildings (even though many had some unreported energy use), or exclude the large number of buildings using district chilled water from the EUI computations. Further analysis showed, surprisingly, that introducing the potential bias in the sample by excluding the many buildings with unreported chilled water use had little impact on the resulting EUIs (they changed from only –9 to 5% and in inconsistent directions). As a result, the oversight committee charged with updating this chapter decided it would be best to not exclude this large number of observations in the calculation of EUIs.

For dormitory and fraternity and sorority facilities, the same analysis by Sharp showed that dropping the district-cooled buildings reduced the sample size by only about 13%, but the 25th percentile EUI decreased 40% and the median EUI increased by 11% (again moving in inconsistent directions with one change being very sizable for a small decrease in sample size). As a result, as before, the chosen approach in the final analysis was to not delete observations for the calculation of EUIs.

For entertainment and culture facilities, the analysis by Sharp showed a reduction of the sample size by 12.4%, a 25th percentile EUI reduction of 11%, and a median EUI reduction of 15%. For libraries, the sample size reduced 15%, the median EUI decreased 26%, and the 75th percentile decreased 5%. For consistency, the same path was chosen for these building use types, to not delete observations in the calculation of EUIs. Although no certain attribution may be made, the presence of entertainment and culture facilities and laboratories on campuses, many of which may be served by district chilled water systems, may be a consideration.

Similar scenarios occurred for hospital/inpatient health and laboratory buildings where facilities using district chilled water comprised 19 and 15% of the samples, respectively. Again, observations were not deleted from the calculation of EUIs due to missing chilled-water use and cost.

For the other building types in Tables 2 through 5, few buildings in their CBECS samples used district chilled water (between 0 to 5%). Little to no impact to values in these tables would be expected from use of district heat for those building types.

One should not assume the EUIs in Tables 2, 3, and 5 would be higher if chilled-water use and cost were included in them. The resulting EUIs could increase, decrease, or change very little in this case.

Table 9 presents distributional building water use intensity metrics for 25 building types (24 commercial and 1 multifamily building residential type). These metrics were developed by analyzing some available state-level data and combining the results with the EPA WaterSense/ENERGY STAR values. Metrics are presented on a water use intensity basis. The sensitivity of building energy performance metrics to regional differences within the United States has been analyzed, and national-level building energy metrics must be used with many cautions when comparing to a local building. Water metrics are not expected to be as sensitive to regional variances, which may make national metrics more reliable for local comparisons, but that is yet to be proven. As more data become available, it will be possible to expand on the metrics in Table 5 and better evaluate their ability to be reliable comparators for indicating water efficiency performance of individual buildings. Note the metrics in Table 9 are developed from rather small samples in all cases, reflecting the limited amount of current publicly available water use data from which such metrics can be developed.

Table 9 Water Use Intensity Metrics for U.S. Buildings

		Calculated Water Use Index, L/yr per gross square metre				
		Percentiles[a]				
Building use	**# Obs**	**10th**	**25th**	**50th[b]**	**75th**	**90th**
Multifamily housing	697.36	1137	1641.07	2251.26	3115.38	697.36
Office	178.13	306.99	469.96	659.46	1053.62	178.13
College/university	159.18	382.79	788.32	1292.39	1595.59	159.18
Hotel	856.54	1432.62	1781.3	2778.07	5362.85	856.54
Residence hall/dormitory	462.38	894.44	1216.59	1576.64	2027.65	462.38
Laboratory	NA[3]	NA[3]	1652.44	NA[3]	NA[3]	NA[3]
Supermarket/grocery store	579.87	890.65	1057.41	1402.3	1641.07	579.87
Medical office	352.47	511.65	856.54	1034.67	1265.86	352.47
Mixed use property	NA[3]	NA[3]	943.71	NA[3]	NA[3]	NA[3]
Retail store	162.97	284.25	651.88	1087.73	1648.65	162.97
Hospital (general medical and surgical)	697.36	1011.93	1606.96	1895	2205.78	697.36
Manufacturing/industrial plant	NA[3]	NA**	170.55	NA[3]	NA[3]	NA[3]
K-12 school	155.39	227.4	314.57	435.85	667.04	155.39
Other: lodging/residential	NA[3]	NA[3]	1425.04	NA[3]	NA[3]	NA[3]
Worship facility	68.22	128.86	219.82	367.63	648.09	68.22
Distribution center	NA[3]	NA[3]	227.4	NA[3]	NA[3]	NA[3]
Financial office	265.3	341.1	545.76	697.36	871.7	265.3
Senior care community	1212.8	2141.35	2982.73	4889.1	6170.12	1212.8
Other: education	NA[3]	NA[3]	284.25	NA[3]	NA[3]	NA[3]
Performing arts	NA[3]	NA[3]	591.24	NA[3]	NA[3]	NA[3]
Energy/power station	NA[3]	NA[3]	144.02	NA[3]	NA[3]	NA[3]
Fitness center/health club/gym	NA[3]	NA[3]	962.66	NA[3]	NA[3]	NA[3]
Indoor arena	NA[3]	NA[3]	208.45	NA[3]	NA[3]	NA[3]
Library	NA[3]	NA[3]	246.35	NA[3]	NA[3]	NA[3]
Strip mall	NA[3]	NA[3]	811.06	NA[3]	NA[3]	NA[3]

[c]

Source: U.S. Department of Energy, Oak Ridge National Laboratory

[a] Building use types with 10th to 90th percentile metrics account for over 60% of the water use in U.S. buildings.

[b] Confidence in percentile values typically decreases as number of observations (# Obs) decreases. Thus, percentile values where # Obs <20, and especially when very low, should be considered as indicators of values and not necessarily reliable values for benchmarking.

[c] NA: Data were not available to enable a determination of this value.

5. SURVEYS AND AUDITS

This section provides guidance on conducting building surveys and describes the levels of intensity of investigation.

Energy and Water Audits

The objective of an energy and water audit is to identify opportunities to reduce energy and water use and/or cost. The results should provide the information needed by an owner/operator to decide which recommendations to implement. Energy and water audits may include the following:

1. Collection and analysis of historical energy and water use
   - Review of more than one year of utility bills (preferably three years)
   - Review of billing rate class options with utility
   - Review of monthly patterns for irregularities
   - Development of target goals for energy, water, demand, and cost indices
2. Study of the building and its operational characteristics
   - Acquiring a basic understanding of the mechanical and electrical systems
   - A walk-through survey to become familiar with construction, equipment, operation, and maintenance
   - Meeting with the owner/operator and occupants to learn of special problems or needs
   - Identifying any required repairs to existing systems and equipment
3. Identifying potential modifications to reduce energy and water use or cost
   - Identifying low- and no-cost changes to the facility or to operating and maintenance procedures
   - Identifying potential equipment retrofit opportunities
   - Identifying training required for operating staff
   - A rough estimate of the breakdown of energy and water consumption for significant end-use categories
4. An engineering and economic analysis of potential modifications
   - For each practical measure, determine resultant savings
   - Estimate of effects on building operations and maintenance costs
   - Financial evaluation of estimated total potential investment
5. A rank-ordered list of all possible energy and water savings modifications
   - Selection of those that may be considered practical by the building owner
   - Assume that modifications with highest operational priority and/or best return on investment will be implemented first
   - Preliminary implementation costs and savings estimates
6. Results report
   - Description of building, operating requirements, and major energy- and water-using systems
   - Clear statement of savings from each modification and assumptions on which each is based
   - Review of list of practical modifications with the owner
   - Prioritizing modifications in recommended order of implementation
   - Recommend measurement and verification methods

ASHRAE *Standard* 211-2018 identifies the following four levels of effort in the energy audit process, which can also be applied to water audits.

Preliminary Energy Use Analysis. This involves analysis of historic utility use and cost and development of the energy utilization index (EUI) of the building. Compare the building's EUI to similar buildings to determine whether further engineering study and analysis are likely to produce significant energy savings.

Level I: Walk-Through Survey. In addition to the work done by the preliminary energy use analysis, this assesses a building's current energy cost and efficiency by analyzing energy bills and briefly surveying the building. The auditor should be accompanied by the building operator. Level I analysis identifies low-/no-cost measures and capital improvements that merit further consideration, along with an initial estimate of costs and savings. The level of detail depends on the experience of the auditor and the client's specifications. The Level I audit is most applicable when there is some doubt about the energy savings potential of a building, or when an owner wishes to establish which buildings in a portfolio have the greatest potential savings. The results can be used to develop a priority list for a Level II or III audit.

Level II: Energy Survey and Engineering Analysis. This includes a more detailed building survey and energy analysis, including a breakdown of energy use in the building, a savings and cost analysis of all practical measures that meet the owner's constraints, and a discussion of any effect on operation and maintenance procedures. It also lists potential capital-intensive improvements that require more thorough data collection and analysis, along with an initial judgment of potential costs and savings. This level of analysis is adequate for most buildings.

Level III: Detailed Analysis of Capital-Intensive Modifications. This focuses on potential capital-intensive projects identified during Level II and involves more detailed field data gathering and engineering analysis. It provides a detailed projection of cost and savings, with the high level of confidence necessary for major capital investment decisions.

The levels of energy audits do not have sharp boundaries. They are general categories for identifying the type of information that can be expected and an indication of the level of confidence in the results. In a complete energy management program, Level II audits should be performed on all facilities.

A thorough systems approach produces the best results. This approach has been described as starting at the end rather than at the beginning. For example, consider a factory with steam boilers in constant operation. An expedient (and often cost-effective) approach is to measure the combustion efficiency of each boiler and to improve boiler efficiency. Beginning at the end requires finding all or most of the end uses of steam in the plant, which could reveal the existence of considerable waste, such as venting to the atmosphere, defective steam traps, uninsulated lines, and lines through unused heat exchangers. Eliminating end-use waste can produce greater savings than improving boiler efficiency.

A detailed process for conducting energy audits is outlined in ASHRAE *Standard* 211-2018.

An effective water audit estimates and reduces water use that is not accounted for, including loss through leaks, unmetered use, and inoperative system control (blow-off valves, etc.). In addition to the standard procedure above, information gathering before a water audit may include the following items (NCDENR 1998):

- Inventory of plumbing fixtures, and water-use equipment with the manufacturers' flow rate
- Review of plumbing risers, diagrams, and irrigation plans
- Obtaining the service vendors' contact information
- For service providers, recording number of meals served, number of rooms, and occupancy data (restaurants, hotels, hospitals, military base, schools, etc.) and calculation of the water usage per service
- For manufacturers, recording the number of products and calculation of the water usage per product
- Identifying the amount of water used to provide services or products

6. IMPROVING DISCRETIONARY OPERATIONS

Basic Energy and Water Management

Control Energy System and Water Use. The most effective method to reduce energy and water costs is through discretionary operations, such as turning off equipment when not needed. Improvement of operations by discretionary means should not compromise safety or environmental health. Ways to conserve energy and water include (but are not limited to) the following:

- Reducing air leakage
- Reducing ventilation rates during periods of low occupancy
- Shutting down exhaust fans when they are not required
- Shutting down HVAC&R systems when operation is not required

- Sealing or repairing leaks in ducts and pipes
- Reducing water leakage
- Turning off lighting: removal of unnecessary lighting, addition of switched circuits and dimming capabilities, use of motion sensors and light-sensitive controls
- Use of temperature setup and setback
- Cooling with outdoor air (free cooling)
- Sealing unused vents and ducts to the outside
- Performing proper maintenance and tune up before heating and cooling seasons begin
- Taking transformers offline during idle periods

Purchase Lower-Cost Energy. This is the second most effective method for reducing energy costs. Building operators and managers must understand all the options for purchasing energy and design systems to take advantage of changing energy costs. The following options should be considered:

- Choosing or negotiating lower-cost utility rates
- Procuring electricity or fuels through brokers
- Correcting power factor penalties
- Controlling peak electricity billing demand
- Utility-sponsored demand response programs
- Transportation and interruptible natural gas rates
- Cogeneration
- Lower-cost liquid fuels
- Increasing volume for on-site storage
- Avoiding sales or excise taxes where possible
- Incentive rebates from utilities and manufacturers

Optimize Energy Systems Operation and Water Use. The third most effective method for reducing costs is to tune systems to optimal performance, an ongoing process combining training, preventive maintenance, and system adjustment. Tasks for optimizing performance include

- Training operating personnel on equipment operations and maintenance
- Tuning combustion equipment and adjusting gas burners to operate at optimal efficiency
- Following an established maintenance program for all equipment
- Reusing condensate or process water for heating or cooling applications (when this would not compromise health)
- Cleaning or replacing filters
- Cleaning fan blades and ductwork
- Cycling ventilation systems to coincide with occupied spaces
- Fine-tuning water treatment based on test results
- Periodically monitoring runtimes to prevent short-cycling

Purchase Efficient Replacement Systems. This method is more expensive than the other three, presents energy managers with the greatest liability, and may be less cost effective. It is critical to ensure that possible equipment or system replacements are objectively evaluated to confirm both the replacement costs and benefits to the owner. The optimum time for replacing less-efficient equipment and related components is near the end of its expected life or when major repairs are needed. Systems commonly replaced include

- Lighting systems and lamps
- Heating and cooling equipment
- Faucets and water fixtures
- Water heaters and pumps
- Energy distribution systems (pumps and fans)
- Motors
- Thermal envelope components such as insulation and windows
- Building automation control systems, energy management systems, and lighting control systems

Optimizing More Complex System Operation

As the complexity of building systems increases, additional strategies are needed to optimize energy systems. According to ASHRAE *Guideline* 0-2019, approaches include **recommissioning** (applied to a project that has been delivered using the commissioning process), **retrocommissioning** (applied to an existing facility that was not previously commissioned), and **ongoing commissioning** (continuation of the commissioning process well into the occupancy and operations phase to verify that a project continues to meet current and evolving owner's project requirements). See Chapter 44 for more information.

These approaches typically require a strong team effort from the facility staff and third-party consultants to identify and fix comfort problems as well as aggressively optimize HVAC operation and control. Some important measures typically include

- Optimizing supply temperature reset schedules
- Optimizing duct static pressure reset schedules
- Optimizing pump control and hydronic system pressure setback
- Optimizing terminal unit settings and control
- Optimizing sequencing and hydronic system temperature reset schedules for heating, cooling, and domestic water
- Identifying and repairing stuck or leaky valves and dampers
- Training operating personnel in optimum operating strategies
- Setting up monitoring and reporting of key system performance indicators

Implementing these measures has been found to reduce energy use by an average of about 20% (Claridge et al. 1998). Approaches to commissioning and optimizing operation of existing buildings can be found in ASHRAE Guideline 1.1-2007, Claridge and Liu (2000), Haasl and Sharp (1999), Kurt et al. (2003), Liu et al. (1997), Poulos (2007), and Tseng (2005).

7. ENERGY- AND WATER-EFFICIENCY MEASURES

Identifying Energy- and Water-Efficiency Measures

It is important to apply strategy in identifying energy-efficiency measures (EEMs) and water-efficiency measures (WEMs). Various EEMs and WEMs can be quantitatively evaluated from end-use energy and water use breakdown profiles, and this is often the most strategic starting point. Focusing on end-use systems that consume the bulk of site energy/water is likely to yield larger potential savings than spending time assessing systems that consume little energy or water.

When identifying EEMs and WEMs, a useful strategy is to do the following:

1. **Minimizing waste** focuses on matching the need, which usually involves reducing equipment operation through decreasing hours of operation, turning unnecessary equipment off, reducing running hours or flows, fixing leaks, and turning set points up or down.
2. **Maximizing efficiency** involves lowering power requirements of equipment. This may include cleaning and tuning equipment, and replacing old equipment with more efficient technology.

3. **Optimizing supply** improves how energy or water is supplied to a system. This may involve heat recovery, water reclamation, procurement of lower-cost energy, and conversion to renewable energy technologies, such as solar or geothermal.

For example, when working with a hydronic heating system using a natural gas boiler, the auditor should first identify measures that minimize waste (e.g., lower set points, night setback, warm weather shutdown), then look to measures that maximize efficiency (e.g., replacing with high-efficiency condensing boilers), and finally measures that optimize supply (e.g., recovering waste process heat to offset natural gas consumption). If these three steps are not applied in this order, the auditor risks missing the most cost-effective strategies for improving energy performance. Also, the minimizing waste measures are often low or no cost, so it is important to first give attention to these.

With mechanical measures, starting the assessment at the point of end use is often the most strategic approach. For a fan system with zone-level flow and temperature control, the auditor should start by assessing the system at the zone (room) level first. Once zone-level operation has been optimized, the auditor should focus on upstream components such as the fan, economizer, and heating/cooling coils. In this example, if EEMs were instead considered at the fan level first, subsequent EEMs identified at the zone level may alter the impact of the fan-level EEMs, leading to rework or lost opportunity.

Accurate energy savings calculations can be made only if system interaction is allowed for and fully understood. Annual simulation models may be necessary to accurately estimate the interactions between various EEMs. ASHRAE *Standard* 100 provides a list of EEMs for use in models.

Using average costs per unit of energy in calculating the energy cost avoidance of a particular measure is likely to result in erroneous calculations, because actual energy cost avoidance may not be proportional to the energy saved, depending on the billing method for energy used. In addition, previously implemented energy-efficiency measures should be evaluated to (1) ensure that devices are in good working order and measures are still effective, and (2) consider revising them to reflect changes in technology, building use, and/or energy cost.

WEMs may be identified by looking at common uses of water in facilities. Typical water use by commercial, institutional, and industrial customers include

1. Domestic (restrooms, kitchens, and laundries)
2. Cooling and heating
3. Landscaping irrigation
4. Process-related

Evaluating Energy- and Water-Efficiency Measures

In establishing EEM and WEM priorities, the capital cost, cost-effectiveness, effect on indoor environment, and resources available must be considered. Factors involved in evaluating the desirability of measures are

- Rate of return (simple payback, life-cycle cost, net present value)
- Total savings (energy, water, cost avoidance)
- Initial cost (required investment)
- Other benefits (safety, comfort, improved system reliability, improved productivity)
- Alignment with corporate goals
- Life of the measure
- Energy/water measurement and verification requirements
- Liabilities (increased maintenance costs, potential obsolescence)
- Risk of failure (confidence in predicted savings, rate of increase in energy costs, maintenance complications, success of others with the same measures)

Project success also depends on the availability of

- Management attention, commitment, and follow-through
- Technical expertise
- Personnel, and involvement and input of operational staff throughout the project

- Investment capital

Some owners are reluctant to implement EEMs and WEMs because of bad experiences with prior projects. To reduce the risk of failure, documented performance of measures in similar situations should be obtained and evaluated. One common problem is that consumption for individual end uses is overestimated during the audit or evaluation phase, and the predicted savings are neither demonstrated nor achieved once implemented. When doubt exists about energy or water consumption, temporary monitoring or spot measurements should be taken and evaluated.

Interactive Effects. Electrical equipment and appliances, from lighting systems and office equipment to motors and water heaters, provide useful services; however, the electrical energy they use eventually appears as heat within the building, which can either be useful or detrimental, depending on the season. In cold weather, heat produced by electrical equipment can help reduce the load on the building's heating system (albeit in an uncontrolled manner and potentially at higher cost per unit of heat). In contrast, during warm weather, it adds to the air-conditioning load.

Energy-efficient equipment and appliances consume less energy to produce the same useful work, and also produce less heat. Thus, efficient electrical equipment may increase the load on heating systems in winter and may reduce the load on air-conditioning systems in summer. Effects of energy-efficient equipment and appliances on energy use for building heating and air conditioning systems are commonly called **interactive effects** or **cross effects**.

Heat from electrical equipment and appliances (lighting systems and office equipment to motors and water heaters) eventually appears as heat load in the building, which can either be useful or detrimental, depending on the season. In cold weather, heat produced by electrical equipment can help reduce the load on the building's heating system. In contrast, during warm weather, it adds to the air-conditioning load.

When considering the overall net savings of an energy-efficiency measure, it is important to consider its interactive effects on building heating, cooling, and refrigeration systems. Weighing the interactive effects results in better-informed decisions and realistic expectations of savings.

The percentage of heat that is useful in a specific building or room depends on several factors, including the following:

- Location of heaters and their thermostats or other sensors
- Type of ceiling
- Size of building
- Whether room is an interior or exterior space
- Internal heat gains (people, equipment, solar)
- Location of light fixtures
- Extent of heating and cooling seasons
- Type of heating, ventilation, and air-conditioning system used in each room

Interactive effects can be difficult to quantify; however, whole-building energy modeling can be used to estimate these effects. See Rundquist et al. (1993) for details.

Exploring Financing Options

Financing alternatives also need to be considered. When evaluating proposed projects, particularly those with a significant capital cost, it is important to include a life-cycle cost analysis. This not only provides good information about the financial merits (or otherwise) of a project, but also assures management that the project has been carefully considered and evaluated before presentation.

Several life-cycle cost procedures are available. Chapter 38 contains details on these and other factors that should be considered in such an analysis.

Capital for audits and efficiency improvements is often available from various public and private sources, and can be accessed through a wide and flexible range of financing instruments. There are variations and combinations, but the five common mechanisms for financing investments in energy efficiency are the following:

- **Internal funds**, or direct allocations from an organization's own internal capital or operating budget
- **Debt financing**, with capital borrowed directly by an organization from private lenders
- **Lease** or **lease-purchase agreements**, in which equipment is acquired through an operating or financing lease with little or no up-front costs, and payments are made over five to ten years
- **Energy performance contracts**, in which improvements are financed, installed, and maintained by a third party, which guarantees savings and payments based on those savings

- **Utility (or other) incentives**, such as rebates, grants, public/private partnerships, or other financial assistance offered by an energy utility or public benefits fund for design and purchase of energy/water-efficient systems and equipment

An organization may use several of these financing mechanisms in various combinations. The most appropriate set of options depends on the type of organization (public or private), size and complexity of a project, internal capital constraints, in-house expertise, and other factors (Turner 2001).

8. IMPLEMENTING ENERGY-EFFICIENCY MEASURES

When all desirable EEMs have been considered and a list of recommendations developed, a report should be prepared for management. Each recommendation should include the following:

- Present condition of the system or equipment to be modified
- Recommended action
- Who should accomplish the action
- Necessary documentation or follow-up required
- Measurement and verification protocol to be used
- Potential interferences to successful completion
- Disruption to workplace or production
- Staff effort and training required
- Risk of failure
- Interactions with other end uses and EEMs
- Economic analysis (including payback, investment cost, and estimated savings figures) using corporate economic evaluation criteria
- Schedule for implementation

The energy manager must be prepared to sell the plans to management. Energy-efficiency measures must be financially justified if they are to be adopted. Every organization has limited funds available that must be used in the most effective way. The energy manager competes with others in the organization for the same funds. A successful plan should be presented in a form that is easily understood by the decision makers. Finally, the energy manager must present nonfinancial benefits, such as improved indoor environmental quality, occupant comfort, product quality, or the possibility of postponing other expenditures.

After approval by management, the energy manager directs the completion of energy-efficiency measures. If utility rebates are used, the necessary approvals should be acquired before proceeding with the work. Some measures require that an architect or engineer prepare plans and specifications for the retrofit. The package of services required usually includes drawings, specifications, assistance in obtaining competitive bids, evaluation of the bids, selection of contractors, construction observation, final check-out, and assistance in training personnel in the proper application of the revisions.

9. MONITORING RESULTS

Once energy-efficiency measures are under way, procedures need to be established to record (regularly) energy consumption and costs for each building and/or end-use category in a manner consistent with functional cost accountability. Turner et al. (2001) found that consumption increased by more than 5% over two years because of component failures and controls changes after implementing optimum practices in a group of 10 buildings. Data may be obtained from the utility, but additional metering may be needed to monitor energy consumption accurately. Metering can use devices that automatically read and transmit data to a central location, or less expensive metering devices that require regular readings by building maintenance and/or security personnel. Costs for automatic metering devices, such as adding points to a DDC system, must be weighed against the benefits. Many energy managers find it helpful to collect energy consumption information hourly.

The energy manager should review data while they are current and take immediate action if profiles indicate a trend in the wrong direction. These trends could be caused by uncalibrated controls, changes in operating practices, or mechanical system failure, which should be isolated and corrected as soon as possible.

10. EVALUATING SUCCESS AND ESTABLISHING NEW GOALS

Comparing facility performance before and after implementing EEMs helps keep operating staff on track with their energy-efficiency efforts, ensuring that performance is maintained. Evaluating and reporting energy performance involves four steps:

1. Establishing key performance indicators
2. Tracking performance
3. Developing or updating goals
4. Reporting

Establishing Key Performance Indicators

It is important to determine performance factors of the energy management program. These are expressed in terms of key performance indicators (KPIs). The definition of key performance indicators determines what data need to be collected, how often to collect it, and how to present it to senior management. Suggested basic key performance indicators are

- Energy use index (EUI): total energy use per unit of gross floor area, or per unit of production
- Water use index (WUI): total water use per unit of gross floor area, per occupant, or per unit of production
- Cost utilization index (CUI): total energy or water cost per unit of total gross floor area, or per unit of production
- Electrical energy use per unit of total gross floor area, or per unit of production

Energy Policy Act of 2005. The Energy Policy Act (109th Congress 2005) set goals for federal buildings to decrease their energy consumption by 2% per year between 2006 and 2015, compared to a baseline of 2004 consumption. Thus, by 2010, for example, the target percentage reduction from 2004 values was 10%. For this initiative, the following sample KPI definitions could be used:

- 2004 benchmark measurement (energy use per unit area) reduced by 4% to set 2007 target, and by 10% to set the 2010 target, and by 16% to set the 2013 target
- Energy use data, summed monthly and annually for reporting against targets

Energy Independence Security Act of 2007. The Energy Independence Security Act (110th Congress 2007) set higher goals than the Energy Policy Act for federal buildings to decrease their energy consumption by 5% between 2007 and 2008 and 3% per year between 2008 and 2015, compared to a baseline of 2004 consumption. Thus, by 2015, for example, the target percentage reduction from 2004 values was 30%. For this initiative, the same sample KPI definitions used for the Energy Policy Act could be used.

Executive Order 13834, May 2018. Executive Order 13834 (NARA 2015) aligns U.S. federal agencies with federal legislation in force; prioritizes building energy and water consumption reductions in terms of cost savings, return on investment, and resiliency enhancement; uses performance contracting to achieve goals related to energy and water reduction, and ensures that all products and services are ENERGY STAR or Federal Energy Management Program (FEMP) designated. Water efficient products may also be designated by the WaterSense program.

ENERGY STAR Tools. The U.S. Environmental Protection Agency's (EPA) ENERGY STAR web site offers the free online benchmarking tool, Target Finder (I-P units only; accessible from portfoliomanager.energystar.gov/pm/targetFinder). This tool compares actual building performance to target values, and to other similar buildings. Figure 6 shows sample results for the Atlanta example building's general office space (omitting the computer center's floor space and electricity use). ENERGY STAR also offers an online Portfolio Manager (portfoliomanager.energystar.gov), which provides secure performance data management and benchmarking for multiple buildings. Annual benchmarking with these (or similar) tools helps track improvements, both over time and compared with other buildings.

Building Energy Labels

The ASHRAE Building Energy Quotient (Building EQ) labeling program rates new and existing buildings (Jarnagin 2009). Like the EPA's ENERGY STAR program, Building EQ focuses solely on energy, but provides additional features, including potential side-by-side comparison of operational and asset (as-designed) ratings; peak-demand reduction and demand management opportunities; on-site renewable energy; indoor environmental quality indicators; and a list of operational features, including commissioning activities, energy-efficiency improvements, and information on improving performance. The Building EQ scale allows differentiation among buildings at the highest levels of performance and encourages the design and operation of net-zero-energy buildings.

TARGET FINDER

May 21, 2004

Target Finder

Target Energy Performance Results (estimated)			
Energy	Design	Target	Top 10%
Score	67	75	90
Site Energy Use Intensity (kBtu/Sq. Ft/yr)	69.8	64.7	49.0
Estimated Total Annual Energy (kBtu)	2,143,077.2	1,986,976.8	1,505,328.2
Total Annual Energy Cost ($)	$ 40,826	$ 37,852	$ 28,677

Facility Information Edit

ASHRAE HQ
Atlanta, GA ....
United States

Facility Characteristics	Edit
Space Type	Gross Floor Area (Sq. Ft.)
Open Parking Lot*	78,242
Office (General)	30,690
Total Gross Floor Area	30,690

* not included in total

Design Energy			Edit
Energy Source	Units	Estimated Total Annual Energy Use	Energy Rate ($/Unit)
Electricity	kWh	628,100	$ 0.065/kWh

Design Energy default values - Source: DOE-EIA

Figure 6. ENERGY STAR Rating for Atlanta Building

The Building EQ program provides an easily understood scale to convey a building's energy use to the public. Through an on-site assessment, the building owner is provided with building-specific information that can be used to improve the building. Documentation on previous energy-efficiency upgrades and commissioned systems is also included. With procedures for both an asset and operational rating, building owners can make side-by-side comparisons that could further reconcile differences between designed and measured energy use. More information is available at www.ashrae.org/technical-resources/building-eq/building-eq-portal.

The label itself is the most visible aspect of the program (Figure 7). It is simple to understand and is targeted at the general public. It could be posted in a building lobby and could satisfy compliance with many of the programs being developed at the state and local level requiring display of energy use. The certificate contains technical information that explains the score on the label and provides information useful to the building owner, prospective owners and tenants, and operations and maintenance personnel. This includes many of the value-added features described previously. The documentation accompanying the label and certificate provides background information useful for engineers, architects, and technically savvy building owners or prospective owners in determining the current state of the building and opportunities for improving its energy use. More information is available at buildingeq.com/.

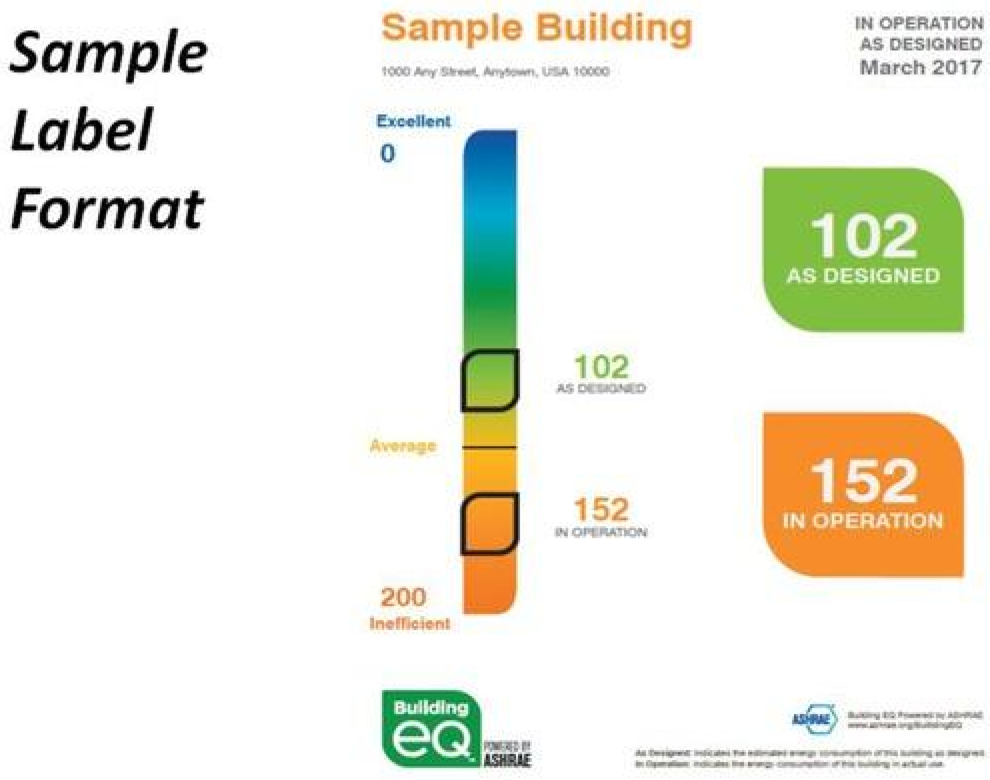


Figure 7. ASHRAE Building EQ Label

In Europe, within the EPBD-EED framework (e.g., EC 2010, 2012), an EPC is issued when buildings are constructed, sold, or rented out. The EPC documents the energy performance of the building and includes recommendations for cost-effective improvement of energy performance.

The EPBD-EED framework mandates energy performance requirements for member states, including minimum energy performance requirements for new buildings and major renovations of large existing buildings. Overall building stock performance, including economic feasibility, alternative energy supply systems, and near-net-zero buildings, is tracked to determine progress toward overall and member state goals. Energy performance remains an important goal that is tracked to end-use sectors, and buildings energy performance is important in the overall framework (EC 2019b).

Tracking Performance

The next step is to create a tracking mechanism to provide high-level KPI views, giving an overall indication of energy performance. Daily monitoring can be a valuable, proactive tool. Most building automation systems can monitor energy performance and notify the energy engineer when energy usage is off track.

For example, using the data presented in Table 1, a daily target usage/day could be determined based on outside air temperature and building occupancy schedule. If the daily use rises above the target use by a predetermined amount, the building automation system can indicate an alarm and send a notification. The energy manager can then investigate the cause of the discrepancy and correct any operational errors before long-term performance is affected. When implementing this type of performance-monitoring strategy, it is important that the measurement and verification plan provide standard operating procedures (SOPs) to facilitate troubleshooting of energy performance alarms. Procedures are discussed in ANSI/ASHRAE *Standard* 105.

Establishing New Goals

Implementing the baseline model is a three-step process: (1) the baseline period is selected, (2) the baseline model is created, and (3) one or more target models are identified to track energy performance. The baseline period should most closely reflect the current or expected building use and occupancy. Utility bill data can be used to create a steady-state baseline model of energy consumption for each building. Steady-state models are useful when using monthly, weekly, or daily data. Utility bills for an entire year are collected and used for baseline development. Many energy managers use spreadsheets or software packages to compile and compare the data. For more information on energy estimating using steady-state, data-driven models, see Chapter 19 of the 2021 *ASHRAE Handbook—Fundamentals*.

Cooling degree-days (CDDs) and heating degree-days (HDDs) are commonly used to track successes compared to EEM targets with respect to weather-dependent energy consumption. Local CDD and HDD information is traditionally based on a balance point of 18°C, which is not typically the actual balance point for any commercial or residential building; therefore, regional or local HDD values are only a general reference point. A building's weather-affected energy consumption may be calculated by using spreadsheets, regression analysis, or building energy modeling software.

For larger, more complex facilities, regression analysis can be used to analyze energy consumption if the energy manager has the analytical expertise. Through linear regression, utility bills are normalized to their daily average values. Repeated regression is done until the regression data represent the best fit to the utility bill data. Figure 8 shows the scatter plot of a best-fit baseline and target models. In this example, cooling degree-days significantly affected building energy consumption, with a best fit for a base temperature (balance point) of 12°C (Sonderegger 1998). Reducing the slope and intercept constants of the baseline by 20% creates a straight-line model equation that represents a target goal for a 20% energy reduction.

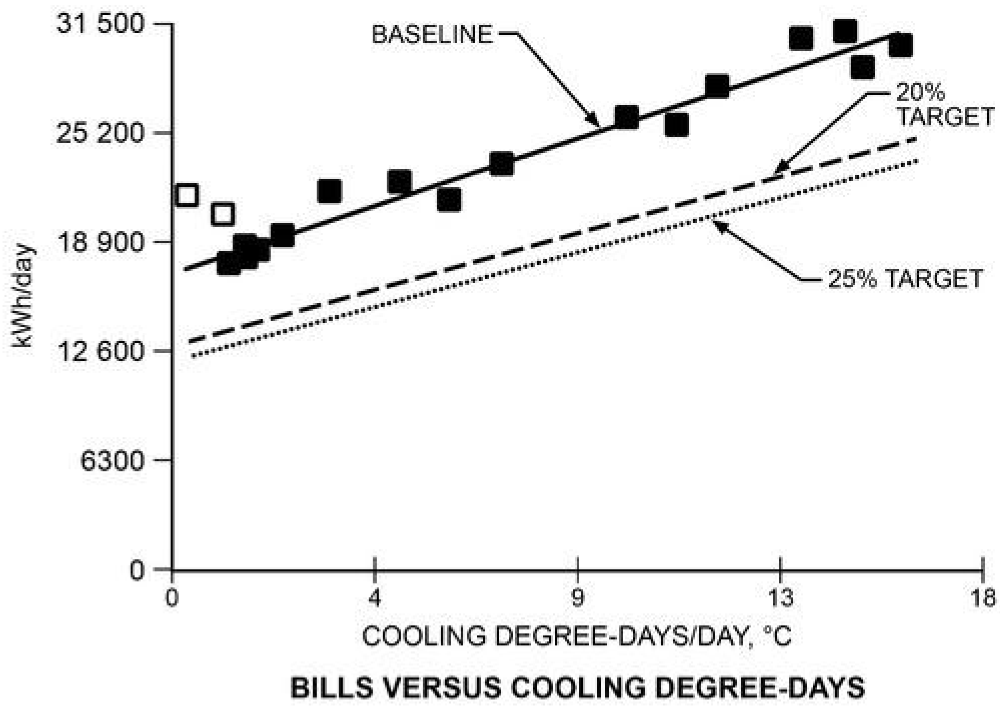


Figure 8. Scatter Plot, Showing Best-Fit Baseline Model and Target Models

The utility bill data steady-state model is also referred to as whole-building measurement and verification. This section offers only an introduction to the subject. More information about this process can be found in ASHRAE *Guideline* 14 and EVO (2002).

Reporting

When developing presentation materials to document energy performance, make sure that report content shows performance as related to key performance indicators (KPIs) used by the organization. Reports should also be pertinent to the audience. Whereas a report to the company’s administration would show how the energy management program affects operating and maintenance costs, a separate report to the operations staff might show how their daily decisions and actions change daily load profiles.

Figure 8 shows progress toward energy reduction goals for federal buildings presented to the U.S. Congress for fiscal year 2001 (DOE 2004). The figure compares energy performance against energy goals established in 1999.

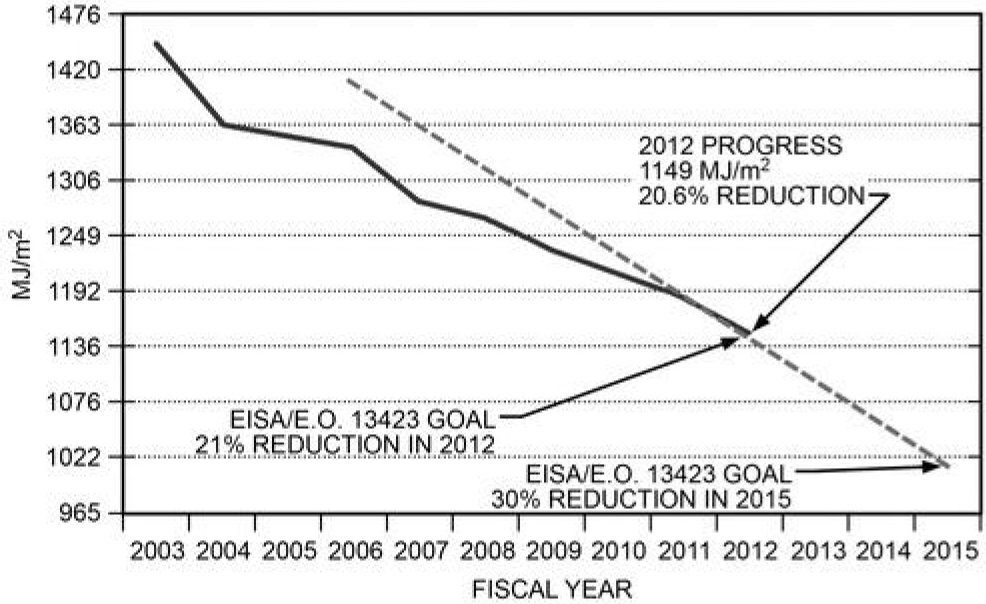


Figure 9. Progress Toward Energy Reduction Goals for Federal Standard Buildings

Reports must be easy to understand by their readers. Often, less is more. Keep management aware of the progress of changes to resource consumption, utility costs, and any effects (positive or negative) on the indoor environment as perceived by staff. Provide information on any major activities, savings to date, and future planned activities. Provide narrative reports with pie charts or bar graphs of cost per resource.

In addition to developing a visually appealing report for the end user, it is important to consider the development of a computer-generated report that can be transferred between various analysis programs. Development of this type of report allows for the building characteristics, energy/water performance, and the evaluation of the EEMs/WEMs to be stored in a machine-readable format that can be easily transferred to third parties for subsequent inspection, sharing, and analysis. The U.S. Department of Energy developed the BuildingSync® schema specifically for the audit use case to ease the transfer of data as well as provide a starting point for future analyses.

11. BUILDING EMERGENCY ENERGY USE REDUCTION

This section provides information to help building owners and operators maintain the best operating condition for the facilities during various energy emergencies. Occasional short-term reductions in energy use have increased mainly because of supply reductions, whether voluntary or mandatory, and supply constraints. In limited instances, utilities have implemented rolling blackouts, requested voluntary reductions, and asked users to operate emergency generators.

Implementing Emergency Energy and Water Use Reductions

Each building manager or operator should identify an individual with the necessary authority and knowledge to review and fit recommendations into a building energy management plan. Because energy and water reduction requirements may arise with little or no advance notice, contingency plans should be developed and reviewed by the energy team. Each type of energy or water emergency requires a specific plan to reduce building energy use and still maintain the best possible building environment. The plan should include measures to reduce specific types of energy and water use in the building, as well as provisions for both slight and major energy and water use reduction. In some cases, existing building energy management systems can be used to implement demand shedding. The plan should be tested regularly. The following steps should be taken in developing a building emergency energy and water use reduction plan:

1. Develop a list of measures applicable to each building.
2. Estimate the amount and type of energy savings for each measure and appropriate combination of measures (e.g., account for air-conditioning savings from reduced lighting and other internal loads, account for water savings from reduced water ornamental and nonessential irrigation systems). Tabulate demand and usage savings separately for response to different types of emergencies.
3. For various levels of possible energy emergencies, develop a plan that maintains the best building environment under the circumstances. Develop the plan so that actions taken can be energy- and water-source-specific. That is, group actions to be taken to reduce energy consumption for each type of energy used in the building. Include

both short- and long-term measures in the plan. Operational changes may be implemented quickly and prove adequate for short-term emergencies.

4. Experiment with the plan; record energy consumption and demand reduction data, and revise the plan as necessary. Much of the experimentation may be done on weekends to minimize disruption.
5. Meet with the local utility provider(s) and back-up fuel suppliers to review the plan.
6. Meet with building occupants annually to review the plan to ensure that actions taken do not cause major disruptions, particularly with equipment or systems identified as mission critical or essential to the building or company operation, or compromise environmental health, life safety, or security provisions. Establish a procedure for notification of building occupants before actions are taken.
7. Be certain that there is a plan to minimize entrapment of occupants in elevators in case of emergency disruptions.
8. Review the plan annually with building security and the fire department to ensure that emergency efforts are not hindered by the plan and that security or emergency people know what to expect (reduced lighting, lower temperatures, elevators out of operation, etc.).
9. Review the plan with the designated environmental health and safety official to ensure that emergency efforts do not compromise the health of personnel working or visiting the building.
10. When preparing the plan, **do not**
    - Take lighting fixtures out of service that are on night lighting circuits, provide lighting for security cameras, or provide egress lighting during a power failure
    - Remove elevators or lifts from service that will be required for emergency or ADA purposes
    - Reduce ventilation or exhaust in laboratories or other areas where hazardous conditions exist
    - Remove electrical service provided to fire detection, alarm, and annunciation systems
    - Alter or remove water flow to fire protection system

Some measures can be implemented permanently. Depending on the level of energy emergency and the building priority, the following actions may be considered in developing the plan for emergency energy reduction:

General

- Change operating hours
- Move personnel into other building areas (consolidation)
- Ensure that emergency generators are tuned up and run frequently enough to increase dependability, service the expected electrical load, and keep alternative fuel supply at an optimal level
- Shut off nonessential equipment
- Review the amount of uninterruptible power supply (UPS) time available for critical equipment, and upgrade if necessary

Thermal Envelope

- Use all existing blinds, draperies, and window coverings
- Install interior window insulation and ensure that windows do not have broken sealant creating envelope exposures
- Caulk and seal around unused exterior doors and windows (but do not seal doors required for emergency egress or that may be required by the fire department in an emergency)
- Install solar shading devices in summer
- Seal all unused vents and ducts to outside

HVAC Systems and Equipment

- Modify controls or control set points to raise and lower temperature and humidity as necessary

- Shut off or isolate all nonessential equipment and spaces
- Lower thermostat set points in winter
- Raise chilled-water temperature
- Lower hot-water temperature (*Note*: Keep hot-water hydronic temperature higher than 63°C if a noncondensing gas boiler is used)
- Reduce or eliminate reheat and recool
- Reduce (and eliminate during unoccupied hours) mechanical ventilation and exhaust airflow
- Raise thermostat set points in summer or turn cooling equipment off

Lighting Systems

- Evaluate overlit areas and remove lamps or reduce lamp wattage
- Use task lighting where appropriate
- Move building functions to exterior or daylit areas
- Turn off electric lights in areas with adequate natural light
- Revise building cleaning and security procedures to minimize lighting periods
- Consolidate parking and turn off unused parking security lighting

Water Use Systems

- Shut off ornamental water displays, such as fountains. Ensure that lack of usage does not result in the introduction of pathogens (e.g. bacterial growth) in the plumbing system
- Reduce or eliminate landscape irrigation
- Reuse water if possible
- Monitor water usage frequently and identify possible leaks

Special Equipment

- Take transformers offline during periods of nonuse
- Shut off or regulate the use of vertical transportation systems
- Shut off unused or unnecessary equipment, such as photocopiers, music systems, and computers
- Reduce or turn off potable hot-water supply

Building Operation Demand Reduction

- Sequence or interlock heating or air-conditioning systems
- Disconnect or turn off all nonessential loads
- Reduce lighting levels
- Preheat or precool, if possible, before utility-imposed emergency periods

When Power Is Restored

- To prevent overloading the system, turn equipment back on gradually
- Test and verify proper operation of critical equipment, security, and fire and smoke alarms

- Check monitors on temperature-sensitive equipment
- Discuss lessons learned with staff and make any necessary changes to emergency plan
- Restock whatever emergency supplies were used, including alternative fuels

When Water and Wastewater Is Restored

- Flush, and provide treatment if necessary to, the plumbing system per ASHRAE *Standard* 188-2018 and ASHRAE *Guideline* 12-2020
- Test and verify proper operation of critical equipment
- Check monitors on temperature-sensitive equipment
- Discuss lessons learned with staff and make any necessary changes to the emergency plan
- Restock whatever emergency supplies were used

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ONLINE RESOURCES

Building EQ: www.ashrae.org/BuildingEQ

ENERGY STAR financial evaluation tools: www.energystar.gov/buildings/tools-and-resources/financial-resources

- Building upgrade value calculator
- Cash flow opportunity calculator
- Financial value calculator

Building energy software tools directory: www.ibpsa.us/building-energy-software-tools-best-directory

This directory provides information on hundreds of building software tools for evaluating energy efficiency, renewable energy, and sustainability in buildings. The energy tools listed in this directory include databases, spreadsheets, component and systems analyses, and whole-building energy performance simulation programs. A short description is provided for each tool along with other information, including expertise required, users, audience, input, output, computer platforms, programming language, strengths, weaknesses, technical contact, and availability.

U.S. Energy Information Administration's commercial buildings energy consumption survey (commercial energy uses and costs): www.eia.doe.gov/consumption/commercial

Emissions associated with energy generation (eGRID): www.epa.gov/cleanenergy/energy-resources/egrid/index.html

Climate zone information: energycode.pnl.gov/EnergyCodeReqs/

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