Related Commercial Resources

CHAPTER 35

ENERGY USE AND MANAGEMENT

ENERGY management in buildings is the control of energy use and cost while maintaining indoor environmental conditions to meet comfort and functional needs. Energy efficiency improvements need not sacrifice any functionality of the facility. This chapter provides guidance on establishing and implementing an effective, ongoing energy management program, as well as information on planning and implementing energy management projects.

Good energy management has the goal of reducing energy expenses to the lowest level possible without sacrificing comfort, productivity, or functionality. The energy manager should understand how energy is used in the building, to manage energy use and costs effectively. There are opportunities for savings by reducing the unit price of purchased energy, and by improving the efficiency and reducing the use of energy-consuming systems.

Water/sewer costs and use may be included in the energy management activity. This could be called "utility management," but "energy management" is used in this chapter.

ENERGY MANAGEMENT

The specific processes by which building owners and operators control energy consumption and costs are as variable as their building types. Many buildings, such as residences and small retail businesses, usually involve the efforts of one person. Energy management procedures should be as simple, specific, and direct as possible. General advice, such as from utility energy surveys or state or provincial energy offices, can provide ideas, but these must be evaluated to determine whether they are applicable to a specific building. Often, owners and operators of smaller buildings only need advice about specific energy management projects (e.g., boiler replacement, lighting retrofit).

On the other hand, very large and complex facilities, such as hospital or university campuses, industrial complexes, or large office buildings, usually require a team effort and process as represented in Figure 1.

Regardless of the number of people involved or the size and complexity of the facilities, energy management for existing buildings has the same basic steps:

1. An energy manager is usually appointed to oversee the process. Doing so ensures that someone is dedicated to the initiatives and accountable to the company.
2. Early communication helps with input and feedback to the other steps of the process.
3. Establish an energy accounting system that records energy and water consumption and costs, thus providing data for analyzing energy use and identifying energy conservation opportunities. It also should include comparisons with energy use and costs of other similar buildings, for use in benchmarking and setting energy performance goals.

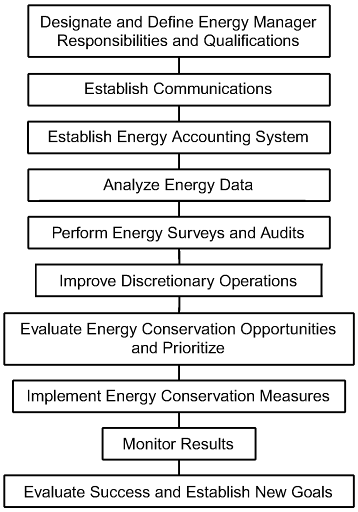


Fig. 1 The Energy Management Process

4. Validate and analyze energy use data.
5. Carry out energy surveys and walk-through audits to provide the information needed to identify low-cost/no-cost operations, maintenance, and energy conservation opportunities relevant to the specific building or buildings. Often, a qualified energy professional is hired to do this.
6. Using the survey results, change how the building is operated, using good judgment to change procedures with energy management in mind.
7. Evaluate energy conservation opportunities for expected savings, estimated implementation costs (including any design work required), risks, and nonenergy benefits (e.g., improved system operation, better indoor comfort). Establish baseline energy use for whole building or individual energy conservation opportunities. Recommend a number of prioritized energy conservation projects for implementation.
8. Implement approved energy conservation measures (ECMs). This includes tendering any projects that must be outsourced.
9. Track trends and monitor results, using the energy accounting system for overall performance supplemented as needed by energy monitoring related to specific projects, and report to senior management.
10. Compare energy performance to past goals, revise as necessary, and develop new goals. Report results to management and tenants. Return to step 7 and continue the process; it requires ongoing diligence to maintain and continually improve energy savings and reduce utility costs.

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

The preparation of this chapter is assigned to TC 7.6, Systems Energy Utilization.

Because energy management is performed in existing facilities, this chapter focuses mainly on these facilities. ASHRAE *Standard* 100 gives details useful in energy management planning. Information on energy conservation in new design can be found in all volumes of the *ASHRAE Handbook* and in ASHRAE *Standards* 90.1 and 90.2. The area most likely to be overlooked in new design is the ability to measure and monitor energy consumption and trends for each energy use category given in Chapter 40. Additional guidelines for this area can be found in Chapter 17 of the 2005 *ASHRAE Handbook—Fundamentals*.

Organizing for Energy Management

To be effective, energy management must be given the same emphasis as management of any other cost/profit center. In this regard, the functions of top management are as follows:

- Establish the energy cost/profit center
- Assign management responsibility for the program
- Hire or assign an energy manager and provide training as necessary
- Allocate resources
- Ensure that the energy management program is clearly communicated to all departments to provide necessary support for achieving effective results
- Set clear program goals
- Encourage ownership of the program to all levels of the organization
- Set up an ongoing reporting and analysis procedure to monitor the energy management program
- Develop a feedback mechanism to allow revisions to the energy management program in a timely manner

Effective energy management requires that the energy manager (supported by a suitable budget) act and be held accountable for those actions. It is common for a facility to allocate 3 to 10% of the annual energy cost for administration of an energy management program. The budget should include funds for additional personnel as needed, and 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 clearly documented. 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. Assistance may be needed with some of the tasks listed.

Technical functions

- Conducting energy audits and identifying energy conservation opportunities
- Establishing a baseline from which energy-saving improvements can be measured
- Acting as in-house technical consultant on new energy technologies, alternative fuel sources, and energy-efficient practices
- Evaluating energy efficiency of proposed new construction, building expansion, remodeling, and new equipment purchases
- Setting performance standards for efficient operation and maintenance of machinery and facilities
- Reviewing state-of-the-art energy management hardware
- Reviewing building operation and maintenance procedures
- Implementing energy conservation measures (ECMs)
- Establishing an energy accounting system for continuing analysis of energy use and results of ECMs
- Maintaining effectiveness of ECMs
- Measuring energy use in the field whenever possible to verify design and operating conditions

Policy-related functions

- Fulfilling energy policy established by top management
- Monitoring federal and state (provincial) legislation and regulatory activities, and recommending policy/response on such issues
- Representing the organization in energy associations
- Administering government-mandated reporting programs

Planning and purchasing functions

- Monitoring energy supplies and costs to take advantage of fuel-switching and load management opportunities
- Ensuring that systems and equipment are purchased based on economics, energy requirements, and ability to perform required functions, not simply on lowest initial cost
- Maintaining a current understanding of energy conservation, grant programs, and demand-side management (DSM) programs offered by utilities and agencies
- Negotiating or advising on major utility contracts
- Developing contingency plans for supply interruptions or shortages
- Forecasting short- and long-term energy requirements and costs
- Providing input into utility budgets
- Developing short- and long-term conservation plans and budgets
- Reporting regularly to top management and other pertinent departments (building operations)

Public relations functions

- Making fellow employees aware of the benefits of efficient energy use
- Establishing a mechanism to elicit and evaluate energy conservation suggestions from employees
- Recognizing successful energy conservation projects through awards to plans and employees
- Setting up a formal mechanism for reporting to top management
- Establishing an energy communications network within the organization, including newsletters, bulletins, manuals and conferences
- Making the community aware of the energy conservation achievements of the organization with press releases and appearances at civic group meetings

General Qualifications

- A technical background, preferably in engineering, with experience in energy-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, from staff to operations and maintenance personnel to top management
- Technical report-writing and verbal communication skills

Desirable Educational and Professional Qualifications

- Bachelor of science degree, preferably in mechanical, electrical, industrial, or chemical engineering
- Thorough knowledge of the principles and practices of energy resource planning and conservation
- Familiarity with administrative governing organization
- Ability to
  - Analyze and compile technical and statistical information and reports with particular regard to energy usage
  - Establish effective working relationships with other employees and to motivate people
  - Interpret plans and specifications for building facilities
- Knowledge of
  - Resources and information relating to utility rates, energy conservation, and planning
  - Basic types of automatic controls and systems instrumentation
  - Energy-related metering equipment and practices
  - Organization’s manufacturing processes

  - Building systems design and operation and/or maintenance
- Interest in and enthusiasm for efficient energy use and ability to present ideas to all levels in the organization

If it is not possible to add a full-time, first-line manager to the staff, an existing employee, preferably with a technical background, should be considered for a full- or part-time position and trained to organize an energy management program. Energy 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 to design, implement, and maintain energy efficiency improvements and provide energy accounting. Some energy services companies (ESCOs) and other firms provide energy management services as part of a contract, with payments based on realized savings. Other companies provide energy management services, based on a nominal fee, to assist the energy manager prepare information to be presented to upper management to meet corporate goals.

COMMUNICATIONS

Entering into an energy management process requires careful planning and help from all that operate and use the facility. A communication plan should be reviewed by both the energy manager and senior management. This plan should be reviewed regularly to ensure that the right messages are relayed to the right parties.

The initial communiqué should introduce the effort that will be put forth by the energy manager and building operations staff. It should at the same time express the support of company's executive to ensure the process to be undertaken is not a passing thought. High-level goals should be expressed without initially quantifying them.

Providing early information to tenants and staff is important, because it takes time to change behaviors of people used to operating their lights and equipment in a certain fashion for many years. 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 includes some or all of the tasks listed here; the scope depends on the size of the company and its facilities.

- Produce, distribute, and post regular newsletters
- Post energy-saving tips or reminders in conspicuous locations
- Hold seminars with maintenance and cleaning staff to review energy-efficient practices to be followed in daily activities
- Meet with operations staff for training and feedback
- Report regularly to management: monthly updates with annual summaries
- Make frequent reports to operations staff so energy consumption or billing anomalies can be addressed in a timely manner

Message content should be tailored to the specific audience. A tradesperson in the building operations department would routinely be concerned with matters such as temperature setbacks, time clock settings, or light fixture lamp types. Meanwhile, office workers would be more receptive to being informed how much money the company saved on utilities last month, or how much it costs to operate their computer monitors for 50 hours a week.

The more successful communication is, the quicker the energy management activities will become second nature to everyone involved. Diligent, regular reporting promotes accountability and persistence in reducing energy consumption.

ENERGY ACCOUNTING SYSTEMS

Establishing and maintaining an energy accounting system to track energy consumption and costs on a continuing basis is very valuable. It provides energy use data to building occupants, helping them see the results of their conservation efforts and support their continued efforts. It also provides some data needed to confirm savings from specific energy conservation projects. The starting point is gathering energy and related data and evaluating the relative intensity of energy use. The primary data source is utility bills, but other sources include

- Detailed printouts from time-of-use meters
- Combustion efficiency, eddy current, and water quality tests
- Recordings of temperature and relative humidity
- Submetered energy use data
- Data from building pressurization and depressurization
- Event recordings
- Occupancy schedules and group types
- Climatic data
- Data from similar buildings in similar climates
- Infrared scans
- Production records
- Computer modeling

Energy Accounting Process

The energy manager establishes procedures for meter reading, monitoring, and tabulating facility energy use and profiles. These tabulations indicate the cost of energy management efforts and the resulting energy cost avoidance. Also, the energy manager periodically reviews utility rates, rate structures, and trends as they affect the facility. Many utilities have free mailing lists for changes in their rate tariffs, which should be subscribed to by the energy manager. The energy manager provides periodic reports of energy management efforts to top management, summarizing the work accomplished, its cost-effectiveness, plans and suggested budget for future work, and projections of future utility costs. Utility bill analysis software can be used to track avoided costs. If energy conservation measures are to be cost-effective, continued monitoring and periodic re-auditing are necessary, because many energy conservation measures lose effectiveness if they are not carefully monitored and maintained. The procedures in ASHRAE *Guideline* 14 for determining energy savings can be used as energy accounting procedures to track changes in consumption and cost.

Energy Accounting

Energy accounting means tracking utility bills and consumption on a monthly basis to provide a current picture of building energy performance and to be able to identify trends and instances of excess use. An Internet search for "energy accounting" will produce Web sites for the major commercial providers of this software or service. In some cases the software is sold for installation on the user's computer; in other cases the program is Web-based and the user has a subscription enabling them to log on and enter data. For many users however, a simple spreadsheet is all that is needed.

Utility Rates

Because most energy management activities are dictated by economics, the energy manager must understand the utility rates that apply to each facility. Electric rates are usually more complex than gas or water rates and some rate structures can make cost calculations difficult. In addition to general commercial or institutional electric rates, special rates may exist such as time of day, interruptible service, on peak/off peak, summer/winter, and peak demand. Electric rate schedules vary widely in North America; Chapters 36 and 55 discuss these in detail. The energy manager should work with local utility companies to identify the most favorable utility rates and to understand how to qualify for them. The local utility representative can help the energy manager develop the most cost-effective methods of metering and billing. The energy manager must understand the utility rates, including the distinction between marginal and average costs and, in the case of demand-based electric rates, how demand is computed. See the Improving Discretionary Operations section in this chapter.

ANALYZING ENERGY DATA

Preparing for Cost and Efficiency Improvements

The first step in preparing for cost and efficiency improvements is understanding how energy is used. Opportunities for savings come in reducing (1) the cost per unit of energy, and then (2) energy consumption. Interest in energy efficiency rises when energy costs rise. It is very important to understand how a building's energy use relates to other similar facilities. If the energy budget is much higher than those for comparable facilities, there are likely to be many ways to reduce energy use cost-effectively. If the energy budget is much lower, there are likely to be fewer cost-effective opportunities.

Historically, energy users had little choice in selecting energy suppliers, and regulated tariffs applied based on certain customer use characteristics. In recent years, though, there has been a move in North America and other parts of the world toward deregulation of energy markets, and electricity and gas markets have much more flexibility in supply and pricing than in the past. Electric rate structures vary widely in North America; Chapter 36 discusses these in detail.

Electric utilities commonly meter both consumption and demand. **Demand** is the peak rate of consumption, typically integrated over a 15 or 30 min period. Electric utilities may also establish a ratchet billing procedure for demand. To fully understand the cost effect of the demand component of the utility bill, contact the local electric utility.

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 (for the next day) to customers. The customer can then determine the amount of power to be consumed at different times of the day. More recently, 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** programs, the utilities ask participating customers to reduce their demand for a period of time on as little as a few hours' notice.

There are many variations of billing methods, and it is important to understand the applicable rates. Caution is advised in designing or installing energy management and energy retrofit systems that take advantage of utility rate provisions, because these provisions can change. The structure or provisions of utility rates cannot be guaranteed for the life of the energy conservation opportunities. Some provisions that change include on-peak times, declining block rates, and demand ratchets. Chapter 55 has additional information on billing rates.

Analyzing Energy Use Data

Any reliable, applicable utility data should be examined. Utilities often provide metered use and demand data, often with measurement intervals as short as 15 min. Data from shorter time intervals are preferable to monthly data because anomalies are 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 for future energy and energy cost reduction activities. In tabulating the data, the dates of meter readings should be recorded so that energy use can be normalized for differences in the number of days in a billing period. Any periods during which consumption was estimated rather than measured should be noted.

If energy data are available for more than one building and/or department under the energy manager's authority, 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 any information on variables that may have affected past energy use, such as heating or cooling degree-days, percent occupancy for a hotel, quantity of goods produced, building occupancy, hours of operation, or average daily weather conditions (see Chapter 28, Climatic Design Information, in the 2005 *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, rather than developing units such as Btu per square foot per degree-day. As the data are tabulated, ongoing energy accounting procedures should be developed for consistent data collection and use in the future. 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 breaking down a facility's energy consumption into base and weather-dependent energy consumption. **Base energy consumption** is the amount of energy consumed independent of weather, such as for lighting, motors, domestic hot water, and miscellaneous office equipment. **Weather-dependent energy consumption** includes energy consumed by equipment such as chillers and boilers.

Identifying the base and weather-dependent energy consumption identifies areas where the greatest savings potential exists. For example, if energy used for cooling is only 10% of total electrical consumption, then savings generated from a chilled-water reset strategy are likely to be small.

Base load energy use is the amount of energy consumed independent of weather. When a building has electric cooling and no electric heating, the base load energy use is normally the energy consumed during the winter. The opposite is true for heating. The annual estimated base load energy consumption can be obtained by establishing the average monthly consumption during nonheating or noncooling months and multiplying by 12. For many buildings, subtracting the base load energy consumption from the total annual energy consumption yields an accurate estimate of heating or cooling energy consumption. This approach is not valid when building use differs from summer to winter; when cooling operates year-round; or when space heating is used during summer, as for reheat. In many cases, base load energy use analysis can be improved by using hourly load data, which may be available from the utility company. **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 used in commercial buildings directly to the severity of the 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 (discussed in Chapter 32 of the 2005 *ASHRAE Handbook—Fundamentals*). Pitfalls of such an analysis are (1) estimated rather than actual utility use data are used; (2) the actual dates of the metered information must be used, together with average billing period weather data; and (3) building use and/or operation are not regular.

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. (Submetering is assumed to not be installed in the building.) Individual metering of various energy end uses provides the energy manager with information to apply energy management principles optimally. For more information, see Chapter 40.

An example spreadsheet using three years of electricity bill data for a two-story office building in Atlanta, Georgia, is presented in Table 1. (See Chapter 30 of the 2005 *ASHRAE Handbook—Fundamentals* for floor plans and elevations of the building.)

Table 1 Electricity Consumption for Atlanta Example Building

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
		Occupancy Factor		38.1%				Building Area: 30,700 ft²				
		Summer ELF 2002		87.3%	Summer ELF 2003		37.4%	Summer ELF 2004		54.7%		
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/ft²	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 to help identify where the greatest potential exists to save electricity. 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 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.

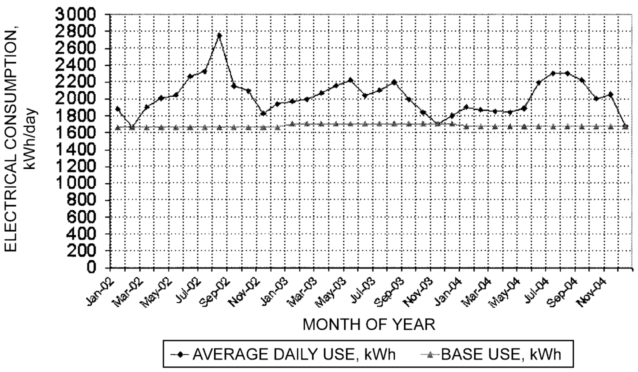


Fig. 2 Electrical Use Profile for Atlanta Example Building

Weather-dependent energy consumption (either electric or other fuels) may then be compared to the **cooling degree-days (CDD)** or **heating degree-days (HDD)** totals for the same time period. This comparison shows how the building performs from month to month or year to year. The HDDs stop and CDDs start at an outdoor temperature called the balance point, which is defined as that value of the outdoor temperature at which, for the specified value of the interior temperature, the total heat loss is equal to the heat gain from the sun, occupants, lights, etc. Use caution when determining daily base use in all-electric buildings, because some have periods of overlap with their heating and cooling systems. In these cases, using this example, the base load is somewhat overestimated, causing the heating and cooling energy consumption estimates to be conservative.

Examine the Average Daily Use line to see if 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. Any errors in meter readings, reading dates, or consumption variances should show up as unusual peaks or valleys. Reexamine the associated data and correct errors as necessary.

If an unusual profile remains after correcting any errors (or after discovering that no errors were made in the data entry), an area of potential energy savings may be identified. 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 illustrated in Figure 2, and often occurs with dual-duct systems.

This simultaneous heating and cooling is also indicated by the values in the Percent Excess Use column of Table 1, which shows the percent difference between the monthly base consumption 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 consumption is calculated by multiplying the lowest value from the Daily Use column 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 electrical rate of consumption occurring past the normal occupancy of the building (e.g., lights or fans are left on after occupied hours, or, for an electrically cooled building, that air conditioning is not shut off as early in the day as possible during summer. Direct digital control (DDC) control strategies, time-of-day scheduling, and lighting controls are several ECMs addressing these concerns.

The ELF is the ratio between the average daily use and the maximum possible use if peak demand operated for a 24 h period. The occupancy factor is the ratio between the hours a building actually is occupied and the maximum possible occupied hours (i.e., if the building were occupied 24 h a day).

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:

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

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

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

Calculating Seasonal ELFs

When applicable, 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 geographic location.

The steps for calculating a seasonal ELF are as follows:

1. The daily base consumption is determined by values appearing in the Daily Use column of the EUP report. Subtract the lowest value (regardless of season) from the highest (peak) value of the appropriate season in this column.
2. The base demand is determined by values appearing on the spreadsheet. Subtract the lowest monthly demand for the year from the demand recorded for the month with the highest average daily use. These calculations can be refined further if on- and off-peak data are entered into the spreadsheet.

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

$$\text{Summer ELF} = \frac{1089}{55 \times 24} = 82\%\text{ (for 2002)}$$

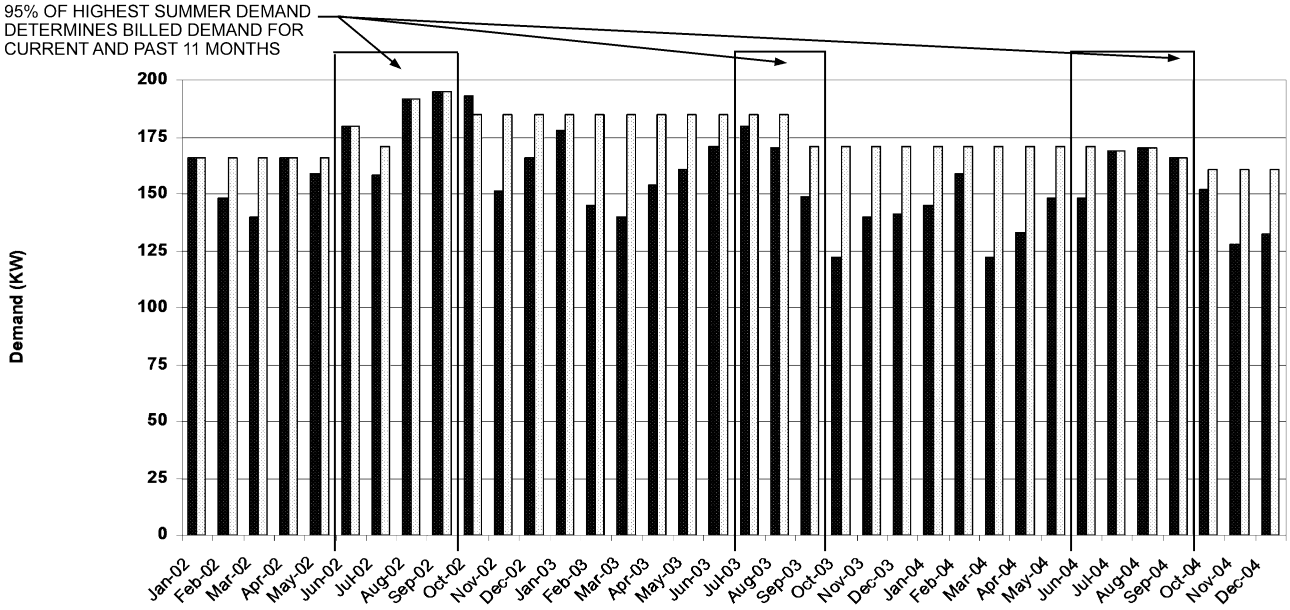
These calculations show that the cooling equipment is operating beyond building occupancy (82% versus 33%) Therefore, savings from energy conservation measures (ECMs) for lights, fans, and cooling equipment run times should be investigated. Note that comparing the ELF to the occupancy factor is meaningless for buildings occupied 24 h a day, such as a hospital.

Similar tables and charts may be created for natural gas, water, and other utilities through an energy management program.

Electric Demand Billing

For the Atlanta example building, the demand rate is of the ratchet type (see Chapter 55) and billed demand is determined as a percentage of actual demand in the summer months. How the ratchet operates is illustrated in Figure 3. In this example, billed demand is the greater of the measured demand or 95% of the highest measured demand within the past 12 months. For example, the billed demand for January 2004 was 171 kW (171 = 0.95 × 180), or 95% of the actual demand from July 2003. Currently, most commercial buildings are not subject to this type of demand billing structure, but in some regions it is a common practice for electric utilities.

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



	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
■ Actual KW	166	148	140	166	159	180	158	192	195	193	151	166	178	145	140	154	161	171	180	170	149	122	140	141	145	159	122	133	148	148	169	170	166	152	128	132
☐ Billed kW	166	166	166	166	166	180	171	192	195	185	185	185	185	185	185	185	185	185	185	185	171	171	171	171	171	171	171	171	171	171	169	170	166	161	161	161

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

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. This means that the energy manager should also investigate whether the facility can purchase electricity using a different rate structure, such as a time-of-use (TOU) or seasonal rate. Most smaller facilities are not billed based on their peak demand requirements.

Benchmarking Energy Use

To determine whether a building or industrial process is a good candidate for energy efficiency improvements, **benchmarking** (comparing a building's normalized energy consumption to that of other buildings) can be a useful first measure of energy efficiency. The most used normalization factor is the gross floor area of a building (energy use per unit area). Benchmarking is less accurate than an audit or engineering analysis, but can provide a good overall picture of relative energy use for a given facility, and is an important first step to understanding energy use and savings potential. 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 30,700 ft^2 in size, so its 2004 EUI is 76,200 Btu/ft^2 and its CUI is \$1.47/ft^2. Natural gas use, or use of any other fuels, are generally added to total energy use and costs to calculate EUI and CUI. Because the building is all-electric, though, no other fuels need be considered for it.

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

Comparing a building's energy use with that of comparable buildings in the same region is a good way to check its relative efficiency. Two sources of benchmarking data for U.S. buildings are ENERGY STAR® (www.energystar.gov) and the U.S. Department of Energy's Energy Information Administration (DOE/EIA). Data on U.S. buildings in all sectors are summarized in periodic reports by the DOE/EIA. Tables 2 to 4 present DOE/ EIA CBECS data in a combined format. Table 2 lists EUI input data and EUI distributions for the buildings surveyed in 2003. Table 3 lists the 2003 *Commercial Buildings Energy Consumption Survey* (CBECS) electricity per unit of floor area, and Table 4 shows CUI distributions. Tables 5 and 6 present data from the 1997 *Residential Energy Consumption Survey* (RECS). Table 5 provides population breakouts by fuel type and end uses, and Table 6 gives breakouts by specific characteristics of homes. More complete and up-to-date information on the CBECS is available at www.eia.doe.gov/ emeu/cbecs, and on the RECS at www.eia.doe.gov/emeu/recs. When referring to these tables, keep in mind the operating or occupied hours of the specific facility and the current utility rates.

When an energy management program for a new building is established, the energy use database may consist solely of typical data for similar buildings, as in Table 2. This may be supplemented by energy simulation data for the specific building, if such data were developed during design. In addition, a new building and its systems should be properly commissioned on completion of construction to ensure proper operation of all systems, including any energy conservation features (see ASHRAE *Guideline* 1 and Chapter 42).

All the data presented in these tables are derived from detailed reports of consumption patterns in buildings. Before using them, however, it is important to understand how they were derived. For example, all household energy consumption data in Table 6 are averages, and may not reflect variations in appliances or fuel selections

Table 2 2003 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, kBtu/yr per gross square foot					
	Number of Buildings, Hundreds	Floor Area, 10^9 ft^2		Percentiles					Mean
				10th	25th	50th	75th	90th	
Administrative/professional office	442	6.63	555	28.1	41	62	93	138	75
Bank/other financial	104	1.10	75	55.7	67	87	117	184	106
Clinic/other outpatient health	66	0.75	100	28.7	41	66	97	175	84
College/university	34	1.42	88	14.1	67	108	178	215	122
Convenience store	57	0.16	28	68.6	156	232	352	415	274
Convenience store with gas station	72	0.28	32	82.2	135	211	278	409	225
Distribution/shipping center	155	5.25	231	8.7	17	33	54	91	45
Dormitory/fraternity/sorority	16	0.51	37	36.3	65	74	100	154	90
Elementary/middle school	177	4.75	331	21.1	35	54	93	127	76
Entertainment/culture	27	0.50	50	1.7	29	46	134	418	95
Fast food	78	0.26	95	176.3	268	418	816	933	534
Fire station/police station	53	0.38	47	6.9	24	82	112	137	78
Government office	84	1.55	150	31.5	52	77	103	149	85
Grocery store/food market	86	0.71	117	98.1	138	185	239	437	213
High school	68	2.52	126	19.8	44	65	99	130	75
Hospital/inpatient health	8	1.90	217	108.1	169	196	279	355	227
Hotel	20	1.90	86	39.7	51	73	116	183	95
Laboratory	9	0.65	43	98.0	165	270	505	925	362
Library	20	0.56	36	35.0	67	92	121	197	104
Medical office (diagnostic)	54	0.50	58	14.1	25	44	100	137	60
Medical office (nondiagnostic)	37	0.22	33	25.7	40	52	66	109	59
Mixed-use office	84	2.30	172	20.0	38	71	106	158	88
Motel or inn	70	1.05	109	23.9	37	67	102	197	87
Nonrefrigerated warehouse	229	3.05	172	2.3	6	19	46	87	34
Nursing home/assisted living	22	0.98	73	41.6	77	116	184	205	124
Other	70	1.08	68	5.5	29	69	96	118	74
Other classroom education	51	0.71	60	4.3	23	40	64	108	51
Other food sales	10	0.10	10	31.5	37	58	190	343	126
Other food service	58	0.33	56	39.6	71	125	309	548	242
Other lodging	16	0.65	28	31.2	54	71	83	146	76
Other office	73	0.41	52	15.3	41	57	84	146	69
Other public assembly	32	0.42	31	9.9	30	42	73	155	65
Other public order and safety	17	0.71	38	44.0	58	93	160	308	127
Other retail	47	0.24	42	32.7	65	92	146	205	120
Other service	139	0.48	171	28.0	50	86	164	303	168
Post office/postal center	19	0.50	23	7.2	58	64	76	97	64
Preschool/daycare	56	0.48	46	18.8	35	59	112	121	75
Recreation	96	1.28	99	13.4	24	40	88	152	68
Refrigerated warehouse	15	0.53	20	6.5	13	143	190	257	127
Religious worship	370	3.75	313	9.3	17	33	63	88	46
Repair shop	76	0.65	51	7.0	13	30	54	72	37
Restaurant/cafeteria	161	1.06	212	51.8	117	207	462	635	302
Retail store	347	3.48	460	14.2	25	45	93	170	72
Self-storage	198	1.26	84	2.1	4	7	10	15	9
Social/meeting	101	1.18	78	7.9	15	41	71	93	52
Vacant	182	2.57	178	1.4	3	12	31	77	26
Vehicle dealership/showroom	50	0.60	40	24.5	40	82	110	248	110
Vehicle service/repair shop	212	1.21	131	10.1	16	37	86	137	58
Vehicle storage/maintenance	176	1.21	99	0.9	4	21	53	152	54
SUM or Mean for sector	4645	64.78	5451	9.8	26	56	108	207	97

Source: Calculated based on DOE/EIA preliminary 2003 CBECS microdata.

for different buildings. Therefore, 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 gathered and published by building owners' 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).

The quality of published energy consumption data for buildings varies because the data are collected for different purposes by people with different levels of technical knowledge of buildings. The data presented here are primarily national. 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

Table 3 Electricity Index Percentiles from 2003 Commercial Survey

	Weighted Electricity Use Index Values, kWh/yr per gross square foot					
	Percentiles					
Building Use	**10th**	**25th**	**50th**	**75th**	**90th**	**Mean**
Administrative/professional office	3.54	6.7	11.0	15.0	24.1	12.7
Bank/other financial	6.23	14.5	22.2	29.5	33.3	22.5
Clinic/other outpatient health	4.94	9.4	15.2	20.7	27.3	16.6
College/university	4.13	10.5	15.0	24.0	42.3	17.7
Convenience store	20.09	43.3	65.3	78.7	107.4	69.6
Convenience store with gas station	24.09	37.7	48.1	79.0	120.0	62.0
Distribution/shipping center	1.77	2.9	4.5	7.4	9.9	5.7
Dormitory/fraternity/sorority	2.16	3.3	5.1	6.6	16.6	6.7
Elementary/middle school	3.45	5.7	9.3	14.0	19.7	12.1
Entertainment/culture	0.49	1.0	7.4	16.9	122.5	20.9
Fast food	27.97	48.0	81.8	131.2	168.1	95.5
Fire station/police station	1.14	3.8	6.6	12.6	22.0	9.8
Government office	3.96	8.1	10.8	19.3	26.0	14.3
Grocery store/food market	26.12	32.2	42.4	54.4	100.6	51.7
High school	3.50	4.5	7.5	12.8	19.3	9.7
Hospital/inpatient health	15.24	21.8	24.0	35.6	45.9	28.7
Hotel	6.73	11.6	14.3	18.3	27.4	16.4
Laboratory	11.43	25.5	39.2	54.6	95.6	44.1
Library	6.34	8.7	15.5	23.2	34.3	17.3
Medical office (diagnostic)	2.21	4.1	7.6	13.8	18.3	9.6
Medical office (nondiagnostic)	2.41	4.5	7.4	12.1	15.3	8.6
Mixed-use office	3.40	5.5	11.1	18.0	28.9	14.3
Motel or inn	4.95	7.5	10.8	18.1	26.3	13.6
Nonrefrigerated warehouse	0.38	1.0	2.9	5.9	10.7	5.4
Nursing home/assisted living	6.33	8.1	14.9	21.0	25.9	15.9
Other	1.60	3.0	5.8	12.2	24.7	9.5
Other classroom education	1.27	2.8	4.9	9.2	15.7	6.6
Other food sales	9.22	9.2	10.8	12.6	58.5	22.0
Other food service	8.85	15.4	27.2	60.1	89.5	40.3
Other lodging	2.86	3.7	14.0	21.0	22.7	12.0
Other office	3.04	4.5	9.4	16.2	18.3	10.8
Other public assembly	1.13	2.6	3.4	12.3	13.8	7.5
Other public order and safety	5.45	14.4	16.7	20.7	42.1	18.9
Other retail	4.87	6.7	22.4	27.2	38.3	19.8
Other service	4.13	7.5	13.4	19.6	28.6	16.3
Post office/postal center	2.10	3.2	7.2	13.3	21.3	9.9
Preschool/daycare	3.34	5.5	8.8	12.1	28.9	11.6
Recreation	1.59	2.9	5.1	10.8	19.3	8.8
Refrigerated warehouse	1.89	3.8	35.2	51.1	55.7	28.5
Religious worship	1.06	1.9	3.5	6.0	8.6	4.5
Repair shop	1.88	2.6	6.1	7.6	14.2	6.8
Restaurant/cafeteria	9.76	15.2	28.7	49.9	88.2	37.9
Retail store	2.41	3.9	8.1	15.2	27.3	12.5
Self-storage	0.63	1.2	2.1	2.8	3.8	2.2
Social/meeting	1.01	1.8	2.9	7.5	12.8	6.2
Vacant	0.29	0.4	1.7	3.8	7.8	3.2
Vehicle dealership/showroom	2.50	7.2	13.8	21.9	33.9	15.7
Vehicle service/repair shop	1.96	3.3	5.6	9.8	18.6	8.2
Vehicle storage/maintenance	0.27	1.2	3.3	6.4	10.4	5.2
SUM or Mean for sector	1.59	3.6	8.3	17.1	35.4	15.7

Source: Calculated based on DOE/EIA preliminary 2003 CBECS microdata.

at http://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/publications.cfm.

SURVEYS AND AUDITS

This section provides guidance on preparing for and conducting building surveys and describes the levels of intensity for investigating ECM opportunities in a building.

Energy Audits

The objectives of an energy analysis or audit are to identify and develop modifications to reduce energy use and/or cost of operating a building. The results should be presented in a format that provides the information needed by an owner/operator to decide if any, some, or all of the recommended modifications should be implemented. Energy audits include some or all of the following:

1. Collect and analyze historical energy use
    - Review more than one year of energy bills (preferably three years)
    - Review billing rate class options with utility
    - Review monthly patterns for irregularities
    - Compare the building's EUI with publicly available indices of similar buildings
    - Derive target goals for energy, demand, and cost indices for a building with similar characteristics
2. Study the building and its operational characteristics
    - Acquire a basic understanding of the mechanical and electrical operating systems

Table 4 Energy Cost Percentiles from 2003 Commercial Survey

Building Use	Weighted Energy Cost Values, $/yr per gross square foot					
	Percentiles					
	10th	25th	50th	75th	90th	Mean
Administrative/professional office	0.50	0.82	1.36	1.92	2.58	1.55
Bank/other financial	1.09	1.37	2.00	2.93	4.47	2.41
Clinic/other outpatient health	0.61	0.87	1.53	2.03	4.13	1.74
College/university	0.44	1.20	1.37	2.27	$3.01	1.82
Convenience store	2.48	3.75	5.26	8.02	10.12	6.17
Convenience store with gas station	1.99	2.75	4.61	6.83	8.74	5.12
Distribution/shipping center	0.24	0.33	0.54	0.88	1.37	0.74
Dormitory/fraternity/sorority	0.58	0.69	0.87	1.29	2.13	1.07
Elementary/middle school	0.54	0.78	1.09	1.57	2.60	1.48
Entertainment/culture	0.14	0.42	0.56	2.25	17.82	2.83
Fast food	2.93	4.98	8.87	12.29	14.14	8.92
Fire station/police station	0.10	0.53	1.15	1.73	2.83	1.31
Government office	0.52	0.90	1.40	1.88	2.66	1.52
Grocery store/food market	2.60	3.07	4.31	5.27	6.85	4.84
High school	0.60	0.87	1.02	1.60	2.19	1.30
Hospital/inpatient health	1.37	2.16	2.46	3.17	3.55	2.70
Hotel	0.74	1.05	1.33	1.76	2.52	1.58
Laboratory	1.34	3.09	4.52	7.64	10.81	5.18
Library	0.78	1.06	1.37	2.41	2.92	1.68
Medical office (diagnostic)	0.33	0.68	1.02	2.13	2.53	1.33
Medical office (nondiagnostic)	0.58	0.79	1.06	1.44	1.92	1.15
Mixed-use office	0.46	0.85	1.30	1.96	2.90	1.78
Motel or inn	0.49	0.83	1.21	1.82	2.67	1.48
Nonrefrigerated warehouse	0.06	0.17	0.38	0.80	1.43	0.61
Nursing home/assisted living	0.73	1.12	1.52	2.47	2.99	1.78
Other	0.15	0.51	0.93	1.81	2.41	1.35
Other classroom education	0.21	0.50	0.92	1.26	2.14	0.96
Other food sales	0.60	0.72	0.95	2.35	6.02	2.20
Other food service	0.79	1.60	2.44	6.50	11.56	4.72
Other lodging	0.55	0.56	1.13	1.71	2.76	1.30
Other office	0.37	0.71	1.19	2.16	2.56	1.47
Other public assembly	0.35	0.50	0.81	1.56	2.06	1.15
Other public order and safety	1.00	1.13	1.56	3.38	4.74	2.06
Other retail	0.97	1.19	1.59	2.98	5.60	2.43
Other service	0.76	1.13	1.58	2.92	7.29	2.71
Post office/postal center	0.32	0.78	1.09	1.44	1.89	1.07
Preschool/daycare	0.46	0.77	1.09	1.57	2.63	1.30
Recreation	0.30	0.53	0.87	1.38	2.33	1.14
Refrigerated warehouse	0.38	0.38	2.21	4.00	5.25	2.45
Religious worship	0.25	0.37	0.60	0.84	1.32	0.72
Repair shop	0.20	0.35	0.61	1.15	1.47	0.75
Restaurant/cafeteria	1.12	1.86	3.33	7.44	10.48	4.80
Retail store	0.36	0.53	0.98	1.77	2.90	1.38
Self-storage	0.05	0.10	0.20	0.27	0.52	0.23
Social/meeting	0.19	0.33	0.66	1.02	2.27	0.89
Vacant	0.04	0.08	0.27	0.70	1.19	0.48
Vehicle dealership/showroom	0.67	0.89	1.37	2.97	3.98	2.07
Vehicle service/repair shop	0.29	0.50	0.77	1.38	2.07	1.10
Vehicle storage/maintenance	0.04	0.16	0.48	1.12	1.96	0.83
SUM or Mean for sector	0.26	0.54	1.06	2.00	3.93	1.80

Source: Calculated based on DOE/EIA preliminary 2003 CBECS microdata.

- Perform a walk-through survey of the facility to become familiar with its construction, equipment, operation, and maintenance
- Meet with owner/operator and occupants to learn of special problems or needs of the facility
- Identify any required repairs to existing systems and equipment

3. Identify potential modifications to reduce energy use and/or cost
    - Identify low-cost/no-cost changes to the facility or to operating and maintenance procedures
    - Identify potential equipment retrofit opportunities
    - Outline effect on occupant service requirements
    - Identify any training required for operating staff to maintain measures
    - Perform a rough estimate to determine the approximate breakdown of energy use for significant end-use categories

Table 5 1997 Residential Annual End-Use Consumption

Energy Source and End Use/Appliance	Households, 10^6	Usage per Household
Electricity, total	101.4	10,219 kWh
Space heating	42.0	2,807 kWh
Air conditioning	72.6	1,677 kWh
Water heating	40.2	2,835 kWh
Appliances	101.4	6,733 kWh
Natural Gas, total	61.9	83×10^3 ft^3
Space heating	54.5	65×10^3 ft^3
Water heating	52.8	24×10^3 ft^3
Appliances	40.4	9×10^3 ft^3
Fuel Oil, total	10.0	730 gal
Space heating	9.8	625 gal
Water heating	5.2	219 gal
LPG, total	8.1	488 gal
Space heating	5.6	502 gal
Water heating	3.3	258 gal
Appliances	4.8	55 gal
Kerosene, total, space heating	3.5	126 gal

Source: www.eia.doe.gov/emeu/recs/recs97 Fuel Tables 1 to 5.

4. Perform an engineering and economic analysis of potential modifications
   - For each practical measure, determine resultant savings
   - Estimate effects on building operations and maintenance costs
   - Review effect on nonenergy operating costs
   - Prepare a financial evaluation of estimated total potential investment using appropriate techniques and criteria
5. Prepare a rank-ordered list of appropriate modifications
   - List all possible energy savings modifications
   - Select 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
   - Provide preliminary implementation costs and savings estimates
6. Prepare a report to document analysis process and results
   - Provide description of building and its requirements, and an inventory of major energy-using equipment
   - Clearly state savings from each modification and assumptions on which each is based
   - Discuss existing situation and why it is using excess energy
   - Review list of practical modifications with the owner, and select those to be pursued
   - Prioritize modifications in order of implementation
   - If necessary, recommend measurement and verification methods to determine effectiveness of measures implemented

Three levels of energy audits or analysis have been defined (Mazzucchi 1992). Depending on the physical and energy use characteristics of a building and the owner's needs and resources, one or more of the three different levels of effort can be used.

Level I: Walk-Through Assessment. This involves assessing a building's energy cost and efficiency by analyzing energy bills and briefly surveying the building, accompanied by the building operator. Level I analysis identifies and provides a savings and cost analysis of low-cost/no-cost measures. It also lists potential capital improvements that merit further consideration, along with an initial judgment of potential costs and savings. The level of detail depends on the experience of the auditor or on 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 complex have the greatest potential for energy savings. The results can be used to develop a priority list for buildings that are recommended for a Level II or III audit.

Level II: Energy Survey and Analysis. This includes a more detailed building survey and energy analysis. A breakdown of energy use in the building is provided. Level II analysis identifies and provides the savings and cost analysis of all practical measures that meet the owner's constraints and economic criteria, along with 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 and measures.

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 detailed project cost and savings information with a level of confidence high enough 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; that is, various measures may be subjected to different levels of analysis during energy analysis of a particular building. In the complete development of energy management program, Level II audits should be performed on all facilities, although Level I audits are useful in establishing the program. The collected data are used to calculate an energy use profile that includes all end-use categories. From the energy use profiles, it is possible to develop and evaluate energy conservation opportunities.

In conducting an energy audit, 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 considerable quantities of steam being wasted by venting to the atmosphere or through defective steam traps, uninsulated lines, and passing through unused heat exchangers. Eliminating this end-use waste could produce greater savings than those easily and quickly developed by improving boiler efficiency. This approach requires care to ensure cost-effective use of time. It may not be cost-effective to track down every end use.

When conducting an energy audit, it is important to become familiar with operating and maintenance procedures and personnel. The energy manager can then recommend, through appropriate departmental channels, energy-saving operating and maintenance procedures. The energy manager should determine, through continued personal observation, the effectiveness of the recommendations.

Stewart et al. (1984) tabulated 139 different energy audit input procedures and forms for 10 different building types, each using 62 factors. They discuss features of selected audit forms that can help develop an audit procedure. A detailed process for conducting audits is outlined in *Procedures for Commercial Building Energy Audits* (ASHRAE 2004).

IMPROVING DISCRETIONARY OPERATIONS

Basic Energy Management

Control Energy System Use. The most effective method to reduce energy costs, both economically and environmentally, is through discretionary operations, such as turning off energy systems when they provide no benefit. Management of existing

Table 6 1997 Residential Energy Consumption

	Total Households, 10^6	Per Household, 10^6 Btu
Total Households	101.5	101.0
Weekday Home Activities		
Home used for business		
Yes	7.4	114.4
No	94.1	99.9
Energy-intensive activity		
Yes	2.4	121.4
No	99.1	100.5
Someone home all day		
Yes	51.3	106.7
No	50.1	95.1
Winter Temperature Settings		
Lower when no one home		
Yes	45.5	99.9
No	56.0	101.8
Lower during sleeping hours		
Yes	47.4	101.6
No	54.0	100.4
Use a secondary heating fuel		
Yes	34.3	116.0
No	66.5	94.0
Adequacy of insulation		
Well Insulated	38.0	98.6
Adequately Insulated	44.4	102.5
Poorly Insulated	18.5	103.0
Central air conditioning use		
All summer	24.6	97.9
Quite a bit	10.4	103.1
Only a few times	12.4	103.5
No central system	53.7	101.6
Room air conditioning use		
All summer	5.7	96.3
Quite a bit	6.6	113.3
Only a few times	13.5	107.5
No room units	75.0	99.0
Use a dishwasher		
Yes	50.9	109.6
No	50.6	92.2
Use a clothes washer		
Yes	78.5	112.3
No	22.9	62.2
Use a clothes dryer		
Yes	72.2	113.7
No	29.3	69.5
Use two or more refrigerators		
Yes	15.4	135.0
No	86.1	94.9
Outdoor lights on all night		
Yes	26.3	108.2
No	75.2	98.4
Census Region and Division		
Northeast	19.7	120.6
New England	5.3	122.9
Middle Atlantic	14.4	119.7
Midwest	24.1	134.0
East North Central	16.9	138.2
West North Central	7.2	124.1
South	35.9	83.9
South Atlantic	18.7	75.1
East South Central	6.3	87.7
West South Central	10.8	96.7
West	21.8	74.9
Mountain	6.2	94.0
Pacific	15.6	67.3
Largest populated states		
California	11.5	63.9
Florida	5.9	54.9
New York	6.8	123.4
Texas	7.0	96.1
Urban/rural location		
City	48.2	95.8
Town	18.2	104.2
Suburbs	18.6	110.4
Rural	16.5	101.9
Climate zone		
<2000 CDD, >7000 HDD	9.3	123.1
Climate zone (*continued*)		
5500 to 7000 HDD	28.0	127.8
4000 to 5499 HDD	22.5	105.5
Under 4000 HDD	19.5	74.3
>2000 CDD, <4000 HDD	22.2	76.6
Type of Housing Unit		
Single-family	73.7	114.7
Multifamily		
2 to 4 units	5.6	91.5
5 or more units	15.8	48.6
Mobile home	6.3	79.5
Heated Floorspace (square feet)		
Fewer than 600	7.9	61.1
600 to 999	21.5	77.4
1000 to 1599	30.4	97.4
1600 to 1999	15.3	116.6
2000 to 2399	7.9	124.3
2400 to 2999	5.3	137.7
3000 or more	4.1	175.2
No estimate provided	9.1	101.5
Year of Construction		
1949 or before	27.9	124.8
1950 to 1959	12.5	106.1
1960 to 1969	14.4	96.0
1970 to 1979	19.6	87.4
1980 to 1989	17.3	81.7
1990 to 1997	9.7	94.6
All Utilities Paid By Household		
All major fuels		
Yes	89.7	104.3
No	11.8	75.3
Electricity		
Yes	96.2	103.0
No	5.3	65.0
Natural gas		
Yes	53.3	123.5
No	8.6	78.8
Fuel oil		
Yes	7.6	145.8
No	2.3	91.9
LPG		
Yes	7.9	103.8
No	0.2	88.5
Kerosene		
Yes	3.5	100.5
No		
1997 Family Income		
Less than $10,000	13.3	76.4
$10,000 to $24,999	29.1	87.3
$25,000 to $49,999	31.1	102.6
$50,000 or more	27.9	125.2
Below Poverty Line		
100%	14.6	83.0
125%	19.7	82.9
150%	26.7	84.2
Eligible for Federal assistance	34.1	86.7
Age of Householder		
Under 25 years	5.7	69.7
25 to 34 years	18.5	87.7
35 to 44 years	23.2	107.4
45 to 59 years	25.6	113.4
60 years and over	28.5	99.4
Race of Householder		
White	78.5	103.9
Black	12.7	105.3
Other	10.3	72.8
Householder of Hispanic descent		
Yes	9.4	75.9
No	92.1	103.5
Household Size		
1 person	25.6	74.7
2 persons	33.0	101.2
3 persons	17.4	109.5
4 persons	15.2	117.7
5 persons	6.4	123.9
6 or more persons	3.9	129.6

Source: www.eia.doe.gov/emeu/recs/recs97 Tables CE1.

CDD = cooling degree-day (65°F base); HDD = heating degree-day (65°F base).

systems and design of new ones should emphasize ease and simplicity of system control. For example, an energy management system may be effective in large and complicated buildings, but inappropriate for smaller buildings or in those with rapid turnover of operators who are unfamiliar with the building systems.

Extensive labeling and inclusive, clear instruction on how to operate these systems lead to better control of their use. Ways to conserve energy include the following:

- Shut down HVAC&R systems when not required
- Reduce air leakage
- Reduce ventilation rates during periods of low occupancy
- Shut down exhaust fans when not required
- Seal or repair leaks in ducts and pipes
- Reduce water leakage
- Turn off lighting: remove unnecessary lighting, add switched circuits, use motion sensors and light-sensitive controls
- Use temperature setup and setback
- Cool with outside air
- Seal unused vents and ducts to the outside
- Tune up systems before heating and cooling seasons
- Take transformers offline during idle periods
- Disconnect or turn off all nonessential loads
- Educate tenants and occupants

Purchase Lower-Cost Energy. This is the second most effective method for reducing energy costs for all owners and operators. Building operators and managers must understand all the options in 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 electric billing demand
- Utility-sponsored demand response programs
- Transportation and interruptible natural gas rates
- Cogeneration
- Lower-cost liquid fuels
- Increasing volume for onsite storage
- Avoiding sales or excise taxes where possible
- Incentive rebates from utilities and manufacturers

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

- Training operating personnel
- Tuning combustion equipment
- Adjusting gas burners to optimal efficiency
- Following an established maintenance program
- Cleaning or replacing filters
- Cleaning fan blades and ductwork
- Cycling ventilation systems to coincide with occupied spaces
- Using water treatment

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. Because the greatest profit by suppliers is made by system replacement, it often draws the greatest attention from building owner/operators and equipment suppliers. 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 is near the end of its expected life or when major repairs are needed. Systems that may be replaced include the following:

- Lighting systems and lamps
- Heating and cooling equipment
- Energy distribution systems (pumps and fans)
- Motors
- Thermal envelope components
- Industrial process equipment
- Controls and energy management systems

Optimizing More Complex System Operation

Basic energy management is appropriate for many types of facilities, but as the level of complexity of building systems increases, additional strategies are needed to optimize energy systems. Approaches include **recommissioning**, **retrocommissioning**, and **ongoing commissioning**. See Chapter 42 for more information on these approaches.

This approach to reducing energy costs typically requires a strong team effort on the part of the facility staff and a consultant team to identify and fix comfort problems in the building, accompanied by an aggressive approach to optimizing HVAC operation and control in the building. It is most effective when preceded by installation of good energy metering and a strong energy accounting program. Some important measures typically implemented include the following:

- Optimizing hot and cold deck reset schedules
- Optimizing duct static pressure reset schedules
- Optimizing pump control
- Optimizing terminal box settings/control
- Optimizing sequencing and water temperature reset schedules of boilers and chillers
- Diagnosing and fixing fundamental causes of comfort problems
- Diagnosing and repairing stuck or leaky valves and dampers
- Training operating personnel in optimum operating strategies
- Using diagnostic tools, data loggers, etc., to diagnose equipment function

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 Claridge and Liu (2000), Haasl and Sharp (1999), and Liu et al. (1997).

ENERGY CONSERVATION OPPORTUNITIES

Identifying Energy Conservation Opportunities

Various energy conservation opportunities (ECOs) can be quantitatively evaluated from end-use energy profiles. Important considerations in this process are as follows:

- System interaction
- Utility rate structure
- Payback
- Alignment with corporate goals
- Installation requirements
- Life of the measure
- Energy measurement and verification requirements
- Maintenance costs
- Tenant/occupant comfort
- Effect on building operation and appearance

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 ECOs.

Using average costs per unit of energy in calculating the energy cost avoidance of a particular measure is likely to result in incorrect energy costs and cost avoidance, because actual energy cost avoidance may not be proportional to the energy saved, depending on the billing method for energy used.

PNNL (1990) discusses 118 ECOs, including the following:

Boilers
Condensate systems
Water treatment
Fuel acquisition
Fuel systems
Chillers
Vapor barrier
Glazing
Piping insulation
Instrumentation
Shading
Fixtures
Swimming pools
Cooling towers
Condensing units
Air-handling units
Unitary equipment
Outside air control
Balancing
Shutdown
Power factor correction
Energy recovery
Filters
Humidification
Dishwashing
Vending machines
Heat/cool storage
Time-of-day rates
Cogeneration
Active solar systems
Occupant indoctrination
Controls
Setback
T5 lighting
Outside air ventilation control
Envelope infiltration
Weatherstripping
Caulking
Vestibules
Steam distribution
Hydronic systems
Pumps
Steam traps
Domestic water heating
Trombe walls
Thermal shutters
Surface color
Roof covering
Lamps
Ballasts
Light switching options
Photo cell controls
Demand limiting
Current leakage
Minimizing reheat
Power distribution
Cooking practices
Refrigeration
System air leakage
System interaction
Space segregation
Computer controls
Heat pumps
Staff training
Documentation
Thermostats
Space planning
Variable-frequency drives (VFDs)

In addition, previously implemented energy conservation 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.

Evaluating Energy Conservation Opportunities

Once a list of ECOs is established, it should be evaluated and implemented. In establishing ECO priorities, the capital cost, cost-effectiveness, effect on indoor environment, and resources available must be considered. Factors involved in evaluating the desirability of a particular energy conservation retrofit measure are as follows:

- Rate of return (simple payback, life-cycle cost, net present value)
- Total savings (energy, cost avoidance)
- Initial cost (required investment)
- Other benefits (safety, comfort, improved system reliability, improved productivity)
- 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)

Some owners are reluctant to implement ECOs because of bad experiences with energy projects. To reduce the risk of failure, documented performance of ECOs in similar situations should be obtained and evaluated. One common problem is that energy consumption for individual end uses is overestimated, and the predicted savings are not achieved. When doubt exists about energy consumption, temporary measurements should be made and evaluated. Causes of past failures should be analyzed carefully to minimize the possibility of their reoccurrence.

Resources available for an energy conservation retrofit opportunity should include the following:

- Management attention, commitment, and follow-through
- Skills
- Manpower
- Investment capital

Heating Effects of Electrical Equipment

Electrical equipment and appliances, from lighting systems and office equipment to motors and water heaters, provide the useful services they are designed to produce. However, the electrical energy they use also appears as heat within the building, which can either be useful or detrimental to the building's HVAC systems, 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, heat produced by electrical appliances adds to the building's air-conditioning load.

Energy-efficient equipment and appliances consume less energy to produce the same useful work, but they also produce less heat. As a result, efficient electrical equipment increases the load on heating systems in winter and reduces 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**.

When considering the overall net savings of an energy conservation opportunity, 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 your specific building or room depends on several factors, including the following:

- Location of light fixtures
- Location of heaters and their thermostats
- Type of ceiling
- Size of building
- Whether room is an interior or exterior space
- Extent of heating and cooling seasons
- Type of heating, ventilation, and air-conditioning system used in each room

Unfortunately, interactive effects are often quite complex and may require assessment by a specialist; for details, see Rundquist et al. (1993).

Exploring Financing Options

Financing alternatives also need to be considered. When evaluating proposed energy management 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 attractiveness (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 36 contains details on these and other factors that should be considered in such an analysis.

Capital for energy-efficiency improvements is 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 general 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, or other financial assistance offered by an energy utility (or other provider of efficiency public benefits funding) for design and purchase of energy-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).

IMPLEMENTING ENERGY CONSERVATION MEASURES

When all desirable ECOs have been considered and a list of recommendations is 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 ECOs
- 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 upper management. Energy conservation measures (ECMs) must generally 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 must be presented in a form that is easily understood by the decision makers. Finally, the energy manager must present nonfinancial benefits, such as improved product quality or the possibility of postponing other expenditures.

After approval by management, the energy manager directs the completion of energy conservation retrofit 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 the contractors, construction observation, final check-out, and assistance in training personnel in the proper application of the revisions.

MONITORING RESULTS

Once energy conservation measures are under way, procedures need to be established to record, frequently and 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. However, if the energy manager is not able to evaluate data as frequently as it is collected, it may be more practical to collect data less frequently.

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, all of which are problems that should be isolated and corrected as soon as possible.

EVALUATING SUCCESS AND ESTABLISHING NEW GOALS

Comparing facility performance before and after implementing ECOs is useful. It helps keep operating staff on track with their energy conservation efforts, ensuring that utility consumptions do not return to preproject levels (assuming occupancy and facility size remain unchanged). It also convinces other staff and tenants that the process is worthwhile. When utility costs increase, energy conservation measures are seen as that much more prudent and rewarding.

Once initial goals have been established, tracking their performance becomes the key to success. Original ECMs would be reviewed and shared with building occupants and operators before implementation. The combination of feedback from both these parties on building comfort and operation with the ongoing analysis of analyzing energy bills provides the building or energy manager with the necessary information to identify a successful measure.

After evaluating the ECMs, new goals may be established or existing ones revised. This step allows energy management staff to prove that they are accountable to building owners and occupants alike. Reviewing goals frequently maintains energy conservation effectiveness and the associated cost savings by separating good initiatives from the less good. Setting new energy management goals can discourage complacency among building operators and occupants so that the overall effort does not diminish.

Evaluating and reporting energy performance involves four steps:

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

Establish Key Performance Indicators

When developing the energy management program, it is important to determine its performance factors of the energy management program. These factors are expressed in terms of key performance indicators (KPIs).

Suggested key performance indicators of a facilities performance as compared to other facilities of similar type are:

- Energy use index (EUI), total energy use per unit of gross floor area
- Cost utilization index (CUI), total energy cost per unit of total gross floor area
- Electrical energy use per unit of total gross floor area

The definition of key performance indicators provides the foundation for determining what data need to be collected, how often to collect it, and how to present it to senior management, the building owner, or relevant agency. Using the KPI method, only the total amount of data required to accomplish primary goals is reported to senior management. All additional energy information is used to help understand whether facility performance is on track with goals.

Energy Policy Act. The Energy Policy Act (EPAct 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 instance, the target percentage reduction from 2004 values is 10%.) Using this initiative, the following sample KPI definition could be used:

- 2000 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

At the end of each year, actual consumption is determined to generate an energy performance report for management.

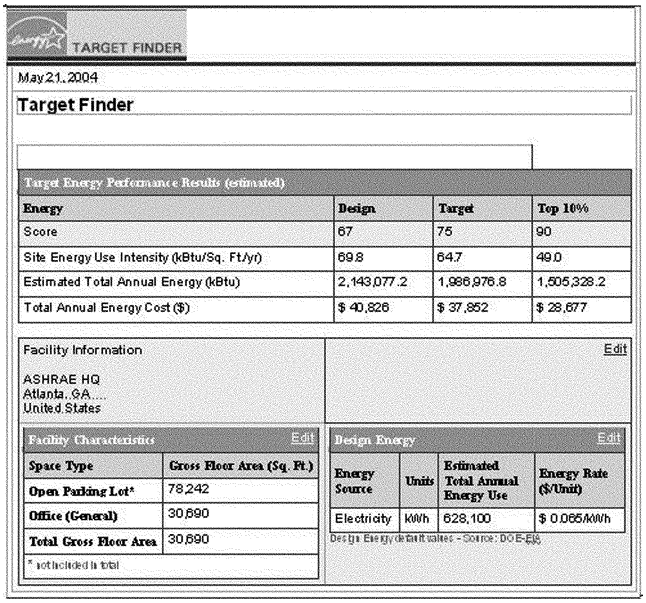
ENERGY STAR® Tools. The U.S. Environmental Protection Agency's ENERGY STAR Web site offers the free online benchmarking tool, Target Finder (I-P units only; accessible from www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder). This tool compares actual building performance to target values, and to other similar buildings. Figure 4 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 (www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager), 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 in comparison with other buildings.

Tracking Performance

The next step is to build data displays using the data and models. The displays should be able to provide high-level KPI views to give an overall indication of energy performance, and to drill down to identify why a plan may not be on track.

DDC systems can monitor energy performance and notify the energy engineer when energy usage is off track. Daily monitoring can be a valuable, proactive tool.

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 DDC system can indicate an alarm and send a notification to the energy manager's pager or cell phone. The energy manager then can investigate the cause of the discrepancy. 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.



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

ASHRAE HQ
Atlanta, GA....
United States

Facility Characteristics

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

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

Fig. 4 ENERGY STAR® Rating for Atlanta Building

Developing 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.

Using utility bill data 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. For more information on steady-state, data-driven models, see Chapter 32 of the 2005 *ASHRAE Handbook—Fundamentals.*

Utility bills for an entire year are collected and used for baseline development. Many energy managers use spreadsheets to compile and compare the data.

Cooling degree-days and heating degree-days are commonly used to track successes compared to ECM targets with respect to weather-dependent energy consumption. Local CDD and HDD information is traditionally based on a balance point of 65°F. The balance point for a building is that outdoor ambient temperature at which the building requires neither mechanical heating or cooling to maintain the indoor occupied temperature set point; 65°F is not typically the actual balance point for any commercial or residential building. Therefore, regional or local HDD from weather stations or utilities 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. The tools used to determine a building's balance point depends on the energy manager's analytical aptitude. Further information on energy estimating using degree-days and balance points can be found in Chapter 32 of the 2005 *ASHRAE Handbook—Fundamentals*.

For larger, more complex facilities and where an building manager has a higher level of analytical experience, regression analysis could be used to analyze energy consumption. Through linear regression, utility bills are normalized to their daily average values. Repeated regression is done until the regression data represents the best fit to the utility bill data. Figure 5 shows the scatter plot of a

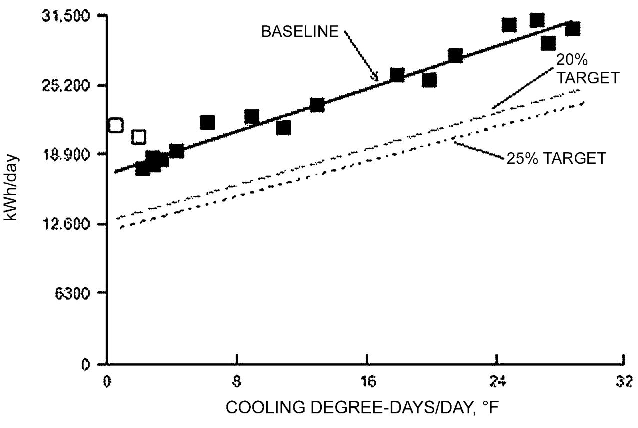


Fig. 5 Scatter Plot, Showing Best-Fit Baseline Model and Target Models

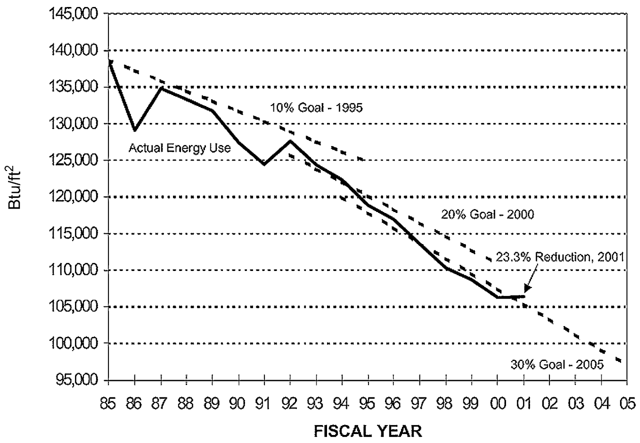


Fig. 6 Progress Toward Energy Reduction Goals for Federal Standard Buildings

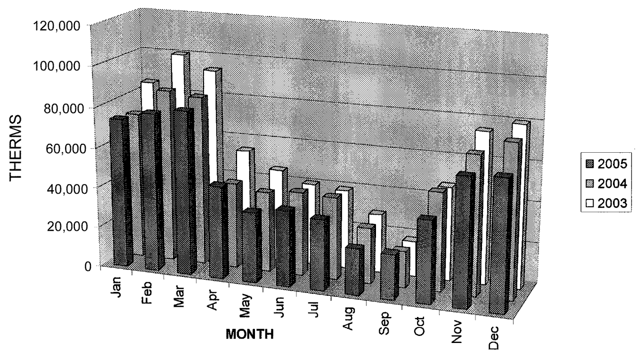


Fig. 7 Monthly Comparison of Natural Gas Use by Year

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 54°F (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.

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

Reporting

Energy performance based on ECMs must be reported to senior management, building operators, and tenants. Reporting can be monthly, quarterly, or annual. 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.

Figure 6 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.

Reports must be easy to understand by their readers. 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. Figure 7 shows an example of monthly gas use in a facility from year to year.

Reports should contain information that is pertinent to the audience. Whereas a report to the company's administration would show how efforts of the energy management program affect operating and maintenance costs, a separate report to the operations staff might show how their daily decisions and actions change daily load profiles.

Bar graphs can compare a breakdown of annual costs for each resource to the base year or previous years, to show trends. Monthly comparisons (e.g., July over July) identify seasonal efforts. These annual costs may also be shown as compared to data for similar facilities, which may be available from local utilities.

BUILDING EMERGENCY ENERGY USE REDUCTION

The need for occasional reductions in energy use during specific periods has increased because of rising energy costs and supply reductions (voluntary or mandatory) or equipment failures. Emergencies include short-term shortages of a particular energy source brought about by natural disasters, extreme weather conditions, utility system equipment disruptions, labor strikes, failures in building systems or equipment, self-imposed cutbacks in energy use, world political activities, or other forces beyond the control of the building owner and operator. Recently, some areas have been subject to electric power supply constraints, with building owners and managers asked or required to cut their electricity consumption for short- or long-term periods. In limited instances, utilities have implemented rolling blackouts, requested voluntary reductions, and asked users to operate emergency generators.

A more challenging case occurred in August 2003 in the northeastern United States and eastern Canada, when a major blackout required numerous cities to implement contingency plans. The International Facilities Management Association (IFMA) surveyed its members to learn what their contingency plans had been, why they were created, and how well they worked (IFMA 2003). Research such as this can help building operators and managers develop emergency energy use reduction plans.

This section provides information to help building owners and operators maintain the best operating condition for the facilities during various energy emergencies, whether electric or fossil fuel in nature.

Implementing Emergency Energy Use Reductions

Each building owner, lessor, and operator should use the energy team approach and identify an individual with the necessary authority and knowledge to review and fit recommendations into a plan for the particular building or complex of buildings. Because energy reduction requirements may occur with little or no advance notice, plans should be developed and reviewed by the energy team in advance. Each type of energy emergency requires a specific plan to reduce building energy use and still maintain the best building environment under the circumstances. The plan should include measures to reduce specific types of energy use in the building, as well as provisions for both slight and major energy use reduction. Implementation of particular recommendations should then be coordinated through building occupants and operators, with assistance from the responsible party as necessary. In some cases, existing building energy management systems can be used to implement demand shedding. The plan should be tested occasionally.

Depending on the type of building, its use, the energy source(s) for each function, and local conditions such as climate and availability of other similar buildings, the following steps should be taken in developing a building emergency energy use reduction plan:

1. Develop a list of measures applicable to the 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). Tabulate demand and usage savings separately for response to different types of emergencies.

3. For various levels of possible energy emergency, develop a plan that maintains the best building environment under the circumstances. Develop the plan so that actions taken can be energy-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 developed, 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 or compromise life safety or security provisions. Establish a procedure for notification of building occupants before actions are taken. Cellular phones may not be a reliable means of communication in some circumstances.
7. Be certain that there is a plan to minimize entrapment of occupants in elevators in case of a rolling blackout or other 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 to ensure that security or emergency people know what to expect (reduced lighting, lower temperatures, elevators out of operation, etc.).
9. 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

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 in the building, keeping in mind the applicability for each individual building or system:

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 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
- 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
- Tune up equipment
- Lower thermostat set points in winter
- Raise chilled-water temperature
- Lower hot-water temperature (*Note*: Keep hot-water temperature higher than 145°F if a noncondensing gas boiler is used)
- Reduce or eliminate reheat
- Reduce (and eliminate during unoccupied hours) mechanical ventilation and exhaust airflow
- Raise thermostat set points in summer or turn cooling equipment off
- Reduce amount of recooling in summer
- Reduce duty cycling on HVAC systems (on later, off earlier)

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
- Clean all lamps and luminaires
- Revise building cleaning and security procedures to minimize lighting periods
- Consolidate parking and turn off unused parking security lighting

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

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