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EDF Climate Corps Handbook

Energy Efficiency Investment Opportunities in Commercial Buildings / SIXTH EDITION

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SIXTH EDITION

Environmental Defense Fund

Environmental Defense Fund is dedicated to protecting the environmental rights of all people, Environmental Defense Fund (EDF), a leading national nonprofit organization, creates transformational solutions to the most serious environmental problems. EDF links science, economics, law and innovative private-sector partnerships.

EDF Climate Corps taps the talents of tomorrow's leaders to save energy, money and the environment by placing specially-trained EDF fellows in companies, cities and universities as dedicated energy problem solvers. Working with hundreds of leading organizations, EDF Climate Corps has found an average of $1 million in energy savings for each participant.

This Handbook is intended for use as a reference manual for identifying, analyzing and prioritizing energy efficiency investments. For more information about the EDF Climate Corps Program, please visit edfclimatecorps.org.

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The complete report is available online at edfclimatecorps.org.

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CHAPTER 1

How to use this handbook

This handbook is a reference manual for identifying, analyzing and prioritizing energy efficiency investments in commercial buildings. Each chapter provides an overview of the steps that an organization can take to reduce energy use—from policy changes and efficient use adjustments to equipment replacement.

The handbook contains chapters that focus on a typical organization's energy use and associated energy savings opportunities, which include HVAC (heating, ventilation and air conditioning), lighting, water heating and office equipment. For many measures, the energy savings and expected rate of returns vary widely because of building and equipment variations. These chapters include short financial examples to illustrate potential savings. Chapters on data centers, industrial facilities and company vehicles are also included.

Chapters are also devoted to concepts that will be useful to EDF Climate Corps fellows and include barriers to energy efficiency, how to interpret utility bills, basic energy efficiency finance, and employee engagement considerations. Each of these chapters contains a set of goals, a topical overview, and an "Information Gathering Guide," which outlines the information an EDF Climate Corps fellow should collect from their host organization and outside engineers. The handbook contains extensive references and additional background information is included in the appendices. The vocabulary terms in **bold green** throughout the text are defined in the glossary.

The chapters contain examples of costs, typical energy savings, and expected returns on investment for a number of the suggested efficiency upgrades. Information on utility rebates and other incentives are referenced within the handbook but specific rebate information should always be sourced from the individual utilities for the most up-to-date and thorough information prior to implementation of any upgrade initiative. Rebate information is available from regional utilities and the Database of State Incentives for Renewable & Efficiency (DSIRE) at www.dsireusa.org. DSIRE is a federally-funded database of state, local, utility company, and federal incentives and policies. However, DSIRE is often not up-to-date, so it's best to check with the local utility, the company's utility account manager, or the utility website for current rebates and incentives.

In conjunction with the handbook, Environmental Defense Fund has developed a companion Financial Analysis Tool, available to EDF Climate Corps fellows, to help analyze the financial attributes of specific energy efficiency investments in lighting, office equipment, HVAC and data centers. Consult the Financial Analysis Tool to generate estimates of energy

Additional background information is included in the appendices, and the vocabulary terms that are in **bold green** throughout the text are defined in the glossary.

savings and **payback** specific to the conditions of a particular building. The savings estimates can be used as the base of a business case for the host organization.

When presenting organizations with a business case for investment in energy efficiency, it is best to cite relevant case studies from organizations that have made successful investments. In addition to the short case examples in the text of the HVAC and EMS chapters, three complete case studies are included in the Appendix of the handbook, along with a reference list of other useful published case studies.

Although the challenge of improving energy efficiency in buildings may appear daunting at first, a good approach is to start with relatively low-cost, simple projects. As such, this handbook focuses on relatively simple and low-cost options. The energy reduction tactics in each chapter are presented to cover simple and low-cost solutions, such as policy and process changes, to more complex and cost-intensive changes like equipment replacement.

CHAPTER 2

Introduction

EDF Climate Corps Program objective

The EDF Climate Corps Program places trained MBA and MPA fellows in companies, city governments and universities to help build the business case for energy efficiency and influence decisions regarding energy efficiency within their host organization. EDF Climate Corps fellows identify and prioritize cost-effective investments that result in energy savings for building owners or lease-holders, and develop plans to fund and implement those projects.

Energy efficiency matters

Increasingly, companies, universities and government agencies see improving energy efficiency as a critical tactic for cutting costs and greenhouse gas (GHG) emissions. The Obama administration has made energy efficiency a central element of national energy strategy, calling energy efficiency "the cheapest, cleanest, fastest energy source." Indeed, increasing energy efficiency across all sectors is key to reducing the nation's greenhouse gas emissions and will yield immediate cost savings.

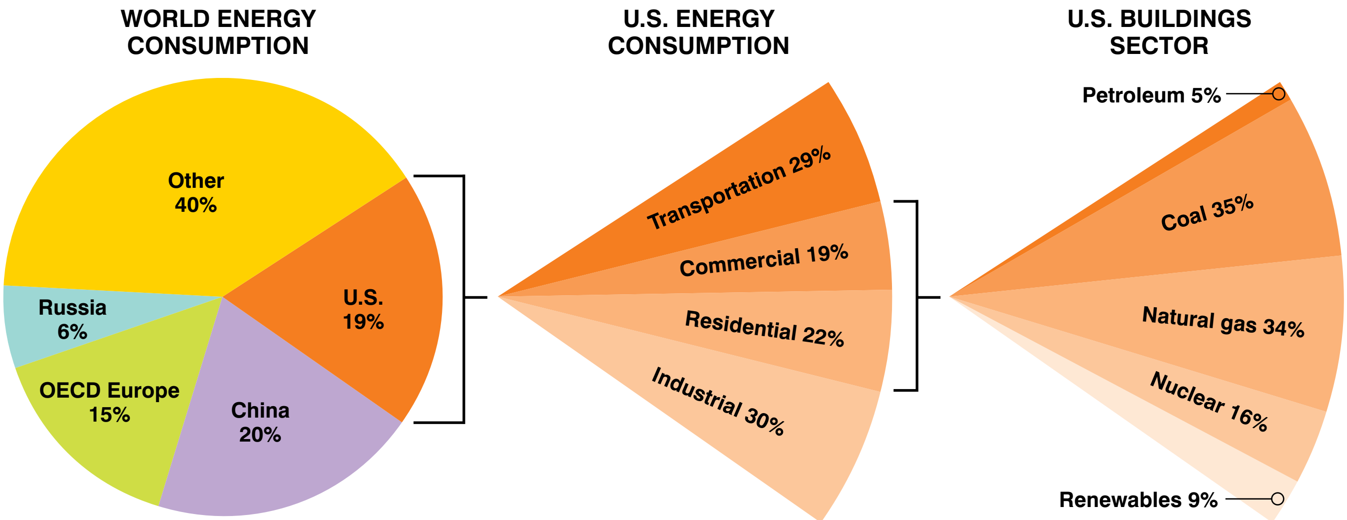
In the United States, the buildings sector accounted for about 41% of primary energy consumption in 2010, more than either the transportation or the industrial sector.[1]

Commercial buildings represent just under one-fifth of U.S. energy consumption, with office space, retail space and educational facilities representing about half of commercial sector energy consumption.[2] U.S. buildings have come to represent an increasing portion of the country's carbon dioxide emissions—40% in 2009, compared to 33% in 1980; yet, the fast growth rate of global emissions means that emissions from U.S. buildings have become a declining percentage of the global total—8.5% in 1980, compared to 7.1% in 2009.[3] Along with cutting GHG emissions, efficiency improvements could translate into major savings for the organizations operating those buildings. The U.S. commercial sector spends $108 billion each year on energy bills for commercial buildings. More than 75% of this spending goes towards electricity.[4]

Despite the opportunities, few organizations have fully invested in cost-effective energy efficiency improvements. Even organizations that have made significant progress on energy efficiency often have not explored the full potential of energy management options. A number of barriers prevent these organizations from identifying or approving smart efficiency investments. Some barriers are organizational. For example, facility managers understandably tend to be concerned primarily with systems performance, reliability and safety and may not be willing or able to focus on opportunities to cut energy costs and reduce environmental impacts. Even when facility managers are directly responsible for improving energy efficiency, they may lack access to financial decision makers who could approve the up-front capital expenditures required.

FIGURE 2.1

U.S. buildings sector energy sources



Source: U.S. Department of Energy, "Buildings Energy Data Book."

Other barriers are financial; efficiency improvements sometimes require a significant up-front investment, followed by years of stable and predictable savings. Lack of available cash or financing can impede this investment, or organizations may impose an overly stringent hurdle (a one-year payback) that prevents many smart, low-risk investments from being approved. For more detail on these problems, see Chapter 5.

As a result, otherwise sophisticated and cutting-edge organizations are missing out on ways to cut energy use. Bottom lines are suffering unnecessarily, and cheap and easy greenhouse gas emissions reduction opportunities are being overlooked. Since 2008, EDF Climate Corps fellows have helped organizations overcome these barriers and reap the energy and cost savings that result.

Notes

[1] U.S. Department of Energy, "Buildings Energy Data Book." March 2012. http://buildingsdatabook.eren.doe.gov ChapterIntro1.aspx

[2] U.S. Department of Energy, "Buildings Energy Data Book—Commercial Sector." March 2012. http://buildingsdatabook.eren.doe.gov/ChapterIntro3.aspx

[3] U.S. Department of Energy, "Buildings Energy Data Book." March 2012. http://buildingsdatabook.eren.doe.gov ChapterIntro1.aspx

[4] Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table C2. Total Energy Expenditures by Major Fuel for All Non-mall Buildings, 2003," Released September 2008. http://www.eia.gov/emeu/cbecs cbecs2003/detailed_tables_2003/2003set9/2003html/c2.html

CHAPTER 3

Commercial building energy consumption

Energy consumption in commercial buildings

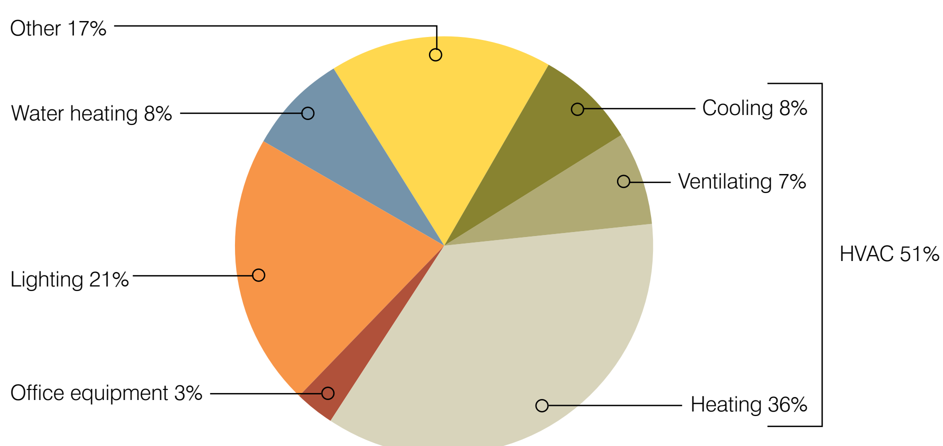
A first step in identifying opportunities that improve energy efficiency is to understand how energy is used within a building. Different building types serve very different purposes, but there are common systems that most commercial buildings share (see Figure 3.1). According to the Energy Information Administration Data, most recently released in 2008, the systems that consume significant portions of energy in an average commercial building include **HVAC** (51%), lighting (21%), water heating (8%), and office equipment and computers (3%). Efficiency opportunities for each of these systems are explored in detail in subsequent chapters.

Energy consumption and energy use intensity by building type

Within the U.S. commercial sector, energy use is spread across a range of building types. Office buildings have the largest aggregated energy consumption, followed by retail and educational buildings (see Figure 3.2). If every office building in the country achieved a 30% decrease in energy use, the combined annual reduction in U.S. energy use would total over 340 trillion **Btus**, enough energy to power over 638,000 homes for a year.[1,2]

FIGURE 3.1

Estimated energy consumption of U.S. commercial buildings

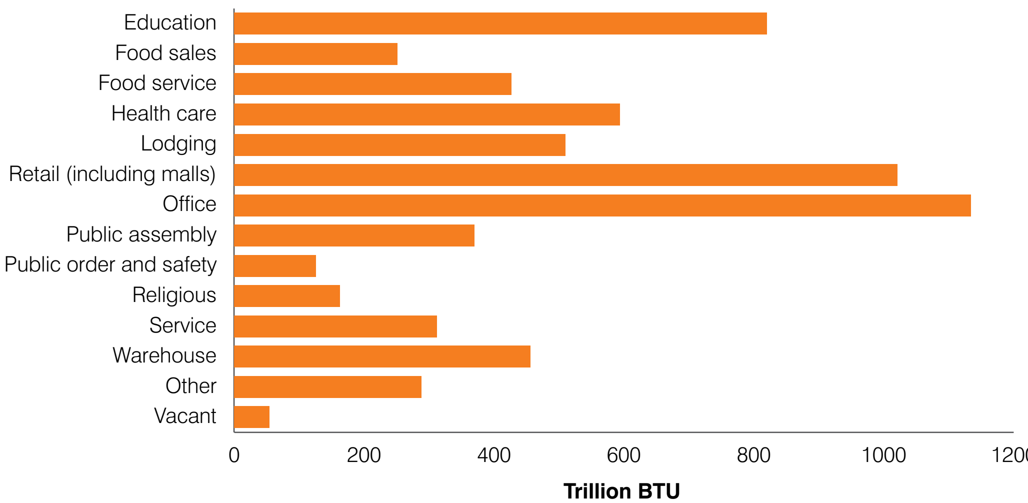


Source: http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

An important measure in understanding variations in energy consumption across building types is Energy Usage Intensity (EUI). **EUI** is the amount of energy a building uses per square foot. Among commercial buildings, food sales, health care and food service buildings have the highest energy use intensity—each uses more than twice the energy per square foot of a typical office building (see Figure 3.3).

FIGURE 3.2

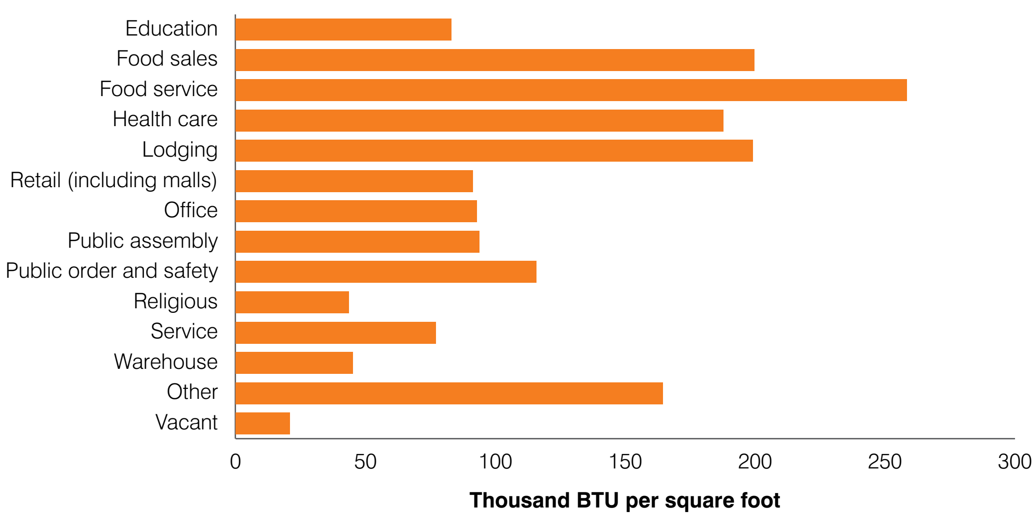
Estimated total fuel consumption by end use for all U.S. commercial buildings



Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E1A. Major Fuel Consumption (BTU) by End Use for All Buildings," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html.

FIGURE 3.3

Estimated energy intensities for U.S. commercial buildings



Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E2A. Major Fuel Consumption (BTU) Intensities by End Use for All Buildings," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html.

Energy use intensity is a useful metric for benchmarking a building's energy performance against the average for the building's type to reveal where there may be opportunities for improved energy efficiency. For more on benchmarking energy usage, see Chapter 7.

For additional information on energy use patterns in a range of specific building types, consult Appendix A.

The data for Appendix A and many of the figures in this handbook are taken from the 2003 Commercial Buildings Energy Consumption Survey (CBECS). The Energy Information Administration (EIA) normally conducts CBECS every four years. However, the most recent 2007 survey suffered issues of data quality and no results were released. New data are expected to be published in 2014 for reference year 2012. Additional sources of data are available, including the U.S. Department of Energy's Buildings Energy Data Book, available at http://buildingsdatabook.eren.doe.gov

Notes

[1] U.S. Department of Energy, "Buildings Energy Data Book—Commercial Sector." March 2012. http://buildingsdatabook.eren.doe.gov/ChapterIntro3.aspx

[2] This statistic was derived using the Environmental Protection Agency, "Interactive Units Converter" and U.S. EPA, "Greenhouse Gas equivalencies Calculator," March 2010. http://www.epa.gov/cmop/resources/converter.html

CHAPTER 4

Steps to identify and prioritize potential efficiency measures

Opportunities for incorporating greater energy efficiency into commercial buildings can occur in many stages of the building cycle, including:

- New building design and engineering
- Acquisition and leasing
- Asset valuation
- Operations and facilities management

EDF Climate Corps fellows, and thus this handbook, focus on operations and facilities management and suggest measures that are suitable for retrofitting or replacing existing building technologies. The basic steps for identifying and prioritizing energy efficiency opportunities are the following:

1. Estimate baseline energy use intensity

High-level calculations of baseline **Energy Use Intensity (EUI)** can be performed by dividing annual purchased energy (electricity and fuel) by the square footage (or square meter) of the building or space. Performing this analysis involves obtaining the documentation of purchased energy from the previous fiscal year and the square footage of the space. Purchased energy can include electricity, natural gas, diesel fuel, and/or district-purchased steam. To provide a rough estimate of possible gains to be accomplished through energy efficiency measures, baseline estimates of EUI can be compared to benchmarked EUI figures. For more information on estimating baseline energy use and benchmarking, see Chapter 7.

2. Commission an energy audit

If initial energy use intensity benchmarking calculations reveal that a building is not maximally efficient, the next step is to commission a professional energy audit. The findings of an energy audit will detail opportunities for increased efficiency in systems throughout the building, ranging from low- to no-cost improvements in system settings and use to full system replacements. Energy audits often reveal obvious inefficiencies such as faulty HVAC controls. Correcting these problems should be a first priority, and will likely yield quick returns. The energy efficiency engineering firms that perform these audits sometimes offer a guarantee that their audit will yield investment opportunities with a certain low payback threshold, or the audit will be free.

3. Consider interactions between systems

It is important that evaluation of possible efficiency upgrades be conducted with a holistic focus—a change to one system may alter the conditions of other systems throughout the building. Most energy projects will have other benefits such as reduced maintenance, lower down-time, increased production or quality, lower labor costs, etc. For example, efficiency upgrades to a lighting system will reduce heat from lighting and will lower the cooling **load** of the air-conditioning (AC) system. Energy efficiency engineers should be able to provide good estimates of the probable collateral effects of a given efficiency upgrade. Try to quantify these collateral effects (even if rough estimates) so these benefits are seen as real rather than rhetorical "fluff." Be sure these are factored into the financial analysis and prioritization.

4. Perform financial analysis of possible efficiency investments

For each potential project, forecast the initial or incremental investment cost, including installation, or the operational expense if this cost doesn't meet capital investment thresholds. On the benefits side of the equation, consider the expected annual savings. Reduction in energy usage will likely be the main financial driver for savings, but reductions in labor and replacement costs may also be significant. Additionally, tax incentives and utility rebates should be included in the calculation. Consideration should also be given as to whether the potential investment is relevant to one site or relevant across an organization's portfolio of sites. Multi-site projects are more complex, but offer significant savings for large companies. Refer to the Finance section for more details. The EDF Climate Corps Financial Analysis Tool (CCFAT) can be used to estimate the **net present value (NPV)** as well as the expected payback period.

5. Prioritize options for investment

Investments should be ranked based on the NPV as well as feasibility and the size of the initial investment. Small and easy NPV-positive investments should be implemented immediately. Larger investments will often create greater energy savings but need to be budgeted and managed with greater resources.

6. Evaluate financing options

Investments can be paid for in cash, financed with a loan, leased or financed through a performance contract (see Chapter 6). The best option for a given organization will depend on the organization's cash availability, budget cycle, incentive and rebate options, and purchasing policy. It is a good idea to work with the chief financial officer and managers to make recommendations based on all of these elements.

7. Post-implementation follow-up

Once the recommended efficiency upgrades have been completed, it will be important to follow up with post-project energy monitoring to quantify and document the effects of the efficiency upgrade. Environmental Defense Fund will follow up with host organizations after six and eighteen months to monitor progress and reductions in energy usage.

CHAPTER 5

Barriers and non-financial considerations to energy efficiency

Goals

- Understand and address the types of barriers that may impede the implementation or continuation of an effective energy management program
- Approach an energy management program from a holistic and strategic organizational change perspective

Overview

If saving energy saves money, why is so much energy still wasted? Organizations face many barriers to implementing energy saving projects, most of which have nothing to do with technology and everything to do with the way people make decisions.

EDF Climate Corps seeks to understand these barriers and help host organizations overcome them. The table below includes information on some of the barriers to energy efficiency that have been identified at EDF Climate Corps hosts since 2008. Each barrier is

TABLE 5.1

Barriers and leading practices map

	Barrier	Leading practice
1. Organizational priorities: How does the organization prioritize energy performance?	Lack of internal motivation Lack of accountability Difficulty assessing energy performance	Greenhouse gas reduction goals Centralized energy management Benchmarking energy performance
2. Access to capital: How do energy efficiency projects compete with other investments?	Invisibility of efficiency investments Short-sighted financial criteria Unpredictable funding levels	Tracking of efficiency investments Including NPV in financial requirements Dedicated funding for efficiency projects
3. Information collection: How does the organization capture data needed to identify and prioritize energy efficiency projects?	Lack of energy use data Lack of data specificity and control	Mandatory reporting and data tracking Sub-metering and EMS
4. Information sharing: How does the organization ensure that employees and decision-makers can spot energy efficiency opportunities?	Lack of knowledge and staff expertise Lack of project sharing Lack of employee engagement	Staff training and educational resources Organization-wide project database Cross-functional teams to advance initiatives
5. External factors: How do factors external to the organization influence decisions related to energy efficiency?	Leases disincentivize investment Organizations ignore rising energy prices Shifting priorities due to capital constraints	Leases that favor energy efficiency Financial decisions account for energy prices Sustained commitment to energy efficiency

paired with an example of a leading practice employed to address it. They fall into five categories: organizational priorities, access to capital, information collection, information sharing and external factors.

In addition to examining these barriers, this chapter will discuss two models related to successful energy program management that are utilized to address these barriers and plan for success. These models are EDF's Virtuous Cycle of Organizational Energy Efficiency and Ecova's Five Keystones framework for creating a holistic and strategic energy efficiency program. First, we discuss the five types of barriers, and best practice responses, for energy efficiency programs and projects.

1. Organizational priorities

In order to optimize efficiency efforts and initiatives, it is essential that leadership prioritize these efforts and make the commitment to energy efficiency known to, and accepted by, the rest of the organization. Without clear goals, effective management and benchmarking practices in place, organizations can lack the internal motivation and perspective to continuously improve their energy performance. In order to establish and maintain commitment to an effective program, the following elements should be established and actively managed:

- **Executive level sponsorship.** Without buy-in from top level leadership to advocate for resources and investments, as well as support from key stakeholders, an energy efficiency management effort will likely fall short of success. As identified in the Virtuous Cycle, actions of individuals within the company serve to reinforce one another over time. When leadership is engaged access to resources, opportunities for visibility, budget and information are more likely to follow.

- **Employee and other engagement.** Leadership alone cannot drive an effective energy efficiency program due to the complexity and nature of energy management considerations—not to mention the sheer number of people making day-to-day decisions that impact energy consumption in an organization. Staff across all levels of the organization need to recognize the effort as a priority, be engaged, and possess the resources needed to support and align with energy efficiency goals. Conflict with different stakeholder priorities such as short-term financial returns, alternative investment priorities and simple lack of buy-in need to be addressed head-on through a concerted effort to engage all critical stakeholders in dialogue.

- **Dedicated staff time, training and resources.** All too often, an energy management effort is launched without consideration given to the realistic staffing needs a robust program requires. Staff time should be formally dedicated to a program (included in their job descriptions, for example) and that staff should have access to the information, knowledge and tools needed to do the job well.

- **Accountability and incentives.** A change initiative as complex as the implementation of an energy management program requires that responsible staff have clear deliverables and performance expectations related to program goals. These should be reviewed at regular intervals and provide staff with clear expectations. Incentives can boost staff motivation with direct and indirect responsibilities and rewards tied to program success. Staff may be recognized for adhering to suggested conservation actions, or contributing to resources and/or information that support program goals.

- **Tie to organizational and financial goals.** An effective energy efficiency program should have goals that roll up directly to the organization's financial and other performance goals to ensure relevance and alignment.

- **Align various needs and efforts.** Different functional groups have different needs which individually may not justify or provide sufficient motivation for action. When these groups come together, however, the groups' needs can make a clear case for effective energy management. Consider some of these groups and their likely needs/benefits:
  - Operations: Cost-savings
  - Procurement: Risk management (cost control)
  - Corporate Social Responsibility or Sustainability
  - Marketing: PR and brand enhancement, competitive pressures
  - Investor relations: reporting transparency (e.g. Corporate Sustainability Report and/or CDP reporting)

Energy management actions typically require cross-functional collaboration and accountabilities; incentives may need to be looked at differently. For example, each department's performance indicators and the respective benefits they gain from participation and support should be considered. Development of clear **key performance indicators (KPI)** and shared goals can help to address some of these concerns.

Each organization has a different set of policies, personalities and decision-making processes. Some of these are formalized and documented in writing, while others are cultural and unwritten. The more these elements are understood, the higher the likelihood that a successful case for energy efficiency investments can be made and aligned with organizational goals. Unwritten organizational policies and processes can often be learned through careful observation during meetings as well as through candid conversations with trusted contacts. More formal assessment tools such as a **social network analysis** takes an inventory of process flows and knowledge transfer mechanisms that can identify issues and opportunities to better affect decision making and policy implementation. In any case, an organization's structure and goals should not always be taken at face value. Relationships, processes and many other dynamics affect the workings of the system and the clarity of its goals and priorities. Even with an airtight business case, energy efficiency investments may not take place. One needs to address organizational barriers in an effort to gain priority.

2. Access to capital

To ensure that energy-saving measures are funded on an on-going basis, budgetary processes and financial requirements need to be structured in ways that allow for sufficient and reliable access to capital. Without effective tracking of efficiency investments, consideration of financial criteria that account for long-term value creation and dedicated funding sources for efficiency, organizations can fail to fund many highly cost-effective and profitable energy performance improvements. Financial considerations, including access to capital, are covered in more depth in Chapter 6, which should be reviewed for more information on the subject, though it is important to highlight which barriers to success may be encountered:

- Size of upfront capital costs (real and perceived)
- Limited budget availability (real and perceived)
- Different functional groups pushing for operational vs. capital expenditures
- Uncertainty around ROI (real and perceived)
- Split incentives

3. Information collection

In order for organizations to identify and aggregate the energy data necessary to build a strong business case for energy performance improvements, it is necessary to invest in and support effective information collection systems. Without mandatory data reporting requirements, continuous tracking, facility **sub-metering** and energy management systems, organizations can lack the energy consumption data, specificity and control to effectively identify opportunities and verify energy savings realized from completed projects. To realize the maximum value of this data in order to drive efficiency improvements, it must be managed, interpreted and communicated to enable action.

Before data can be managed well, ensuring sufficient in-house knowledge, information or expertise should be assessed, especially in the following areas. Does the organization have:

- Data transparency—from visibility and management of utility bill consumption and demand, to **energy management system** data and alarms, or real time data?
- Dedicated staff with technical energy management knowledge?
- Knowledge regarding how to analyze/calculate benefits of energy efficiency investments such as life cycle cost-benefit analysis?
- Experience prioritizing opportunities?
- Experience with successful, holistic program implementation that leads to sustained savings? (The lack of sustained savings results in limited support for broader program implementation as illustrated with the Virtuous Cycle discussed below).

4. Information sharing

In order for organizations to develop the knowledge and communication channels necessary to regularly implement energy performance improvements, it is necessary to develop and support an effective data and information sharing strategy. It is essential to have staff training, educational resources, cross-functional teams, and/or an accessible database of performance metrics with potential and completed projects, to advance energy initiatives. Without any of these, organizations can lack the staff expertise, idea sharing, and employee leadership and engagement that ensure projects are completed and past experiences are leveraged for continuous improvement.

Care should be taken to make certain that data and information sharing initiatives are in line with existing processes and protocols. Look to existing change or engagement initiatives, such as health and safety, customer service or general training and development for opportunities to share knowledge with little need for investment. Consult with groups such as Communications, Human Resources, Operations, Training and Development and IT to explore opportunities.

When planning and implementing an information sharing strategy, it is important to consider a number of factors including, but not limited to:

- Needs of key audience groups and individuals
- Desired outcomes such as buy-in, awareness, behavior change, investment, performance improvement, etc.
- Depth of information or education required
- Key advocates to leverage for specific messages and audiences

5. External factors

In addition to the internal conditions that can affect an organization's capability to continuously improve its energy performance, a variety of external factors can also influence performance.

Without lease agreements that encourage on-going capital investment in facilities, high prioritization of risk management related to changing energy prices, and a sustained commitment to energy improvement despite fluctuating economic conditions, organizations can find themselves frustrated by landlord-tenant split incentives, unpredictable energy price fluctuations, and capital and staffing constraints that force priorities to shift erratically with time.

Additional considerations include, but certainly aren't limited to:

- Infrastructure limitations such as old, inefficient buildings, which can be expensive to retrofit.
- Landlord/Tenant split incentives: Owners have little incentive to make energy efficiency investments, because they would receive little financial benefit, and the return received by tenants would depend on the length of their tenure—only long-term tenants would be likely to benefit from making such an investment.
- Focus on short-term investment, or even survival, in a volatile or difficult market can mean that an organization is not in the position to consider investment for longer-term savings.
- Investor expectations: The expectations around quarterly earnings are intense and create a barrier for energy efficiency investments; this is particularly true for organizations that are publicly-traded or owned by private equity funds or other sophisticated investors.

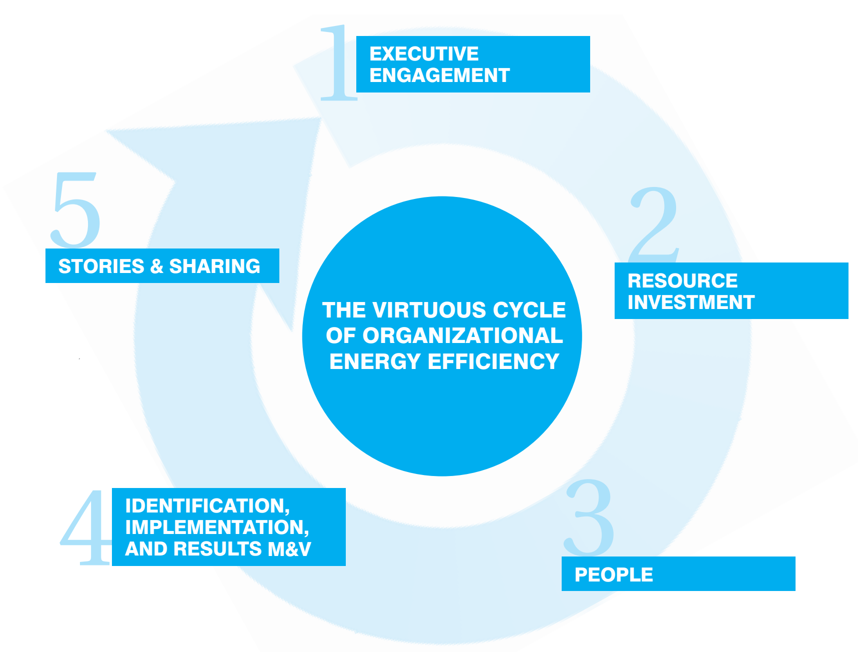
Frameworks to simplify development of strategic energy plans and implementation programs

In addition to the barriers identified above, it is important to ensure that the approach to barriers (and the inverse opportunities they present) be addressed from a holistic and strategic approach. Use of the Virtuous Cycle of Organizational Energy Efficiency and the Five Keystones for Total Energy and Sustainability Management models together can assist in achieving this.

EDF's **Virtuous Cycle of Organizational Energy Efficiency** (Figure 5.1) provides a perspective on the organizational considerations listed above and examines how these can deplete the

FIGURE 5.1

EDF's Virtuous Cycle of Organizational Energy Efficiency



momentum applied to an energy efficiency effort.[1] Additionally, the model encourages the examination of organizational goals, employee engagement, and the role that strategic initiatives and their successes play in creating a system of practices that support one another in enabling a reinforcing feedback loop of capability development. The five components of the "Virtuous Cycle" model affect one another for better or worse. When the performance of one component (e.g., Executive Engagement) improves, the performance of other components (e.g., Resource Investment) is more likely to improve in a "virtuous cycle" of positive feedback. Conversely, if the performance of one component worsens, this can negatively impact the performance of other components through a "vicious cycle" of negative feedback. In an optimized organization, all components function at full capacity, and the virtuous cycle runs smoothly to improve energy performance, generating maximum financial and environmental returns.

To better understand how the model works, each of the key components is explained below:

1. Executive engagement. Top-level executives recognize energy efficiency as a key strategic priority for generating cost savings and building long-term value. They shift from seeing energy as an inevitable and growing cost, and instead see its optimization as a source of continuous leverage for building an efficient and resilient organization capable of meeting its broader mission and goals.

2. Resource investment. In order to empower their organization to capture energy savings, executives make strategic, capacity-building investments to free up the necessary human and financial resources to make concrete action possible. Energy efficiency projects will pay for themselves but need dedicated seed capital to get started and attentive managers to ensure those seed funds grow and are reinvested on an on-going basis.

3. People. Resources are deployed to build staff capabilities and equip them to go after efficiency opportunities. Providing training opportunities, organizing cross-functional teams and establishing full-time positions all help to build employee knowledge, foster enthusiasm and create accountability for improvement. A workforce that feels ownership and responsibility for its energy use at all levels and is actively encouraged by leadership to work toward a shared vision of efficiency will maintain the momentum needed to make real progress.

4. Identification, implementation and results M&V. In order to aid the organization's staff, effective processes and tools are developed and refined over time to make sure increasingly ambitious projects are identified and implemented. Comprehensive and detailed energy data collection is vital to identifying sources of inefficiency and measuring the energy savings achieved through specific interventions—generating the verified financial and environment results that prove the benefits of taking action in the first place.

5. Stories and sharing. To maintain momentum beyond a first round of projects, successful results are leveraged into stories that are shared directly back with top-level executives, validating their prioritization of energy efficiency as a key strategy and proving the business case for doing additional energy projects. By re-engaging the executives continuously, success stories keep energy performance at the top of the agenda and encourage the investment of additional human and financial resources to go after even bigger wins, keeping the virtuous cycle spinning for yet another round.

Ecova's Five Keystones for Total Energy and Sustainability Management (Figure 5.2), for enterprise-wide total energy and sustainability management, helps organizations develop a strategic approach to energy management. The five categories structure the complexity of energy and sustainability management into mission-critical, actionable and results-oriented tasks. These five essential elements are described below.

1. Data. Data empower intelligent decision making and help organizations focus resources on high-impact areas and provide quantitative feedback critical for making adaptive management decisions.

2. People. Leadership, communication, knowledge management and employee engagement are critical to the success of any change initiative that relies on sustained organizational commitment and continual improvement to drive long-term success.

FIGURE 5.2

Ecova's Five Keystones for Total Energy and Sustainability Management

3. Infrastructure. Infrastructure and operations innovations continue to evolve, providing new opportunities to create organizational value through investments in efficiency, renewable energy and closed-loop material flows.

4. Marketing & reporting. Communicating accurately and effectively with customers, shareholders and other stakeholders maximizes your energy and sustainability efforts by enhancing brand image and increasing transparency.

5. Continual improvement. Given daily advances in the drivers and techniques for total energy and sustainability management, enduring success will be predicated on an organizations' adoption of continual improvement process management.

Using these frameworks

When dealing with barriers around energy management, it can be helpful to share these frameworks with stakeholders and explain the prevalence of the barriers and challenges, but also point toward simple solutions. For example, when dealing with challenges around stakeholder engagement (People keystone) or data availability and communications planning (Data and Marketing & reporting keystones), consider presenting the Five Keystone Framework—explain the five critical components, and then discuss the Virtuous Cycle and the self-reinforcing nature of the interplay—which can be extremely effective in driving improved and sustained energy performance. Sharing these frameworks, alongside some of the identified barriers can provide a positive solutions-oriented perspective that can in and of itself drive action to overcome barriers.

Information gathering guide

- What information-sharing, employee engagement and organizational change programs and mechanisms are in place and work well? Who is responsible for these and how can you collaborate to build upon those existing resources?

- What are the needs and challenges facing leaders representing different functional groups in relation to an energy efficiency effort? Utilize the five barriers, Five Keystones and Virtuous Cycle to frame your discussions with leaders and other stakeholders.
- What feedback do key stakeholders have when presented a summary of barriers, with the Five Keystones and Virtuous Cycle models? What solutions do they suggest for overcoming the barriers?
- What are overarching organizational priorities, in the short-, mid- and long-term? Where does savings investment fall in line with those priorities and what factors may put those priorities at risk?
- What is the quality and quantity of data available to inform a program and measure progress? How can these data be used to align program goals with organizational goals?
- What are the most effective means of gathering and sharing information? What are the formal and informal mechanisms for doing so? What information needs to be shared with whom and for what purpose?
- What stakeholders outside of staff and leadership should be engaged in an energy efficiency effort?

CHAPTER 6

Energy efficiency financing

Goals

- Develop a financial analysis method that reflects the host organization's investment analysis framework
- Develop a financial analysis approach that evaluates **life cycle costing (LCC)** of projects rather than just the initial investment
- Develop a plan recommending energy efficiency projects with identified external or internal funding options
- Understand best practices for overcoming common barriers to funding energy efficiency projects

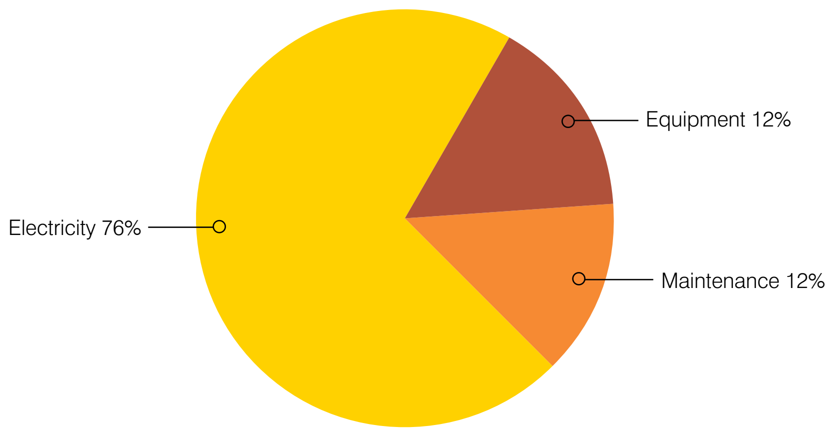
Overview

Energy-saving projects are different from most maintenance projects in that they often pay for themselves in cost savings over the life of the equipment. Energy efficiency projects tend to fall into one of three major categories:

1. Low-cost opportunities that cost less than the organization's defined capital investment threshold. The costs associated with these types of projects are typically considered "operating expenses" rather than capital expenditures.
2. Capital investments when a non-maintenance investment is greater than the defined capital threshold. From an accounting perspective these types of projects are classified as capital expenditures.
3. Purchases to replace failing or aged equipment or for new construction that is not initiated purely to meet energy efficiency objectives, yet often present an energy efficiency opportunity. For these investments, the incremental cost—the additional cost of a more efficient piece of equipment—should be compared to the lifetime energy savings of the efficient equipment over the standard option. These projects are typically categorized as capital investments.

Evaluating a project based on the total costs of using equipment over its entire expected life is referred to as life cycle costing (LCC), sometimes called total cost analysis (TCA). LCC considers the initial operating expense or capital investment, as well as the energy and maintenance expenses associated with the equipment, discounted into present value equivalent dollars. Knowing the LCC of a piece of equipment is important because the energy expenses over its lifetime can be several times the initial cost of the equipment. For example, the upfront costs for a compressed air system represent only 12% of the total life cycle costs of the equipment while costs for electricity account for 76% of the LCC (Figure 6.1). Traditional

FIGURE 6.1
Life cycle costs of compressed air system



Source: Industrial Energy Analysis. http://industrial-energy.lbl.gov/node/169

low-bid contracting and purchasing strategies focus on minimizing the initial purchase cost only—which can often result in higher energy use and operating expenses. When replacing failed equipment or specifying equipment for new construction, a marginally larger initial investment in more efficient equipment can result in a positive net present value (NPV) compared to lower initial cost alternatives, including continuing with the existing status quo.

Each potential energy efficiency project will require a forecast that includes the initial or incremental investment along with the annual savings. Energy cost savings will likely be the main financial driver, but the analysis should also account for costs associated with changes in maintenance labor and equipment replacement frequency, which may also be significant.

It is important to keep in mind that the cost and savings values used in pre-project financial analysis (evaluating a project before it is implemented) are estimates, and estimates often have significant uncertainty. This uncertainty results from difficulties in accurately forecasting costs and performance, owing to the complexity of a system's physical characteristics and operations. Post-project analysis has the benefit of using actual project costs, but must still use estimates of future energy and maintenance costs. When performing a financial analysis, clearly document all assumptions and conduct a sensitivity analysis to understand which variables have the most influence on the results and recommendations. Although calculations may provide precise results, it should not be assumed that these calculations will always accurately predict future outcomes.

As an example of project complexity and uncertainty, consider impact of the most common efficiency upgrade, lighting, on a building's HVAC system. Traditional incandescent bulbs generate significant heat; when they are replaced with more efficient fluorescent lamps, less heat is produced in the space. In the summer this may result in additional savings due to lower air conditioning use. However in the winter, heating bills may actually increase since the heat that was previously generated by lighting must now be provided by the HVAC equipment to maintain a comfortable working environment.

Financial analysis of efficiency opportunities

The EDF Climate Corps Financial Analysis Tool is designed to help expedite a simplified investment analysis. This chapter discusses the overall framework of the tool and the financial variables it uses.

Net Present Value (NPV), is the sum of forecasted discounted cash flows minus the initial investment, and is the primary measure of a project's attractiveness. Using NPV properly positions energy savings opportunities as an investment, not as an expense, regardless of whether the project is paid for out of operating budgets or capital investment budgets. In general projects with a positive NPV should be considered carefully for implementation.

There are several variables included in the Financial Analysis Tool that influence the calculation of NPV, including discount rate, tax rate and depreciation.

Discount rate: Generally the discount rate that should be used in the Financial Analysis Tool will be the host organization's internal hurdle rate. Discount rates reflect both the time value of money and the risk involved in a specific project. Energy efficiency investments may often have lower risk than other investments that organizations can choose to pursue. From a strictly financial perspective, efficiency investments should therefore be evaluated using correspondingly lower discount rates.

Some organizations have different hurdle rates for low, medium and high risk projects, or at a minimum consider the risk level in evaluating the project in comparison to other investment opportunities. While energy efficiency experts have confidence in the low level of risk associated with efficiency investments, many corporate leaders perceive a higher risk for energy efficiency investments than investments they are more familiar with. For example, an executive may be more comfortable investing in remodels that are designed to drive higher traffic and sales, than investing in less familiar energy efficiency opportunities.

What is the right discount rate?

Determining the right discount rate in the NPV calculation is very important as the discount rate has a strong direct effect on the NPV. If the discount rate is estimated to be too high relative to the risk represented by the investment, the NPV may be lower than it should be, or even negative. This may result in the avoidance of investments that might have been made otherwise and thus represents a lost opportunity. Most CFOs will not want to adjust discount rates for relatively small investments because of the time and discussion entailed in settling on the "right" number. If a large energy efficiency investment, such as a new HVAC system, is on the threshold of profitability, however, it may be worth recommending a sensitivity analysis using multiple discount rates.

As noted above the most appropriate discount rate is the organization's **hurdle rate** or discount rate for low risk investments. If your host organization is struggling with assigning a low risk discount rate to energy efficiency projects because it is unfamiliar or lacks experience with these types of initiatives, it can be helpful to share the following about where leading organizations with experience in the industry set their discount rates:

- EPA uses a 4% real discount rate (not considering the effects of expected inflation) in its ENERGY STAR efficiency investment calculators.
- The *2013 California Building Energy Efficiency Standards Life-Cycle Cost Methodology* issued by the California Energy Commission defines a 3% real (inflation adjusted) discount rate for energy efficiency analysis.[1]

Tax rate: Some companies will want to analyze investments on a pre-tax basis and some on a post-tax basis. Whereas a post-tax analysis is more accurate, it also creates opportunities for errors if the company's tax policies are not followed precisely. The Financial Analysis Tool is structured to include tax and depreciation impacts if desired. The default marginal tax rate is 35%.

If the financial manager of the host company prefers a post-tax analysis, it is important to learn from finance managers how purchases for lighting and other improvements are depreciated. In particular, some purchases may qualify for a Section 179 deduction, which allows firms to deduct the full expense in the year of purchase.[3]

Depreciation: Organizations will vary in terms of which assets they choose to depreciate. Using IRS guidelines, the Financial Analysis Tool assumes five years for computers, copiers and printers, seven years for office fixtures (furniture) and equipment, and 39 years for HVAC systems.[4] In some cases, special or temporary tax treatment for some capital projects allows full depreciation to be taken in the same year that the investment is made—effectively treating the capital expenditure as an expense. Discuss the organization's specific approach to depreciation and special tax treatment with the corporate tax specialist, and keep in mind that some organizations will be tax exempt. If taxes are not included in the financial analysis, including or excluding depreciation will have no effect on the analysis as there will be no **tax shield**.

Other financial metrics for assessing efficiency projects

Simple payback refers to the length of time required for accumulated savings of a project (in dollars) to equal the cost (in dollars) of the initial investment. This metric is frequently used to assess energy efficiency investments, especially in the commercial and industrial segments. The calculation is simple to understand and can be convincing when the project payback period is one to three years. Simple payback calculations typically ignore the time value of money and cash flows that occur after the payback period, thus underestimating the value of a longer-term investment. Payback calculations should be accompanied by an NPV calculation to allow for a full assessment of the efficiency opportunity.

The **internal rate of return (IRR)** is closely related to NPV and is used by corporations just as often. If IRR is used as the principle criterion, however, it could sway the corporation towards efficiency improvements that require little to no upfront investment, even if these generate less financial value (and energy savings) to the firm. On a more positive note, the relatively simple cash flow structure of most energy efficiency projects prevents some of the common calculation errors that plague this metric.

The run rate is the annual dollar value of savings. Some hosts will be interested in the ongoing benefits to operating budgets delivered through investments in energy efficiency. The run rate calculates the net annual benefits (i.e. reduction in energy expenses minus any added operating expenses associated with the project) that are assumed for a specific number of years following the investment in efficient equipment.

Return on investment (ROI), the most commonly used investment metric, is a simplistic measurement that does not consider the time value of money, but does provide flexibility in what is used to determine costs and return. This flexibility depends on the underlying assumptions around those costs and returns and ROI calculations often don't include the Life Cycle Costing considerations (see below). Given this, and the fact that ROI does not consider the time value of money, NPV or IRR are much more sophisticated and suitable measures for energy efficiency investments.

Life cycle costing—items to include

When conducting financial analysis it is important to use the correct financial metric (NPV or IRR are most recommended) and to understand the parameters of these metrics and what they represent. It is also important, as noted in the opening of this section, to include a full accounting of all the costs and benefits associated with a particular investment opportunity over the life of the equipment. The analysis should include the following components, where relevant:

- Initial investment (including installation costs)
- Energy expenses avoided through the efficiency upgrade during equipment life

- Estimated maintenance expenses avoided or incurred during equipment life, including:
  - replacement costs
  - labor costs
  - downtime costs

There may be non-financial benefits to consider and share with decision makers along with supporting case studies or documentation. Generally, however, it is not best practice to include estimates in the financial analysis itself. Some of these benefits may include:

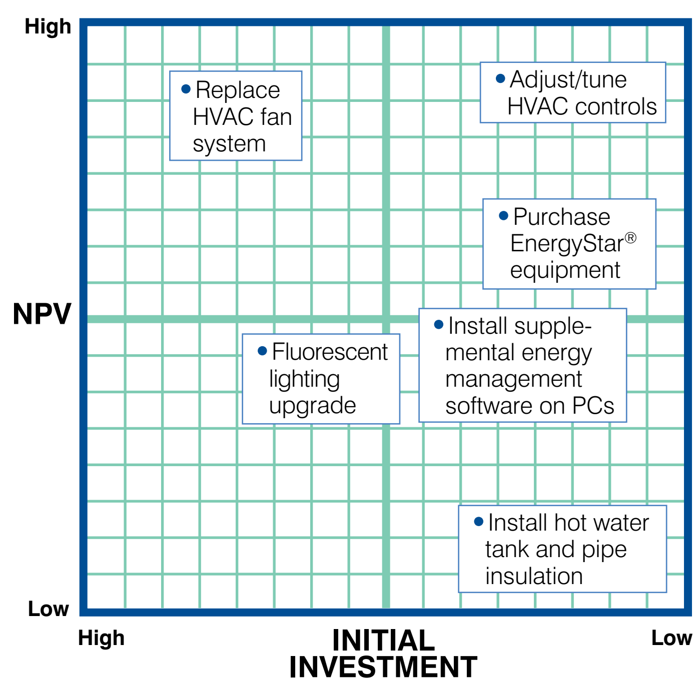
- Risk reduction associated with reduced exposure to volatile energy prices
- Improved lighting quality or indoor environmental quality, leading to:
  - potential reductions in absenteeism
  - improved safety
  - increased productivity
- Environmental benefits—i.e., Greenhouse Gas emissions reductions
- Contributions to Corporate Social Responsibility strategy and related brand enhancement and employee engagement benefits

Prioritizing efficiency investments

From a financial perspective, the most attractive investments will be those that generate the greatest cash flow in excess of the cost of capital—those with the largest NPV. Recognizing that

FIGURE 6.2

Example prioritization matrix for potential energy efficiency investments



the size of the upfront investment does have an impact on the decision, one way to present this information is with a matrix with NPV and initial investment on each axis as represented in Figure 6.2.

Investments with relatively low initial costs and high NPV or energy savings potential, such as "Adjust/Tune HVAC controls" in Figure 6.2, should be pursued first.

Alternatively a weighted prioritization table might include the following attributes, where the weightings of the attributes can be adjusted to the host needs and priorities:

- Payback period
- NPV
- Upfront capital required
- Cost of environmental benefit (i.e. cost per metric ton of avoided carbon dioxide- equivalents)

Navigating capital budget and expense budgets

Using Total Cost Analysis and engaging decision makers and stakeholders is essential to overcoming the challenge of bringing together capital and operating budgets around a common goal of funding energy efficiency projects. Analysts will need to be creative in showing how the organization as a whole benefits, and presenting recommended capital expenditures in a framework for making the capital budget "whole" to compensate for the higher initial cost of energy projects. The following discussion provides context for this challenge and recommended best practices to address it.

Most organizations budget separately each year for capital and operating expenses, each with its own independent review and approval processes. A common barrier to implementing energy efficiency projects is that they are funded from the capital budget but result in savings to the operations expense budget, where utility costs are counted. Host finance staff can provide valuable assistance in implementing energy projects by helping those with the authority to approve the projects become aware of the benefits and costs to all budgets over the lifecycle of the investment.

Additional challenges can present themselves at organizations where each site is responsible for a pre-determined operating expense budget, which typically will not include provisions for efficiency improvements. This challenge is exacerbated where those responsible for the operating budgets are incentivized for maintaining spending at or below the budgeting level on short term cycles such as monthly or quarterly. In these cases there may significant resistance to undertaking operating expenses even for low cost efficiency measures with relatively short payback such as one to three years. This is often the case with chain retail and restaurants, where site managers may relocate frequently and the bonus structure and management approach can encourage very short-term decision horizons.

Energy capital projects are often financed out of the facility capital budget. In most organizations this budget is intended to fund "major maintenance" that includes the replacement of building equipment that fails or is near the end of its useful life. This budget is often tightly controlled and minimized since purchases of replacement equipment are traditionally thought of as unlikely to increase revenue or profits for the organization. When confronted with the constraints of a fixed budget, the higher costs of energy efficient equipment (when compared to standard energy consuming equipment) often overshadows and marginalizes the lifetime financial benefits provided by this equipment. There is a perceived downside to allocating more of one's budget to replace broken HVAC units with high efficiency units—it can result in reduced funds for other needed equipment replacements and may reflect poorly on decision makers. To address this problem, demonstrate to relevant stakeholders and budget managers, the long-term expense-reducing value of more efficient, if more expensive to purchase, equipment.

Utilities often offer incentives to offset the higher initial cost of energy efficient equipment. However, many organizations fail to account for these incentives in the capital budget used to fund the project. So while the organization as a whole benefits from the utility funds, the budget and its owner who must approve the project may not. This can reduce the likelihood of the investment being approved. Regardless, identifying the utility incentives and including those in the life cycle cost analysis is important to show the overall organizational benefits and make the case for project implementation. A useful resource for investigating incentives is the Database of State Incentives for Renewables & Efficiency (dsireusa.org), which covers incentives at both the state and federal levels. Utility incentives may vary significantly from one site to the next, so it is important to understand the specific incentives for each specific location.

Similarly, the owner of the operating expense budget that would benefit from energy projects may not have a capital budget to use to fund those projects. Thus organizational silos and standard budgeting and approval processes may hinder a project that the financial analysis indicates should be funded.

Some common best practices that are used to overcome these issues:

1. Engage relevant financial decision makers responsible for the various aspects of financial management. This means discussing the challenges outlined above and potential approaches for overcoming those barriers, with financial analysts, the CFO and capital budget directors. Identify the language, metrics and assumptions they use in financial analysis, as well as their concerns and perception of opportunities in regards to energy efficiency projects. Ensure that your financial analysis reflects an understanding of their typical approach.

2. Understand the host's financial and non-financial drivers and include information about the financial and non-financial benefits of your recommended upgrades in the project analysis.

3. Present the recommendations simultaneously to all financial stakeholders and facilitate a conversation regarding the benefits and impacts of the recommendations on specific budgets, as well as the overall benefits to the organization.

4. Recommend the creation of a dedicated energy efficiency capital budget, with specific expectations for returns. This budget can fund high priority capital projects. It can also close efficiency project funding gaps for departments that have budgets for basic equipment replacement, but not incremental amounts to enable the purchases of higher efficiency equipment.

Financing investments

Once investments are prioritized, the next challenge is to determine how they will be paid for. As noted above, financing can occur internally or externally. There are four broad categories of funding: cash or institutional revolving funds (internal), debt (.e.g. bonds), equipment leasing and performance contracts (external).

Cash: Paying with cash is ideal if the investment is relatively small and the organization has a strong balance sheet. The organization can depreciate the investment and no adjustments need to be made to the base NPV analysis.

Some organizations may maintain dedicated budgets for energy efficiency improvements. When these funds are replenished with the energy savings from the projects they finance they are known as **green revolving funds (GRF)**. GRFs are becoming more popular in the university segment. More information on the topic is available from the Sustainable Endowments Institute.[5]

Debt: if the upfront cost of the investment is greater than available cash, debt financing may be required. It may be useful to identify whether there are any below market rates available for specific energy efficiency investments. These might include financing through community development funds, or through special government or charitable funds.

Lease: Although uncommon for most energy efficiency investments, certain office equipment is often leased. Unfortunately the leasing decision is typically independent of whether the equipment is ENERGY STAR certified. There is also some capital lease options for larger investments which are typically related to the performance contractor model explained below.

Performance contracts: This method of financing shifts some or all of the risk to an outside vendor and can be applied to owned and leased buildings. In this structure, a service provider, often called an Energy Service Company (ESCO), pays the up-front costs of an efficiency upgrade and receives the resulting savings from reduced energy costs. Alternatively, the service provider pays a percentage of the up-front costs in exchange for a percentage of the resulting savings. Any performance contract should be valued against the cash flows from the purchase option (i.e. funding with debt financing) and should consider staff time required to negotiate the contract and manage the project implementation and maintenance. This model is mostly used by institutional organizations (municipalities, universities, schools and hospitals), which tend to have greater equipment needs, subsequent lower transaction costs, and fewer complications of ownership present in the commercial and industrial segments. Due to differences in capital budgeting structures in the private sector, performance contracts may be less attractive than by institutional organizations.

Other: A variation on debt financing is referred to as PACE (Property-Assessed Clean Energy) financing. PACE is innovative means of financing energy efficiency upgrades whereby municipal governments offer a bond to investors and then loan the money to consumers and businesses to fund energy efficiency investments. The loans are repaid over the assigned term (typically 15 or 20 years) through an annual assessment on their property tax bill. Given that the municipal bonds require a complex approval process, and are only available in certain jurisdictions, opportunities to use PACE financing (or institution specific bond financing) are limited. Unfortunately PACE programs are very young with a limited track record and face some challenges before they will become widespread.

Additionally, there are some emerging financing options such as on-bill repayment, Efficiency Services Agreements and Managed Energy Service Agreements. There are strengths and benefits with each of these, but also challenges to overcome before then become more widely available. For more information on these emerging financing options as well as performance contracting and PACE financing, see EDF's *Show Me the Money*.[6]

Information gathering guide

- The CFO or controller should be able to provide information on the organization's budgeting process and investment criteria.
- Who are the decision makers for approving capital and operating budgets, and what are the typical budgeting processes? Does the organization have specialized budgeting methods for energy efficiency investments?
- How are capital versus operating expenses determined?
  - Is the investment threshold applied at the level of individual equipment pieces or is there aggregation of items installed at a particular site? For example, if four new energy efficient

motors are installed in one site's walk-in cooler, and individually each motor falls below the capital investment threshold, but when added together they exceed the threshold, does the company typically capitalize these expenses?

  - Are installation expenses or project management expenses capitalized? If so, are there special considerations to be aware of?
  - For hosts with multiple sites, are upgrades or equipment purchases that fall below the threshold of being classified as a capital investment but are implemented at a large number of sites, typically bundled together and thus treated as capital investments? If so, what is the bundling threshold?
- What discount rate does the host organization typically use? How was this discount rate determined? Are there different rates for different levels of investment risk?
- Does the host organization evaluate investments on a pre- or post-tax basis? If post-tax, what tax rate does the organization assume?
- Are the following items depreciated? On what schedule?
  - Lighting equipment
  - Computers and office equipment
  - HVAC systems
  - Specialty equipment relevant to the organization (processing equipment for industrial facilities, cooking equipment for restaurants, etc.)
- Has the organization considered developing a revolving fund, or other central budget to support energy efficiency investment?
- Can the host organization provide an analysis or presentation for a recent, successful investment?
- When are budgets determined for each department? Is there flexibility in this process or is it fixed?
- When does the host organization choose leasing over purchasing assets?
- What types of services does the host organization outsource and how might those services impact energy efficiency project planning?
- Does the organization have an outside contractor that does preventative maintenance (PM) on a regular schedule and thus could help minimize installation costs associated with some efficiency upgrades by rolling in the installation expense with an already planned trip (that is paid for out of the PM budget, not the efficiency budget)?

Notes

[1] California Energy Commission http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/2011-01-14_LCC_Methodology_2013.pdf

[2] Internal Revenue Service, U.S. Department of Treasury, "Electing the Section 179 deduction." http://www.irs.gov/publications/p946/ch02.html

[3] Internal Revenue Service, U.S. Department of Treasure, "Publication 946: Additional Material," Table B-1. Table of Class lives and recovery periods. http://www.irs.gov/publications/p946/ar02.html

[4] United States Code, Title 26, Section 168: Accelerated Cost Recovery System. http://www.law.cornell.edu/uscode/text/26/168

[5] *Green Revolving Funds: An Introductory Guide to Implementation & Management* http://greenbillion.org/wp-content/uploads/2013/01/GRF_Implementation_Guide.pdf

[6] Environmental Defense Fund, *Show Me the Money, Energy Efficiency Financing Barriers and Opportunities*, July 2011.

CHAPTER 7

Benchmarking energy usage and interpreting utility bills

Goals

- Understand the amount of electricity and gas used at the host organization and current payment and pricing structures
- Benchmark electricity and gas usage against similar facilities

Overview

Tenants pay for electricity through one of three ways:

- **Direct meter:** The tenant contracts with, and is billed by, the utility.
- **Submeter:** The tenant pays the landlord based on the meter as well as a "handling fee" that will vary based on negotiations, but is typically not more than 12%.
- **Rent inclusion:** The tenant pays a fixed amount per square foot.

If an organization is directly metered or sub-metered, it will have financial incentive to improve the energy efficiency of its space. Any reductions in usage or **peak demand** will directly reduce the organization's monthly utility bills. However, if an organization is paying for energy by rent inclusion, it will have little financial incentive to reduce usage until a sub-metering agreement is negotiated.

There are several different ways utilities charge large customers:

- **Energy and demand:** This is the most common pricing scheme. The dollar amount that organizations pay at the end of each billing period is based on an energy charge and a **demand charge**. For electricity, the energy charge is based on the total amount of energy used and is measured in **kilowatt-hours** (**kWh**, a unit of work). The demand charge is based on the maximum load in **kilowatts** (**kW**, a unit of power) drawn by the organization's equipment, normally recorded over a 15-minute time interval each month. The demand charge is significant because it sets the amount of generation and transmission system capacity the utility needs to build to meet customer demand. Building new power plants is expensive and can lead to higher electricity rates for customers. For more information on demand and demand response programs, see Chapter 16.

  Electric bill = (energy charge x energy usage) + (demand charge x maximum load)

- **Time of use:** This pricing scheme is also based on energy use and demand; however, there are different rates for peak and **off-peak** demand and different seasons. Under this scheme,

TABLE 7.1

U.S. average energy use intensities for commercial buildings

	BUILDING SIZE		
	1,001 to 10,000 square feet	10,001 to 100,000 square feet	More than 100,000 square feet
Electricity intensity	15.1 (kWh/sq. ft.)	11.8 (kWh/sq. ft.)	16.4 (kWh/sq. ft.)
Natural gas intensity	0.675 (therms/sq. ft.)	0.409 (therms/sq. ft.)	0.388 (therms/sq. ft.)

Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table C21. Electricity Consumption and Conditional Energy Use Intensity by Building Size and Table C31. NaturalGas Consumption and Conditional Energy Use Intensity by Building Size, 2003,"r eleased September 2008. http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

electricity drawn during periods of highest demand will be more expensive than electricity drawn during periods of lower relative demand.

- **Real-time pricing:** Prices vary by hour and day, and are linked to the wholesale market price. In addition, many utilities offer **demand response (DR)** programs that provide monetary incentives for customers to reduce their energy usage during periods of peak **demand**, most often on hot summer days. Opportunities to take advantage of demand response programs should be evaluated on a case-by-case basis.

Benchmarking energy usage

The energy use intensity of a facility can be expressed by two values: electricity intensity and fuel intensity. To calculate these values for an office building or floor, simply divide total electricity or fuel usage of the space for one year by total square footage of office space.

For example, Building X is a 50,000-square-foot facility with annual electricity consumption of 1,000,000 kWh and annual natural gas consumption of 7,500 **therms**:

$$\text{electricity intensity} = \frac{1{,}000{,}000 \text{ kWh/year}}{50{,}000 \text{ sq. ft.}} = 20 \text{ kWh/sq. ft.-year}$$

$$\text{fuel intensity} = \frac{7{,}500 \text{ therms/year}}{50{,}000 \text{ sq. ft.}} = 0.15 \text{ therms/sq. ft.-year}$$

To determine how a building performs compared to similar buildings, compare its energy use intensity values to known benchmarks for the building type and geographic area. If a given building has energy use intensity values that are higher than the benchmarks, there could be significant potential for cost-effective energy efficiency improvements.

One of the most popular options for facility benchmarking is the EPA Portfolio Manager, an online tool that has been used to benchmark 250,000 commercial buildings as of early 2012. Portfolio Manager uses input information about building characteristics and energy consumption for comparison against CBECS data. A rating of 1–100 is assessed, corresponding to a percentile rank for that building compared to similar buildings nationwide (e.g., a rating of 90 indicates that a building has better energy performance than 90% of similar buildings).

Information gathering guide

- The facilities manager or head of operations should have information about electricity usage.
- Ask for monthly electricity bills going back at least two years. Is this information available through the utility's website?

- How many meters are in the building? What portion of the facilities do they cover?
- Check the lease agreement to determine if the organization pays the utility directly for energy use or if payments are made to the landlord or management company?
- What is the host organization's electric pricing or rate structure agreement?
- How many employees are located in the space?
- Are there any employee activities that drive significant incremental energy usage (e.g., high intensity computing)?
- What is the square footage of both the total building and tenant-occupied space?

Additional information

- For further information on billing structure and demand response programs, consult the regional utility company.
- For more information on CBECS and energy use intensities by climate zone and region, see: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS), 2003." Released September 2008. http://www.eia.doe.gov/emeu/cbecs/cbecs2003 detailed_tables_2003/detailed_tables_2003.html
- For more information on EPA Portfolio Manager, see: EPA "Portfolio Manager Overview." http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

CHAPTER 8

Energy management systems

Goal

- To determine whether host organization could benefit from an energy management system (EMS) installation or upgrade

Overview

Energy Management Systems (EMS) allow for centralized monitoring and control of energy use across building systems, for example, centralized monitoring and control of lighting, HVAC, refrigeration and electric meters across building systems. The upgrades to controls for lighting, office equipment, HVAC and water heating that have been described in previous chapters all constitute "stand- alone" control systems (e.g., **photo sensor**-based dimming controls for lighting); an EMS is a "central" control system, allowing facilities managers to operate all stand-alone control systems in a building simultaneously from a single control pad or web application. Sensors throughout the building that measure conditions such as light level, indoor/outdoor temperature and water temperature (called "monitoring points"), serve as data inputs for the EMS, which uses that information to adjust control components (called "control points") such as **dimmers**, **chillers** and **boilers**. When a new EMS is installed, it is a best practice to replace sensors to ensure reading accuracy. Many sensors are proprietary and thus are not compatible with new EMS systems.

In recent years, EMS technologies have become more affordable and more widely used. According to the California Energy Commission (CEC), vendors estimate that energy management systems are currently installed in 75% of commercial facilities with more than 50,000 square feet of commercial space.[1]

Building management systems (BMS) or building automation systems (BAS)

Facilities managers and energy efficiency engineers may also refer to **building management systems (BMS)** or **building automation systems (BAS)**. The distinction between these terms and EMS often depends on context or the preferred terminology of a given manufacturer, and can be confusing.

BMS or BAS typically include automated controls for a range of building systems: HVAC, security, fire alarms, sprinklers, etc. The term EMS is usually used to refer to an automated system specifically engineered to manage energy use, which often employs additional and more sophisticated energy monitoring and control technologies than a BMS or BAS. However, some systems referred to as EMS can be configured to control other building functions in addition to energy management. Conversely, some BMS or BAS are designed to include sophisticated energy management technologies. As a result, the terms BMS, BAS and EMS refer to an overlapping range of system types and are often used interchangeably.

Energy information systems (EIS)

Energy usage data is data just like the data it is monitoring, such as lighting status and space temperatures. Most EMS have the capability to record and track the real-time energy usage data of a building or floor, and to transmit that data to a central data repository, which should be done daily for proper analysis at a later date. Many EMS systems have a limited amount of storage so the trend data may only be stored for two to ten days. Increasingly though, **energy information systems (EIS)** are being used to supplement EMS with functions including weather information, pricing structures and more sophisticated real-time energy usage data. An EIS can enable an organization to further reduce energy costs by integrating factors such as weather and energy prices into energy management decision making. EIS also enable organizations to participate in utility **load curtailment** programs, where utilities incentivize end users to reduce energy consumption during periods of peak demand.

Information gathering guide

Information should be gathered from the host organization's facilities manager, and consideration should be given to whether a building can benefit from an EMS installation or upgrade.

Questions for the host organization's facilities manager

- Does the host organization currently use an Energy Management System (EMS)? If so, when was it installed?
- Does the host organization currently use an Energy Information System (EIS)?
- What is the building/floor's current peak demand?
- Does the host organization currently participate in a utility peak load curtailment program? If so, what has the organization's experience been? If not, has the organization considered participating in such a program?
- Does the facilities engineer feel that building energy performance would benefit from increased automation of systems controls? What portion of efficiency controls is currently being controlled manually?

Questions for an EMS installation engineer

- Has the host organization identified a good candidate for a new EMS installation or EMS upgrade?
- What is the range of options available in terms of system sophistication? What are the estimated savings potentials and installation costs associated with each of these options?
- What sensor and control points does the host organization's building currently employ? Can EMS be configured to interface with existing sensors and system controls?
- What additional sensor and control points would improve EMS performance?

EMS options

New EMS installation/retrofit upgrade

Energy Management Systems range broadly in complexity. More complex systems have greater numbers of "points"—monitoring points (inputs) and control points (outputs)—which typically translate into higher energy savings potential, as well as higher installation costs. More complex systems are more fully automated and require minimal manual adjustment by building operations staff once the systems are operational.

According to the California Energy Commission (CEC), any building with a peak demand over 200 kW should consider employing an EMS.[2] Additionally, if an existing EMS is over 12 years old, full system replacement should be considered.[3] If a host organization currently employs an EMS that has been installed within the last 12 years, it may be advantageous to undertake a retrofit upgrade to a more sophisticated system. A retrofit upgrade can often be accomplished by installing and connecting additional sensor and control points to the existing EMS system and reprogramming the software to incorporate the added equipment. An EMS specialist can advise on the feasibility of retrofit upgrades.

Selecting the correct system for a given building requires considering the needs and capabilities of the organization's operations staff. Clearly, an organization should not invest in a system with features it is unlikely to fully utilize. The best EMS for a given organization is the system that maximizes energy savings potential per dollar invested. An EMS specialist should present a range of installation or upgrade options accompanied by estimates of energy savings potential and installation cost. These estimates, along with knowledge of host organization needs, can provide the basis for analysis of whether an EMS installation or upgrade is worthwhile and what level of system is best for the organization.

Costs and rebates: The cost of an EMS installation or upgrade varies greatly depending on the number and type of sensor and control components installed. Table 8.1 provides a rough estimate of the cost of new systems of varying degrees of complexity. Upgrades typically cost approximately $1,100 per point.[4]

On a case-by-case basis, utilities will provide rebates per verified kW of load reduced as a result of an EMS or EIS installation or upgrade.[5]

Financial case study: In 2002, Swinerton, Inc. moved into new 67,000-square-foot headquarters at 260 Townsend in San Francisco. The existing building management system (BMS was 20 years old and in need of replacement. Swinerton installed a new Emcor BMS with timed start-up and shutdown for lighting and HVAC. The new BMS system also allowed Swinerton to track energy use on each floor separately, known as **sub-metering**) and charge the groups using each floor their true portion of the energy costs. The BMS installation cost $40,000 and reduced electricity and gas costs by 50%, achieving a 1.7-year payback period for the project.[6]

TABLE 8.1

EMS system complexity levels and costs

Systems complexity level	Control components	Average cost per building square footage
Static	Packaged units and chiller start/stop control based on time and temperature; fan and possible lighting on/off control based on time; and/or water temperature control based on time and temperature	$1.75
↓	Static plus: Economizer controls; Chiller plant controls; variable-speed drive control; night temperature control; CO_2 ventilation strategies; and/or lighting control strategies	$3
Dynamic	Plus: optimal start/stop; demand limiting strategies; daylighting controls; thermal storage controls; and/or optimizing HVAC operations	$4

Source: California Energy Commission, "Technical Options Guidebook," p. 28. http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF

Financial case study: Until 2001, the 1.4-million-square-foot Hewlett Packard (HP) campus in Roseville, California, was operating an EMS with limited automation, which required labor-intensive manual adjustment of controls in order to curtail energy loads during peak demand periods. Using funds available from the California Energy Commission and the local municipal utility (Roseville Electric), HP upgraded its EMS and added additional sensor and control points for ventilation and lighting systems. The changes gave HP the capability to shed 1.5 MW of its 10.9 MW peak demand without disrupting occupants. HP now uses the EMS load-shedding capabilities on a day-to-day basis, saving $1.5 million annually in energy costs as a result. The EMS upgrade cost $275,000, but incentives covered $212,000 of the project cost, giving HP a payback of less than one month on the project.[7]

Additional information

For more information on EMS installation and retrofit upgrades, see:

- California Energy Commission, "Enhanced Automation: Technical Options Guidebook," Section 5, Energy Management Systems. http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF
- California Energy Commission, "Enhanced Automation: Business Case Guidebook." http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_BUSINESS_CASE.PDF

For more information on EIS and load curtailment programs, see:

- California Energy Commission, "Enhanced Automation: Technical Options Guidebook," Section 6, Energy Information Systems. http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF

Notes

1 California Energy Commission, "Technical Options Guidebook," p. 24. http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF

2 California Energy Commission, "Technical Options Guidebook," p. 24. http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF

3 California Energy Commission, "Technical Options Guidebook," p. 32. http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF

4 California Energy Commission, "Technical Options Guidebook," p. 28. http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF

5 PG&E, "Customized Retrofit Incentives." http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/ief/

6 California Energy Commission, "Enhanced Automation Case Study 12. Swinerton." http://www.energy.ca.gov/enhancedautomation/case_studies/CS12_Swinerton_w2.pdf

7 California Energy Commission, "Enhanced Automation Case Study 2 Hewlett Packard." http://www.energy.ca.gov/enhancedautomation/case_studies/CS02_HewlettPackard.pdf

CHAPTER 9

HVAC (heating, ventilation and air conditioning)

Goals

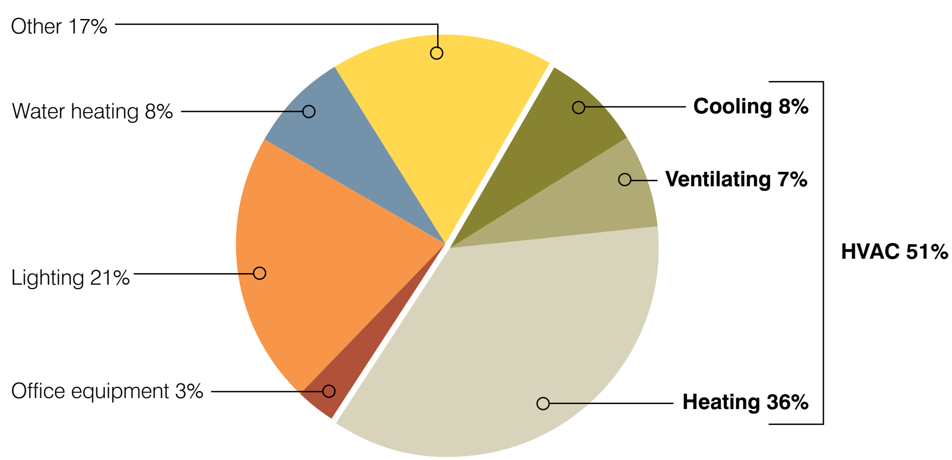
- Survey current HVAC system, operating procedures and maintenance schedule
- Analyze results of energy audit for HVAC system (performed by an HVAC professional)
- Perform due diligence and conduct financial analyses on recommendations of energy auditors

Overview

Building heating, ventilation and air conditioning (HVAC) systems are responsible for controlling temperature and humidity as well as circulating fresh air throughout a building. HVAC systems are relatively energy intensive and represent a significant portion of a building's energy consumption—51% on average in commercial buildings in the U.S. (36% heating, 7% ventilation, 8% cooling).[1]

FIGURE 9.1

HVAC: Estimated energy consumption of U.S. commercial buildings



Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E1A. Major Fuel Consumption (BTU) by End Use for All Buildings," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

The annual breakdown of HVAC energy draw among heating, ventilating and cooling end-uses can vary widely depending on geographic location. It is not uncommon for larger buildings to require cooling year-round because of the substantial heating effect of office equipment, lighting, water heaters and people within the building. Additionally, HVAC systems often operate at high levels during periods of regional **peak load** (for example, hot summer days) when electricity prices are highest, which can significantly increase an organization's power costs.

HVAC designs vary widely across building types. Standard HVAC systems are considered "active" technologies, which require energy input to drive mechanical equipment. A typical HVAC system involves components including chillers, boilers, air ducts, fans and heat exchangers. "Passive" heating and cooling technologies, although typically more energy efficient, are rarely implemented into existing buildings. They are more feasible and effective when they can be designed into the systems at the design and construction stages of new buildings. These technologies include natural ventilation, evaporative cooling systems and radiant heating and cooling systems.

A range of methods can be used to decrease the energy draw of an HVAC system, but one of the easiest is reducing a building's cooling load by lowering waste heat generated by inefficient lighting systems, office equipment and water heating systems. These measures are extremely cost-effective and should be undertaken before any upgrade to HVAC equipment is considered. If HVAC equipment has recently been upgraded to an efficient model, maintaining system performance at the proper level of efficiency should be a primary consideration.

Like lighting quality, HVAC performance is key to the comfort and productivity of building occupants. In fact, many HVAC efficiency upgrades have the added benefit of improving air quality and comfort throughout a space (e.g., precise tuning of thermostat controls or installation of outside **air economizers**). An HVAC engineer should ensure that efficiency upgrades to an HVAC system do not cause any reduction in the quality of a building environment.

The recommended efficiency improvement strategies for HVAC are presented in the order in which they should be undertaken:

1. Ensure that proper maintenance is being performed

2. Investigate possibilities for reducing heating/cooling load (occupancy, temperature settings)

3. Calibrate and tune system controls

4. Consider upgrading HVAC equipment.

Note: Costs and energy savings for HVAC efficiency measures vary widely depending on building characteristics. In this section, examples of costs and savings potential are presented through financial case studies.

Information gathering guide

A number of key questions are important to consider before addressing improved HVAC system function and efficiency:

- Does the host organization own or lease its building space?
- Does the host organization pay the utility bill or is it included in the rent?
- Is the landlord (if not the host organization) interested in pursuing efficiency reductions for tax credits or other financial incentives?

- What type of HVAC system is in place? For example, is the system a packaged unit or centralized, and who is in charge of operating the system? For a description of HVAC system types, see Appendix B: HVAC Information.
- When was the existing HVAC system installed?
- Has the host organization experienced any problems with the HVAC system?
- How do building managers control the HVAC system? Which controls are manual? Which controls are automated?
- Are there other systems opportunities that could benefit the HVAC system (for example, lighting upgrades, adding insulation or upgrading doors and windows)?
- What data on building temperature and energy consumption does operations staff have access to? How are the data delivered, recorded and tracked?
- Who conducts maintenance on the HVAC system (is it done internally)?
- What is the maintenance schedule?
- Has the HVAC system undergone recent **recommissioning**?
- What has been done to date to improve efficiency of the HVAC system?
- Is the HVAC system about to undergo a scheduled upgrade or replacement? Efficiency improvements can be most cost-effectively implemented in conjunction with the regular equipment upgrade schedule.

Tactics for reducing energy use

1. Maintenance and commissioning

The efficiency of existing HVAC systems can be maximized through a combination of regular in-house maintenance and periodic **commissioning**. In-house maintenance typically involves cleaning and replacing worn-out parts. Commissioning is a process by which equipment is tested to make sure it is performing according to design intent. Testing, adjusting and balancing (TAB) are examples of commissioning tasks. Most commissioning services are completed by professional technicians specializing in particular building systems.

Regular maintenance of heat exchange equipment should involve:

- Removal of deposit buildup from heating coils/chiller tubes
- Replacement of HVAC air and water filters
- Boiler tune-ups
- Checking steam traps for leaks

Commissioning is performed by a specialized commissioning technician. A commissioning technician should:

- Verify that HVAC system components are functioning correctly
- Identify and correct any problems with the system controls
- Ensure that the HVAC system is providing proper indoor air quality
- Calibrate temperature sensors and controls to align with original design specifications

Financial case study: HVAC maintenance performed by Real Estate Services company, Cushman and Wakefield at Adobe Towers in San Jose, California, resulted in tune-ups including modified boiler control programming, which cost $600 in labor and saved $41,779 in annual energy costs. An additional correction to chilled-water pump controls cost $1,200 and netted $42,960 in annual energy savings. For additional information, see Case Study 1 in Appendix G.

2. Efficiency tune-ups

Complete envelope upgrades. An energy efficiency engineer can evaluate whether upgrades to the **building envelope** can reduce heating/cooling load. Envelope upgrades include:

- Locating and sealing air leaks in windows, doors, roofs and walls. Eliminating infiltration due to air leaks in a large office building typically saves up to 5% of heating/cooling energy.[2]
- Installing window films/shading. Window coverings block solar radiation from entering the building and reduce internal heat loss through windows by improving insulation. The typical cost for specialized window films is $1.35–$3.00 per square foot. Window films have a typical lifetime of five to fifteen years.[3]

Financial case study: Equity Office Properties installed 140,000 square feet of window film on floor-to-ceiling windows throughout One Market Plaza in San Francisco, a 1.4-million-square-foot complex. The project qualified for efficiency incentives from PG&E and reduced heating and cooling costs significantly. After the PG&E rebate, the project had a payback period of less than two years.[4]

Tune/install thermostat controls. An HVAC engineer should compare a building's heating/cooling patterns with its occupancy schedule to determine whether controls can be adjusted to reflect occupancy. Additional savings can be accomplished through the installation of combined automated control systems for HVAC and lighting (see Chapter 8). HVAC and lighting can then be continuously monitored and adjusted based on occupancy and the environment. An HVAC engineer should evaluate the feasibility of preheating or pre-cooling the building at night using off-peak electricity.

Financial case study: Cushman and Wakefield performed a modification of temperature and runtime settings of boilers for Adobe Systems, costing Adobe $400. The adjustments reduced the boilers' natural gas use by 20% for an annual savings of $42,960, representing an immediate payback on investment.

3. Equipment replacement/purchasing

Full replacement of up-to-date HVAC systems is unlikely to be cost-effective if undertaken solely to increase energy efficiency. However, many modern buildings are operating with outdated and inefficient HVAC systems. Upgrading an older system to a higher efficiency system should be considered, particularly if the building in question has experienced HVAC performance problems. The principle objectives of HVAC upgrades are to improve year-round occupant comfort and convenience, and to achieve higher energy efficiency with lower operational costs.[5]

Often HVAC upgrades can be made by replacing certain components of the existing HVAC system or purchasing and installing equipment that can be integrated into the system.

Install outside air economizers. Air-side economizers use a damper to control intake of outside air. When outside air is cooler than return air, the damper adjusts to maximize air intake; when outside air is warmer, the damper reduces outside air intake to the minimum required by building codes.[6] Air-side economizers can also be used to pre-cool buildings at night.

Correctly size and retrofit HVAC fan systems. Fan systems (which distribute heated or chilled air throughout a building) are often more economical to replace than the heating/chilling equipment. Building maintenance staff can often identify opportunities to replace oversized fans but it will normally be necessary to contract with an HVAC engineer to conduct a more detailed analysis and make recommendations for optimizing the system.[7]

Constant volume fan systems, which circulate a set volume of air and regulate temperature through heating or cooling air, are common in commercial buildings, but are relatively inefficient. Variable air volume (VAV) systems, which regulate temperature primarily by varying the volume of circulated air, are typically more efficient. Conversion from a constant volume system to a VAV system can reduce horsepower requirements for fans by 40–60%.[8]

A VAV system can be retrofit to control fan speed using a variable-frequency drive (VFD), also called Variable Speed Drive and Adjustable Speed Drive. VFDs vary fan speed according to need, resulting in energy savings from reduced fan speeds. A recent EPA study found that installing a VFD in an existing Variable Air Volume (VAV) system achieved a mean savings of 52% in fan system energy requirements.[9]

Financial case study: A 36-story high-rise in San Francisco at 100 Pine Street is undertaking a retrofit conversion of its constant volume system to a variable air volume system. The retrofit project will cost approximately $848,000, but 100 Pine Street will receive $179,000 in utility incentives and is expected to save $473,000 in annual energy costs, for an adjusted payback period of 1.3 years. For additional information, see Case Study 3 in Appendix G.

Financial case study: A VFD was added to the fan system at Adobe Towers in San Jose, enabling the system to adjust air volume and fan power to meet cooling load. The retrofit cost $126,960 and received a $63,500 rebate. Estimated annual energy savings are $78,000, representing a ten-month payback period.

Measure existing heating/cooling loads and correctly size HVAC heating and chilling components. An HVAC engineer should periodically re-measure heating and cooling loads to capture savings achieved through previous efficiency improvements and assess whether heating/chilling components can be downsized.

Generally, HVAC engineers will apply an "integrated system approach" to evaluating opportunities in heating and cooling systems. If heating systems and cooling systems are assessed separately, the process will be more time consuming and whole system efficiency upgrade opportunities may be missed.

When feasible, replace outdated or highly inefficient HVAC systems. "Reheat systems," which cool and circulate a set amount of air and then reheat the cooled air as necessary to achieve desired temperatures, and "multi-zone systems," which mix cooled and heated air to produce desired air temperatures, are extremely inefficient. An HVAC engineer can consult on the feasibility of converting these types of systems to more efficient ones.

Financial case study: While renovating First Financial Plaza, a 223,000-square-foot (six-story) office building in Encino, California, Glenborough Realty Trust replaced an outdated chiller during an HVAC system retrofit. The 375-ton R-12 centrifugal chiller was near the end of its life, so a new chiller was required. Glenborough selected an energy-efficient Carrier 19XRV as a replacement, which has reduced annual energy costs by $15,500. After the receipt of a $15,750 utility rebate, the net cost of the chiller replacement was $273,884.[10]

Additional information

For more information on maintenance and commissioning, see:

- U.S. EPA, “Energy Star® Building Upgrade Manual—Recommissioning,” October 2007. http://www.energystar.gov/index.cfm?c=business.EPA_BUM_CH5_RetroComm
- Ellicott and Rothstein, National Conference on Building Commissioning, “Procuring Commissioning Services—Who, When, and How,” May 2005. http://www.peci.org/ncbc/proceedings/2005/11_Ellicott_NCBC2005.pdf

For more information on building envelope upgrades, see:

- U.S. EPA, “ENERGY STAR® Building Upgrade Manual—Reducing Supplemental Loads.” August 2007. http://www.energystar.gov/index.cfm?c=business.EPA_BUM_CH7_SupLoads

For more information on heating and cooling systems, see:

- U.S. EPA, “ENERGY STAR® Building Upgrade Manual—Heating and Cooling,” January 2008.

Notes

[1] Source: Energy Information Administration, “Commercial Buildings Energy Consumption Survey (CBECS): Table E1. Major Fuel Consumption (Btu) by End Use for All Non-Mall Buildings, 2003.”September 2008. http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

[2] U.S. EPA, “ENERGY STAR® Building Upgrade Manual: Retrocommissioning: Supplemental Loads,” October 2007. http://www.energystar.gov/index.cfm?c=business.epa_bUm_CH5_retroComm#ss_5_4_2

[3] U.S. EPA “ENERGY STAR® Upgrade Manual—Reducing Supplemental Loads: Window Films,” August 2007. http://www.energystar.gov/index.cfm?c=business.epa_bUm_CH7_suploads#ss_7_3_1

[4] Clear innovations, Case study—One Market. http://clearinnovations.net/case_history.html

[5] “EPRI Office Complexes Guidebook, Innovative Electric Solutions,” Chapter 6: Heating, Ventilating, and Air-Conditioning (HVAC), December 1997, tr-109450, pp. 208, 191–215.

[6] U.S. EPA “ENERGY STAR® Building Upgrade Manual—Air Distribution Systems,” April 2008. http://www.energystar.gov/index.cfm?c=business.epa_bUm_CH8_airdistsystems#ss_8_4_5

[7] U.S. EPA “ENERGY STAR® Building Upgrade Manual—Air Distribution Systems: Right Size Fans,” April 2008. http://www.energystar.gov/index.cfm?c=business.epa_bUm_CH8_airdistsystems#ss_8_4_3

[8] EPA “ENERGY STAR® Building Upgrade Manual—Air Distribution Systems: Variable Air Volume System,” April 2008 http://www.energystar.gov/index.cfm?c=business.epa_bUm_CH8_airdistsystems#ss_8_2_2

[9] U.S. EPA “STAR® Building Upgrade Manual—Air Distribution Systems: Variable -Speed Drives,” April 2008. http://www.energystar.gov/index.cfm?c=business.epa_bUm_CH8_airdistsystems#ss_8_4_4

[10] Personal Conversation with Raul Mendez, Glenborough Realty Trust (Chief Engineer), February 2008.

CHAPTER 10

Lighting in commercial buildings

Goals

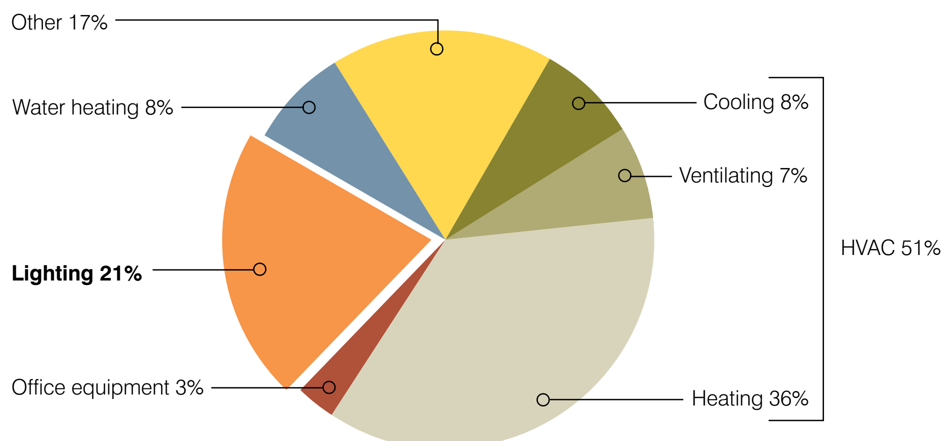
- Identify lighting opportunities for energy savings in locations in the building that are overlit, unoccupied locations that are lit, and areas where lighting sources can be replaced with lower wattage alternatives
- Develop estimates of energy usage and calculate the estimated savings potential of installing improved lighting controls and/or more efficient lighting sources

Overview

On average, lighting consumes 21% of the energy used by commercial buildings in the U.S.[1] Even with advances in lighting technology and the nationwide adoption of stricter lighting codes, many commercial buildings continue to operate with highly inefficient lighting systems. Poor control schemes, lighting of unoccupied space, lack of daylight harvesting, and over-illumination all contribute to higher than necessary energy demand. In addition to energy inefficiencies for general illumination, all lighting sources, (**incandescent**, fluorescent metal

FIGURE 10.1

Lighting: Estimated energy consumption in U.S. commercial buildings



Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E1A. Major Fuel Consumption (BTU) by End Use for All Buildings," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

halide, etc.) produce latent heat, which is a major contributor to a building's cooling load. Improvements in lighting system efficiency not only decrease energy costs associated with lighting, but also reduce energy costs associated with HVAC and building cooling systems.

The efficiency of a lighting system can be increased through:

- Education and behavioral changes, such as encouraging employees to turn off unnecessary lights and maximizing the use of daylighting
- Lighting controls that ensure light levels are adjusted to the correct intensity and that lamps are illuminated only when and where necessary
- Upgrading to higher efficiency lighting technologies

Information gathering guide

Before conducting a lighting efficiency cost analysis, consider the following questions:

- Where is the building geographically located?
- What is the age of the building?
- What is considered to be the main building activity, e.g. retail, food service, offices?
- How many weeks of the year is the building open? Are there any seasonal fluctuations?
- Does the host organization own or lease the space?
- If the host organization leases space, does the organization pay their utility bills directly or is a charge for utilities included in the rent? (See Chapter 7.)
- Who is the electric utility provider? Do they offer rebates or incentives for energy efficient lighting projects?
- If the host organization leases space, is the landlord interested in pursuing efficiency reductions for tax credits or other financial incentives?
- Who in the host organization has the authority to make lighting design and purchasing decisions?
- What upgrades have been made to lighting in the last three to five years?
- How often is the space renovated?
- How much indoor and outdoor lighting is required for security?
- Are there any official lighting policies in place? (For example, lights dimmed after 6:30 pm.) Who has the authority to change these policies?
- What are the responsibilities of cleaning staff with regard to lighting? Is cleaning staff receptive to requests?
- Have there been complaints from building occupants about over- or under-lit spaces?
- To what degree, and in what areas, do building occupants have the ability to control or adjust lighting?
- Do any local or state ordinances restrict exterior lighting options?

In addition, a rough estimate of lighting savings potential can be calculated simply by walking through each building area once during workday hours and then again after hours. A blueprint of the floor space is useful for this exercise. During a walkthrough, the following questions should be considered for each room or area:

- What are the hours of occupied use? Are the lights on when the area is unoccupied? How long?
- Is the lighting level adequate, inadequate or excessive?

- Is daylighting (natural light) being used where possible?
- Consider how lights are being controlled. Which lighting systems use timers? Which use occupancy or photocell sensors? Which are manually controlled?
- What are the existing types and wattages of lamps used? What type of **fixtures** are used?
- Are any fixtures, sensors or switches broken?

A lighting engineer or specialist can offer more detailed assessment capabilities. A lighting audit from an energy consultant or local utility would also provide an additional opportunity to assess potential lighting upgrades or projects.

Tactics for reducing energy use

1. Policy and process changes

- **Train/educate staff to turn off lights.** One of the simplest efficiency upgrades an organization can make is to institute policies and processes that prevent lights from being left on when spaces are vacant. Determine which users of the space have the primary responsibility for turning lights on and off at different times of the day/week and ensure those responsibilities have been adequately communicated. Increased coordination among occupants, from office managers to office staff and, particularly, cleaning crews, can result in decreased energy consumption. Installing a master switch that can simultaneously turn off all lights on a floor will make it easier for the last person who leaves to ensure that all lights are off.
- **Incorporate task lighting.** Task lighting can provide illumination where it is most needed (on paper documents, for example) more efficiently than the most energy efficient ceiling **ambient light** because task lighting is located closer to where light is needed. In addition, individual workers have more control over task lighting and can adjust it as needed for the task being completed. Incorporating adjustable task lighting in addition to low ambient light can:
  - Improve lighting quality, comfort and control for workers
  - Reduce unnecessary or ineffective lighting
  - Reduce lighting costs
- **Practice regular lighting maintenance.** It is important to ensure that a regular maintenance and cleaning schedule is in place for existing light fixtures, **reflectors**, **diffusers** and **lenses**. See Table 10.1 for the Federal Energy Management Program's recommended maintenance schedule for commercial lighting systems.

2. Lighting control efficiency measures

CONTROL DEVICES

Automatic lighting controls are now mandated by energy code in most commercial applications.[2] The benefits of integrated lighting controls include energy savings, flexibility, increased safety and higher-quality building environments.

Many buildings still employ manual control devices, such as light switches, manual dimmers and window blinds that can be directly accessed and controlled by occupants. Automatic control devices, such as occupancy sensors, timers and photo sensors, are designed to take the place of occupant action and inaction.

TABLE 10.1

Lighting maintenance checklist

Description	Comment	MAINTENANCE FREQUENCY Daily	Weekly	Monthly	Annually	As needed
Overall visual inspection	Complete overall visual inspection to be sure all equipment is operating and safety systems are in place.	✓				
Lighting use and sequencing	Turn off unnecessary lights.	✓				
Task lighting	Highlight the importance and efficiency of task lighting.	✓				
Use daylighting	Make use of daylighting where possible.	✓				
Replace burned out lamps	Replace flickering and burned out lamps. Burned out lamps can cause ballast damage.		✓			
Perform survey of lighting use	Perform survey of actual lighting use to determine lighting need.				✓	
Measure illumination levels	Measure footcandle levels. Where possible, reduce illumination levels to industry standards.				✓	
Clean lamps and fixtures	Lamps and fixtures should be wiped clean to assure maximum efficiency.			✓		
Clean walls, ceilings and floors	Clean surfaces reflect more light.			✓		
Repaint with light colors	When repainting, use light colors to reflect more light.					✓
Replacement lenses	Replace lens shielding that has become yellow or hazy.					✓

Source: Federal Energy Management Program, EERE, U.S. DOE. http://www1.eere.energy.gov/femp/pdfs/lighting_checklst.pdf

Occupancy sensors, vacancy sensors and **time clocks** can be programmed to automatically turn off lights after hours or in spaces that have been unoccupied for a pre-set amount of time. Installing time clocks to turn lighting on and off eliminates human error in lighting control. Time clocks are best utilized in spaces where occupancy patterns are regular and predictable.

A lighting specialist can provide guidance on the appropriate time clocks and occupancy sensors for a given space, but generally 24-hour time clocks can be used where occupancy patterns are similar throughout the week and weekend, whereas 7-day time clocks should be used in spaces with occupancy patterns that vary from day to day.

Three-phase time clocks may be used to control lighting and HVAC simultaneously.

Payback period: Energy and cost savings will depend on current indoor lighting schedules.

OCCUPANCY SENSORS

Install occupancy sensors. Occupancy sensors can save significant amounts of energy in spaces that are often unoccupied or occupied unpredictably (stairwells, restrooms, conference rooms, etc.). They are especially effective during the night and early morning when buildings have significant unoccupied space that does not require lighting. To avoid performance problems, it is important that occupancy sensors be positioned correctly to respond to movement anywhere in the spaces they serve. It is also important to maintain the ability to override the automatic controls, if necessary.

TABLE 10.2
Sample rebates for lighting controls

Description	Rebate/unit measure
Wired wallbox switch	$5/sensor
Wireless wallbox switch	$5/sensor
Wired sensor controlling < 500 watt	$35/sensor
Wireless sensor controlling < 500 watt	$35/sensor
Wired sensor controlling > 500 watt	$50/sensor
Wireless sensor controlling > 500 watt	$50/sensor
Fixture integrated low-bay occupancy sensr fixture wattage < 150 watt	$15/sensor
Fixture integrated low-bay occupancy sensr fixture wattage > 150 watt	$10/sensor

Pacific Gas and Electric (PG&E) catalog of lighting rebates is available at: http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/lighting_catalog_final.pdf

TABLE 10.3
Estimated energy savings achieved via occupancy sensors

Type of room	Energy savings (%)
Private office	13 to 50
Conference room	22 to 65
Restroom	30 to 90
Corridors	30 to 80
Storage area/closet	45 to 80

Source: FPL Business Energy Advisor, "Buying Equipment: Lighting: Occupancy Sensors." http://www.fpl.com/business/energy_saving/energy_advisor.shtml

Payback period: According to a Rutgers University study of NJ municipal buildings where occupancy sensors were installed, the paybacks (before any state or local rebates are considered) ranged from one to just over two years.[3]

PHOTO SENSORS

Install photo sensors, dimmable ballasts and dimming controls in indoor zones that have natural daylight. Photo sensors are electronic control units that automatically adjust the output level of electronic lights based on the amount of ambient light detected. In areas that receive daylight throughout the day, photo sensor controls can adjust artificial light levels as necessary to supplement the available natural light. A continuous dimmer controlled by a photo sensor reduces artificial lighting by depending on daylight to maintain an optimum light level. Energy and cost savings will vary widely depending on natural light availability.

Electric lighting **dimming controls** which can be either manual or automatic, not only reduce energy, but also provide flexibility. Instead of turning off all lights at any given time, lighting can be dimmed. Fluorescent lamps can be dimmed when fitted with dimming ballasts. Low-voltage **tungsten halogen** bulbs are dimmed with low-voltage dimming controls. **light emitting diodes (LEDs)** require a dimming power supply in combination with LED dimming controls.

Full-power artificial lighting is often unnecessary in areas that receive good natural daylight. Dimmable ballasts operated in conjunction with photo sensors or other control devices achieve a gradual, controlled change in lamp output.

The installation of photo sensors with dimming controls and dimming ballasts is most cost-effective when undertaken simultaneously with another lighting retrofit where ballasts and controls must be replaced. In this situation, the project cost is limited to the cost of the photo- sensor installation plus the incremental cost of dimming ballasts and controls over standard ballasts and controls.

Payback period: Energy and cost savings will vary greatly depending on current outdoor lighting practices.

3. Lighting source efficiency upgrades

Upgrading to more efficient lighting sources often yields the most significant efficiency gains in building lighting. Outdated lighting includes incandescent and **T12** linear fluorescents. Replacing them with modern, more efficient sources, including **T8** linear fluorescents, **compact fluorescent lamps (CFLs)**, LEDs and **HID** lamps, will reduce lighting energy costs. For background information on lighting types, consult Appendix C.

- **Replace T12 and first generation 32 watt linear fluorescent lamps with newer generation T8 linear fluorescents lamps and high efficiency ballasts.**

T8 linear fluorescents (narrower in diameter and more efficient than T12 linear fluorescents) are the standard lighting source used in most commercial buildings constructed after 1995. Much less efficient T12 lamps may still be in use in older buildings and should be upgraded to T8s.

T12s are typically controlled by magnetic ballasts and T8s require electronic ballasts; therefore, ballasts usually must be replaced when T8s are installed in place of T12s. T8s and T12s come in the same standard lengths, so replacing a T12 with a T8 usually does not require a replacement of the entire fixture. However, a project cost analysis should include options for replacing fixtures and for retro-fitting existing fixtures with new ballasts and lamps. While often slightly more expensive, replacing the whole fixture can have other benefits such as replacing dated fixtures or fixtures with lenses that have discolored over time. These non-financial benefits should be considered when deciding to keep or replace fixtures.

T8 lamps with reflectors and electronic ballasts are about 30% more efficient than T12 lamps with magnetic ballasts. T8 lamps also have a longer life than T12 lamps, requiring less maintenance and producing less waste. **T5** fluorescents (narrower than T8 in diameter) are better suited for higher mounting or indirect applications and require dedicated fixtures due to metric lengths. T5 fluorescents should be considered if building space is being renovated, but will not likely be cost-effective as a retrofit.

The original generation T8 lamps consumed 32 watts; today many manufactures have T8 amps that only require 27 or 28 watts to produce the same output. These bulbs are interchangeable in most fixtures, so making a practice to only buy 27-watt lamps is an easy way to save 15% with no added costs. Note that 32 watt lamps are still common and are still manufactured This can be remedied by checking lamp inventory to separate the 28-watt and 32-watt lamps, and updating part numbers on purchase orders, removing these for the 32-watt lamps..

- **Remove unnecessary light fixtures.** Incentives may be available for de-lamping, or permanently removing unnecessary light fixtures or removing fixtures entirely. Because T8 lamps have a greater lighting **efficacy** (measured in **lumens per watt**), the same quality/brightness of light can often be accomplished with fewer bulbs following a T12 to T8 retrofit. Be aware of building code requirements for lighting minimums when designing a de-lamping plan.

Most utilities with an incentive program will offer a specific dollar amount for each fluorescent lamp that is permanently removed.[4]

Payback period: Simple payback for a T8 retrofit typically has a one to two year payback.

- **Replace incandescent lamps with comparable compact fluorescent lamps (CFLs) or LEDs.** In a typical incandescent bulb, 95% of energy is released as wasted heat. CFLs are designed to be compatible with traditional incandescent fixtures, but are 60–75% more efficient than comparable incandescent lamps and have an expected life of up to 10,000 hours vs. about 1,000 hours for an incandescent. With an expected life of between 50,000 and 100,000 hours and a rapid decrease in price, LEDs are becoming a more attractive option for retrofits.

Recent and continuing advances in technology allow LEDs to be dimmed and to provide color control. LEDs emit light in a specific direction. As such, the use of LEDs reduces the need for reflectors and diffusers. Replacing incandescent lamps with CFLs or LEDs will save on maintenance and cooling costs in addition to lighting energy costs.

CFLs and LEDs come in a variety of shapes and sizes and can serve many different lighting needs. For example, variable-output technologies feature three-way lighting outputs or dimmable lighting. CFLs and LEDs are viable replacements in almost all lighting applications.

LEDs have become standard for the replacement of exit signs. Although exit signs draw a relatively low wattage, they run continuously. LEDs long life provides the added benefit of increased safety and reduced maintenance since they last ten times or more than incandescents.

Payback period: Typical payback for replacement of incandescent bulbs with comparable CFLs is under six months. Typical payback for replacement of incandescent bulbs with comparable LEDs is seen anywhere from six months to four years, depending on the specific application. Payback for the replacement of incandescent exit signs with LED exit signs is typically less than one year.[5]

To generate more specific payback estimates for CFL installation, consult the EPA ENERGY STAR® calculator. http://www.energystar.gov/index.cfm?c=cfls.pr_cfls_savings

The ENERGY STAR® qualified lamp and fixture lists, including a varied selection of CFLs and LEDs. http://www.energystar.gov/index.cfm?c=lighting.pr_lighting_landing

Figure 10.2 illustrates lamp purchase and five-year operating costs.

- **Upgrade outdoor lighting** by installing bi-level controls or replacing incandescent fixtures with pulse-start **high intensity discharge (HID)** lamps or LED fixtures. HID lamps and

TABLE 10.4

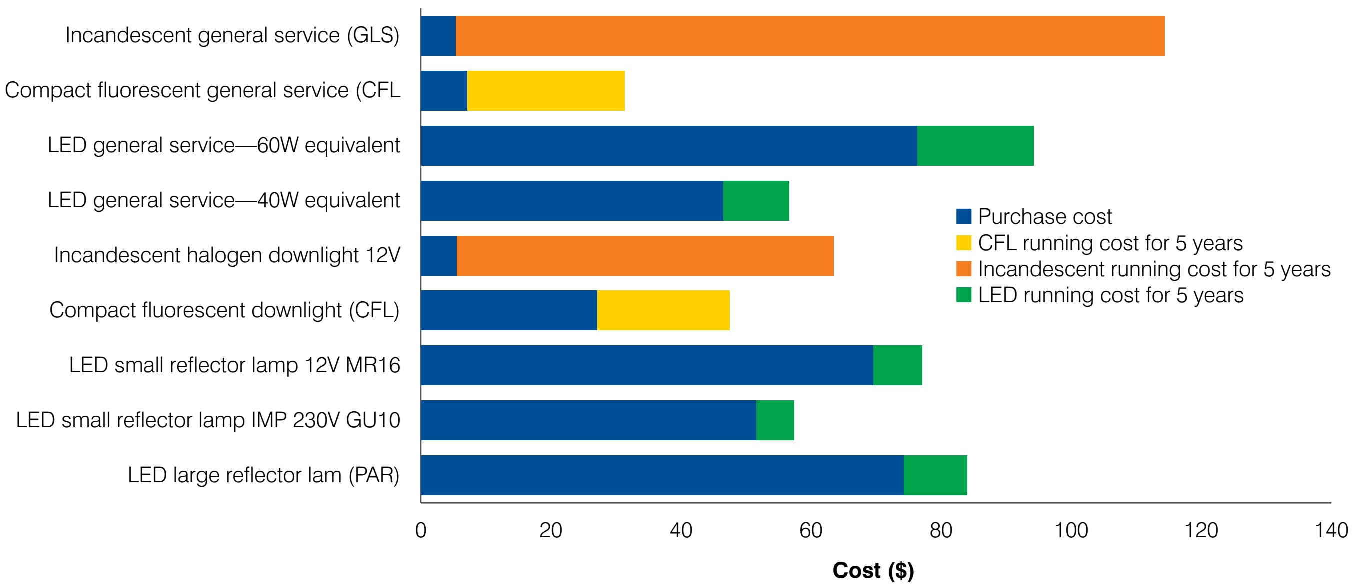
Comparison of lamp types: price, energy and savings

Fixture type	Typical wattage (watts)	Bulb life (years)	Annual bulb + labor cost	Purchase + install cost	Annual energy cost	1st year cost	10th year cost savings
Incandescent (existing)	40	0.5	$26	0	$39	$65	—
Fluorescent (existing)	11	1.0	$27	0	$11	$38	$269
LED (new installation)	40	10+	$0	$20 + $25	$2	$47	$581

Source: Green Building Elements, “Measuring Efficient Emergency Products.” http://greenbuildingelements.com/2012/05/17/guest-post-measuring-efficient-emergency-products/

FIGURE 10.2

Cost of bulb purchase and operating cost for 5 years



Source: http://www.consumer.org.nz/reports/led-cost-comparisons/running-purchase-costs

LEDs provide energy savings greater than 50% over incandescent sources and are well suited to outdoor applications.

HID lamps are typically dimmed using a "stepped dimming" feature implemented with a magnetic ballast which reduces lamp current and lamp wattage to a preset increment between full output and 50% of full output. The ballast uses bi-level or tri-level dimming.

In a typical dimming request, there would be one step (bright to dim), which is why the dimming system is called "two level" or "bi-level." However, some systems are referred to as tri-level dimming systems and can operate at three fixed levels.

Step dimming is ideal for saving energy and still providing a minimum amount of illumination for safety and security during hours of non-occupancy. For example, an occupancy sensor responds to the absence of people by signaling a step-dimming ballast to reduce lamp power to 50%, which saves energy. Tri-level systems provide this benefit but with greater flexibility. Some spaces that may be unoccupied for long periods of time, but still need to be lighted, such as parking lots, warehouses, supermarkets and malls are perfect for this step dimming application.

Pulse-start HID lamps offer several benefits, including longer lamp life, faster lamp start times and better lumen maintenance. Pulse-start HID lamps require a compatible pulse-start ballast. Lamps using a traditional probe-start ballast can be replaced on a one-for-one basis for about 20% energy savings. For new design, the higher light output of pulse-start technology can be used to provide high light levels using fewer **luminaires**.

The unique characteristics of LEDs, including, long life, ease of maintenance, resistance to breakage, good performance in cold temperatures, and instant-on performance are beneficial for outdoor lighting applications.

Costs and rebates: HID and LED prices vary broadly depending on application, but are generally significantly more expensive to purchase than comparable incandescent lamps. Most utilities with an incentive program offer reasonable rebates for the replacement of incandescent or HID fixtures with LED fixtures.

Payback period: Despite the high incremental cost of HID and LED fixtures, the wattage reductions achieved are significant enough to keep payback under two years, (before any state or local rebates are considered).[6]

Additional information

- U.S. Department of Energy: "Lighting Development, Adoption, and Compliance Guide." http://www.energycodes.gov/sites/default/files/documents/Lighting_Resource_Guide.pdf

Occupancy sensors

- Ernest Orlando Lawrence Berkley National Laboratory. "A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings." http://efficiency.lbl.gov/drupal.files/ees/Lighting%20Controls%20in%20Commercial%20Buildings_LBNL-5095-E.pdf
- Lighting Research Center, "Controls." http://www.lrc.rpi.edu/researchareas/controls.asp
- U.S. Department of Energy. "Lighting Controls." http://energy.gov/energysaver/articles/lighting-controls
- Wisconsin Public Service, "Lighting Tips." http://www.wisconsinpublicservice.com/home

Dimmable ballasts

- Lawrence Berkley National Lab, "Retrofit Fluorescent Dimming With Integrated Lighting Control—Economic And Market Considerations." http://lighting.lbl.gov/pdfs/economic_considerations.pdf
- WSU "Energy Efficiency Fact sheet: Daylight Dimming Controls." http://cru.cahe.wsu.edu/Cepublications/wsuceep00-154/wsuceep00-154.pdf
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- Lighting Controls Association, "The Next Generation of Electronic Lighting Systems: Smaller, Smarter and Greater Energy Savings." http://lightingcontrolsassociation.org/

Photo sensors

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- FPL Business Energy Advisor, "Buying Equipment: Lighting, Lighting Controls." http://www.fpl.com/business/energy_saving/energy_advisor.shtml
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- U.S. DOE Federal Energy Management Program, "Energy Cost Calculator for Compact Fluorescent Lamps." http://www1.eere.energy.gov/femp/technologies/eep_fluorescent_lamps_calc.html

High intensity discharge (HIDs) lamps

- Lighting and Daylighting: High-Intensity Discharge Lighting. http://www.eere.energy.gov/basics/buildings/high_intensity_discharge.html
- Gardco Lighting, "Saving energy in outdoor lighting." http://www.sitelighting.com/brochure/g-e_energy_brochure.pdf
- Lighting Research Center. "Lighting Answers: Mid-wattage Metal Halide Lamps." http://www.lrc.rpi.edu/programs/nlpip/lightinganswers/mwmhl/differenceprobepulse.asp

LEDs

- U.S. Department of Energy, "LED Basics." http://www1.eere.energy.gov/buildings/ssl/sslbasics_ledbasics.html
- U.S. Department of Energy, "Using LEDs." http://www1.eere.energy.gov/buildings/ssl/sslbasics_usingleds.html
- ENERGY STAR®, "Learn About LEDs." http://www.energystar.gov/index.cfm?c=lighting.pr_what_are

Notes

[1] Energy information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E1A Major Fuel Consumption (Btu) By End Use for All Buildings," September 2008. http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

[2] U.S. Department of Energy: "Lighting Development, Adoption, and Compliance Guide." http://www.energycodes.gov/sites/default/files/documents/Lighting_Resource_Guide.pdf

[3] Rutgers University, "NJ Green Manual—Existing Commercial." http://greenmanual.rutgers.edu/existingcommercial/strategies/occupancysensors.pdf

[4] PG&E, Business Rebates & Incentives information. http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/

[5] Estimate generated using EDF Climate Corps Financial analysis tool.

[6] Estimate generated using EDF Climate Corps Financial analysis tool.

CHAPTER 11

Water heating

Goals

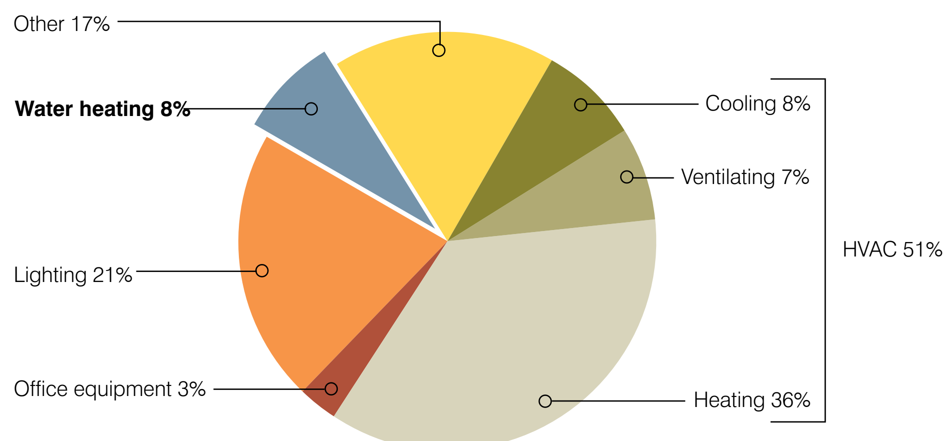
- Determine whether the host organization has potential to benefit from reduced energy costs through increases in water heating efficiency
- Determine whether the water heating system is aligned correctly with hot water applications and demand
- Develop estimates of energy usage from water heating and calculate estimated savings potential of efficient use upgrades and heating equipment upgrades

Overview

Water heating accounts for 8% of the energy consumed by an average commercial building. Many organizations may be wasting money by heating water unnecessarily. Heating water at too high a temperature for daily applications and having an oversized water heater are both common wasteful practices. Like inefficient lighting and inefficient use of office equipment,

FIGURE 11.1

Water heating: Estimated energy consumption of U.S. commercial buildings



Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E1A. Major Fuel Consumption (BTU) by End Use for All Buildings," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

inefficient and unnecessary use of water heaters releases waste heat that must be countered by increased cooling, resulting in additional wasted energy.

The energy costs of heating water tend to be low relative to the costs of HVAC and lighting. In office buildings, water heating accounts for only 8% of energy costs.[1] However, a business case can likely be made for many of the measures outlined in this chapter, most of which are no-cost or low-cost. It is also important to note that organizations often pay three times when they use heated water—with charges incurred for water use, energy and sewage disposal. Therefore, measures taken to reduce heated water use will net more than just energy savings.

Information gathering guide

The facilities manager will most likely be the best source of information on water heating. Important considerations to make while looking at water heating efficiency improvements include:

- **Ownership:** Who owns or operates the water heating equipment, the building operator or the host organization?
- **Costs:** Who is financially responsible for the water heating and how is it billed? How much does the host organization spend on heating water annually?
- **Applications/demand:** For what purpose is water being heated and how much water is needed?
- **Heat source and methods:** What types of water heaters are currently in use?
- What is the **thermal efficiency percentage** of the existing water heater(s)?
- Does the building use central or distributed water heating equipment?
- What are the current temperature settings on the hot water heater(s)?

Tactics for reducing energy use

The measures outlined below can reduce the energy required to heat water and the quantity of waste heat released from tanks and pipes.

1. Efficient use adjustments and upgrades

- Set water heater temperature appropriately. The factory temperature setting for water heaters is typically 140°F, but can usually be lowered to 120°F (or lower) without affecting performance. An energy efficiency consultant can determine the appropriate temperature setting for a specific application. By one estimate, a switch from 140°F to 120°F can save 18% of water heating energy and a 10°F thermostat reduction can save 6% of water heating energy.[2]

  Table 11.1 gives an estimate of temperatures required for a range of applications.

- Install pipe and water tank insulation. Pipe and tank insulation reduces standby heat loss from hot water, reducing energy required to maintain the correct water temperature. Energy saved with pipe and tank insulation varies widely depending on application, but can be estimated for a specific building by an energy efficiency engineer.

Costs, rebates and payback period: Consult with an energy efficiency engineer for an estimate of insulation installation costs and payback period.

PG&E provides rebates for insulating previously bare liquid storage or transfer pipes connected to gas-fired water heaters, at $2-$4/linear foot.[3]

- **For electric heaters: install timers and heat water at night using off-peak electricity.**

TABLE 11.1

Hot water temperatures required for given activities

Use	TEMPERATURE °F	°C
Handwashing	105	40
Showers and tubs	110	43
Commercial and institutional laundry	Up to 180	Up to 82
Residential type dishwashing and laundry	140	60
Commercial spray type dishwashing—wash	150 minimum	65 minimum
Commercial spray type dishwashing—final rinse	180–195	82–90

Source: Benjamin Stein and John Reynolds, *Mechanical and Electrical Equipment for Buildings*, Chapter 10: Water Supply, 2000, p. 599.

Costs, rebates and payback period: Consult with an energy efficiency engineer for an estimate of timer installation costs and energy savings.

When calculating payback, it is important to account for savings due to off-peak electricity purchase. Payback periods vary greatly depending on specifics of the time-of-day power pricing structure.

- Install low-flow fixtures and automatic sensor controls. Lowering flow in hot water fixtures (faucets, showerheads, etc.) reduces the energy required to heat water by reducing the volume of hot water consumed. The Energy Policy Act of 1992 established maximum flow rate guidelines for faucets, showerheads, toilets and other fixtures. Average flow rates for faucet aerators and showerheads are now around 2.5 gallons per minute (GPM). Super-efficient faucet fixtures have flows of 0.5 GPM and super-efficient showerheads have flows of 1.5 GPM.[4]

In addition to energy savings from avoided water heating, installation of low-flow fixtures and automatic sensor controls will result in savings from reduced water use. According to Greener Buildings, a resource center for environmentally responsible building: "In a typical 100,000-square-foot building, low-flow fixtures coupled with sensors and automatic controls can save a minimum of one million gallons of water per year, based on 650 building occupants each using an average of 20 gallons a day.[5]

Costs, rebates and payback period: Consult with an energy efficiency engineer for an estimate of low-flow fixture installation costs and energy and water savings.

When estimating payback, it is important to account for savings due to energy and water savings.

2. Equipment upgrades

Upgrading equipment will require substantial up-front capital investment and will therefore be easiest to justify financially when existing equipment is due or nearly due for replacement.

- **Correctly size water heater for organization needs.** The host organization may be operating with a larger-than-necessary water heater. An energy efficiency consultant can evaluate the heater size required to meet hot water demand. The hot water needs of a typical office building are: 0.4 gallons per person maximum per hour, 2.0 gallons per person maximum per day, and 1.0 gallons per person average per day.[6]

Costs, rebates and payback period: Consult with an energy efficiency engineer for an estimate of costs and payback period for a water heater replacement.

PG&E will rebate $1.00/therm saved for customized water heating efficiency projects.[7]

- Purchase a water heater with higher thermal efficiency. Efficiency of commercial water heaters is expressed as a thermal efficiency percentage (0–100%), which represents the percentage of energy from the fuel or electric heating element that is transferred to the water being heated (the higher the value, the more efficient the heater). Commercial heaters are also rated on **standby loss**, a measure of the percentage of heat lost per hour once water is heated. Standby loss is also expressed as a percentage, typically ranging from 0.5–2.0% (the lower the value, the more efficient the heater).[8] **Note:** Residential water heater efficiency is expressed in a different unit: energy factor (EF), which ranges from 0.00 to 1.00 (higher values are more efficient). EF is a combined measurement of thermal efficiency and standby loss.

Typical oil and gas-fired heaters have thermal efficiencies of ~80%, but can reach up to 95%. Gas-condensing water heaters are more efficient than traditional gas-fired heaters because they can increase thermal efficiency by up to 20%. Electric water heaters typically have a thermal efficiency of 98%. Whereas electric units themselves are very efficient, it is important to consider that the process of electricity generation and distribution is quite inefficient. The average thermal efficiency of American power plants is around 33% (33% of input fuel energy is output as electricity). Additional efficiency losses occur during electricity transmission and distribution (9.5% on average in 2001).[9] These inefficiencies contribute to the high price of electricity in relation to gas and oil in most markets. As a result, in most areas, oil and gas-fired water heaters have better economics and reduced climate impacts compared to electric water heaters.

In many applications, a tankless water heater may be the most efficient option. Tankless heaters heat water on demand instead of storing preheated water, which eliminates standby loss. An energy efficiency engineer can estimate potential efficiency gains from a switch to a tankless heater at the host organization. Tankless heaters are typically more expensive than comparable storage type heaters.

Costs, rebates and payback period: Consult with an energy efficiency engineer for an estimate of costs and payback period for a water heater replacement.

PG&E will rebate $1.00/therm saved for customized water heating efficiency projects.[10]

Notes

1 Energy information administration, "Commercial buildings energy Consumption Survey (CBECS): table E1A. Major Fuel Consumption (Btu) by End Use for All Non-Mall Buildings, 2003" released September 2008. http://www.eia.doe.gov/emeu/cbecs/becs2003/detailed_tables_2003/detailed_tables_2003.html

2 City of Portland Office of Sustainable Development, "Green Office Guide," November 2001, p. 18. http://www.oregon.gov/ENERGY/CONS/BUS/docs/Green_Office_Guide.pdf

3 PG&E, Business Rebates & Incentives information. http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/

4 Mike Opitz, U.S. Green Building Council, "Efficient Plumbing Fixtures—Saving Water at a Profit." http://www.fmlink.com/article.cgi?type=Sustainability&pub=USGBC&id=40639&mode=source

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CHAPTER 12

Office equipment (PCs, monitors, copiers, vending machines)

Goals

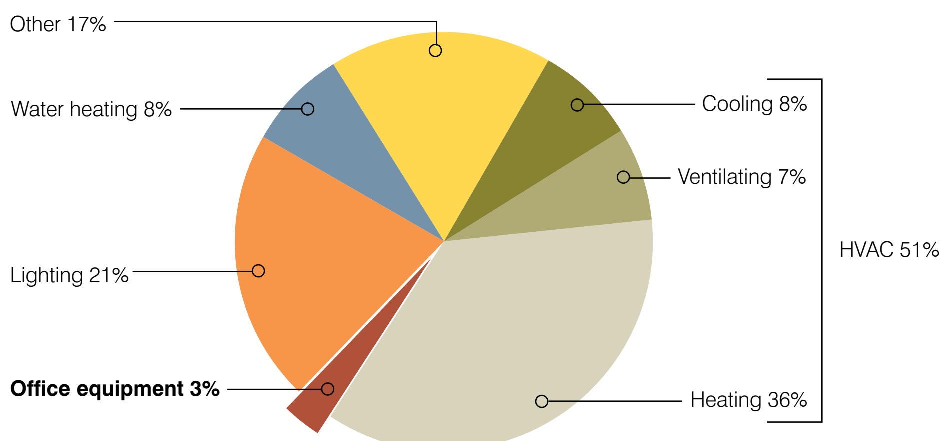
- Develop an inventory of current office equipment and document usage patterns
- Understand lifecycle of equipment from purchase/lease decision to initial configuration and ongoing maintenance
- Develop estimates of energy usage from office equipment and calculate estimated savings potential of efficient-use technologies and equipment upgrades

Overview

In a typical commercial building in the U.S., 3% of energy is used for office equipment like computers, monitors, printers, copiers and vending machines. In an office building, however, office equipment accounts for a larger portion of energy consumption—9% on average.[1] Waste heat from office equipment can also increase a building's cooling load, which adds

FIGURE 12.1

Office equipment: Estimated energy consumption of U.S. commercial buildings



Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E1A. Major Fuel Consumption (BTU) by End Use for All Buildings," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

to the energy requirements of the HVAC system. Potential to increase efficiency exists across office equipment, from PCs to copiers and vending machines.

This chapter presents a combination of strategies for reducing the power draw of typical office equipment. These strategies include applying power management settings, consolidating and reducing the quantity of equipment, and purchasing more efficient equipment. A number of relatively simple solutions can be implemented to reduce power consumption of existing equipment. In many offices, even the simplest efficiency measures have not been taken. For example, in a recent survey of large offices by Lawrence Berkeley National Laboratory, 59% of desktop PCs were left on at night. Of those computers, only 6% had power management settings activated to reduce their energy draw.

Activating **power management settings** is the easiest method to reduce the energy draw of office equipment not in use. This can be accomplished (at least in part) by encouraging employees to enable power management settings on PCs, monitors, printers and copiers. IT Management can install centralized power management software to automatically control individual power settings is a more comprehensive solution.

Because office equipment is typically replaced at shorter intervals than building systems like lighting and HVAC, further reductions in energy draw can be made through the purchase

TABLE 12.1

Energy saving potential and strategies for typical office equipment

Equipment	Average annual energy consumption (average available new non-Energy Star® certified products) (kWh/yr)	Estimated energy savings potential (kWh/yr)	Estimated energy savings potential percentage	Energy saving strategies
Desktop PC[a] (60% left on at night)	408	133	33%	• Enable power-saving settings • Install power management software • Energy Star-certified equipment purchase
Laptop PC[b]	126	40	32%	• Enable power-saving settings • Install power management software • Energy Star-certified equipment purchase
Computer Monitor[c]	72	15	21%	• Enable power-saving settings • Install power management software • Energy Star-certified equipment purchase
Monochrome Laser Printer (31-40 ppm)[d]	313	156	50%	• Energy Star-certified equipment purchase • Use of duplex mode
Copier (26-50 ppm)[e]	302	151	50%	• Energy Star-certified equipment purchase • Use of duplex mode
Vending Machine[f]	3,113	1,659	53%	• Energy Star-certified equipment purchase • Install energy-saving device (e.g., Vending Miser)

[a-e] Derived from detailed information found on grey tabs of the Energy Star® Savings Calculator—"Office." http://www.energystar.gov/ia/business/business/bulk_purchasing/bpsavings_calc/Calc_office_eq.xls

[f] Derived from Energy Star Vending Machine Savings Calculator. Accessible at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=VMC

of more efficient equipment. EPA's ENERGY STAR program sets standards for efficiency in office equipment, providing a convenient way for groups prioritizing efficiency in purchasing criteria to identify more efficient equipment. Most importantly, ENERGY STAR-rated equipment often carries little to no price premium.

Information gathering guide

An IT manager should be able to answer computer-related questions. Other office equipment such as copiers and faxes may be the responsibility of the facilities or operations manager.

- How many PCs, laptops, copiers, printers and vending machines are in use at the host organization? What percentage of each is ENERGY STAR?
- What equipment is owned? Leased?
- If PCs are non-ENERGY STAR, what is the timing of the next upgrade cycle? Who is in charge of the computer selection and purchasing process?
- What percentage of computers and monitors are turned off at night?
- What power settings, if any, are used on most computers and monitors?
- What is the policy for using laptops vs. desktop computers?
- Does the organization have any old CRT monitors?
- Who is in charge of configuring and maintaining office computers? Has the organization explored installing auxiliary computer power management software?
- Are the power-save settings turned on for printers and copiers?
- Are printers and copiers set to print duplex by default?
- Who is in charge of office equipment policy changes?

Tactics for reducing energy use

1. Efficient use of office technologies

Office equipment is most commonly made more energy efficient by switching the equipment to a low-energy state when not in use.

- **Install supplemental computer power management software** (such as EPA's EZ Save, Verdiem Surveyor, 1E Nightwatch or Desktop Standard's PolicyMaker on PC networks). Centralized power management software sets the power settings of all networked PCs and monitors, overriding individual user power settings. If operations require that computers not be turned off at night, centralized power management software allows IT administrators to put PCs in a low power state and then power them up as needed (to install software, update virus definitions, etc.).

For a full listing of software providers, consult the ENERGY STAR power management products website: http://www.energystar.gov/index.cfm?c=power_mgt.pr_power_mgt_comm_packages

Some power management software vendors will perform a free audit of network PC energy use and conduct an analysis of energy savings and payback.[2] Consult specific vendors for more information.

- **Install energy saving devices on vending machines or ask vendors to provide more efficient vending machines.** Installation of a Vending Miser® or a similar device should be considered for each cooling-equipped vending machine. These devices manage both the lighting and the compressor in vending machines, and turn lighting on and off as necessary using a motion sensor. VendingMiser makes the claim that its devices reduce the energy consumption of vending machines by about half, while maintaining proper temperature and necessary illumination.[3]

For more information on energy efficient vending machines on the ENERGY STAR website: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=VMC

2. Equipment replacement/purchasing

- Purchase ENERGY STAR certified PCs and servers equipped with 80 PLUS® certified power supplies (AC to DC converters). The 80 PLUS performance standard requires that power supplies be at least 80% efficient at 20%, 50% and 100% of rated load, with increasing badge levels of efficiency (i.e. Bronze, Silver, Gold, Platinum and Titanium). PCs with 80 PLUS certified power supplies are estimated to be –33% more efficient than those without.[4] The ENERGY STAR Version 4.0 specification for desktop computers, which went into effect in July 2007, required that PC power supplies meet 80 PLUS baseline performance standards. In 2009, the Version 5.0 specification required the 80 PLUS Bronze criteria level in order to achieve compliance. For enterprise and computer servers, ENERGY STAR's Version 1.0 specification released in 2009 requires a minimum of 80 PLUS Silver and Gold criteria levels.

A full listing of 80 PLUS certified power supplies can be accessed at: http://www.plugloadsolutions.com/80PlusPowerSupplies.aspx

- Replace desktop PC with laptops. Laptops use significantly less energy and provide employees the benefit of taking their laptop home or when traveling.
- Replace all remaining CRT (cathode ray tube) monitors with flat-panel LCD monitors. The new LCD monitors are economical, use much less electricity, take up less space and don't have issues with flickering that can cause eye strain.
- Purchase ENERGY STAR certified PCs, printers, copiers, and monitors. These products automatically switch to low-power standby modes after a period of inactivity. Overall, ENERGY STAR certified office equipment uses 30–75% less electricity than standard equipment.[5]

Costs and rebates: There is little to no incremental cost for ENERGY STAR certified printers, copiers and monitors and for this reason, utilities typically do not provide rebates for efficient office equipment. Savings calculators for ENERGY STAR office equipment can be found at this website: http://www.energystar.gov/index.cfm?c=bulk_purchasing.bus_purchasing

- Purchase high-speed, duplex-capable laser printers, and make duplex printing the default print setting. Although high-speed printers draw energy at a higher rate, shortened printing time outweighs increased energy draw and results in less energy use per page printed. For example, a Lawrence Berkeley National Laboratory study found that an eight page per minute (ppm) laser printer drew 60 watts, while a 24 ppm printer drew 100 watts. Because of the reduced printing time per job on the faster printer, however, average energy draw per print job was reduced by 40% on the 24 ppm printer.[6]

Reduce use of individual personal printers in favor of centralized networked printers. Each device uses energy when idle—even when in "sleep mode." Larger, newer printers tend to be more efficient per page and the lower quantity of devices reduces total energy use and often is less expensive to maintain.

Costs and rebates: High-speed printers are generally priced higher than low-speed printers, but because they can handle larger print loads, fewer high-speed printers are needed to meet printing demand. Thus, especially when energy savings are accounted for, the net cost of high-speed printers tends to be lower on a cost/ppm basis. Utilities typically do not provide rebates for efficient printers.

Duplex printing reduces the cost of paper and paper disposal by up to half. A reduction in paper use will also lower the organization's upstream greenhouse gas footprint. For more information, see: http://c.environmentalpaper.org/home

For a more information on efficient office equipment, see the New Building Institute's Plug Load Best Practices Guide. http://newbuildings.org/sites/default/files/PlugLoadBestPracticesGuide.pdf

Additional information

- Efficient Products Survey of Residential Plug Loads http://www.efficientproducts.org/product.php?productID=11
- Efficient Products Commercial Office Plug Load Savings Assessment http://www.efficientproducts.org/reports/plugload/PlugLoadSavingsAssessment.pdf
- Efficient Products Commercial Office Plug Load Savings and http://www.efficientproducts.org/reports/plugload/OfficePlugLoadAssessment_ExecutiveSummary.pdf

Notes

1 Energy Information administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E1A. Major Fuel Consumption (Btu) by End Use for All Buildings," September 2008. http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

2 Personal conversation with Joe Burke, Verdiem (Director, Strategic Accounts), March 2007.

3 Vending Miser website http://thevendingmiser.com/

4 Plug Load Solutions, "80 PLUS Benefits Fact Sheet." http://www.plugloadsolutions.com/docs/collatrl/print/80plus_benefits.pdf

5 U.S. EPA and U.S. DOE, Energy Star, "Office Equipment." http://www.energystar.gov/index.cfm?c=ofc_equip.pr_office_equipment

6 Portland Office of Sustainable Development, "Green Office Guide," November 2001, p. 8. http://www.oregon.gov/ENERGY/CONS/BUS/docs/Green_Office_Guide.pdf

CHAPTER 13

Data centers and IT equipment

Goals

- Investigate energy used in organization's data centers
- Understand the high-level linkages between data center efficiency and business profitability
- Identify the major energy end uses and sources of data center inefficiency
- Analyze and recommend initiatives to capture cost-effective energy savings

Overview

Although many organizations do not realize it, data centers are major contributors to total operating costs and environmental impact. This is because data centers typically have been designed and operated with little consideration for energy efficiency. The data centers (also known as computer rooms, server rooms, or IT rooms or closets) in most organizations are located within larger office buildings so in most cases the cost and environmental impact of this equipment goes unmeasured and unmanaged. As a result, there are many efficiency opportunities with exceptionally strong business cases, as discussed below.

Data centers are critical to business

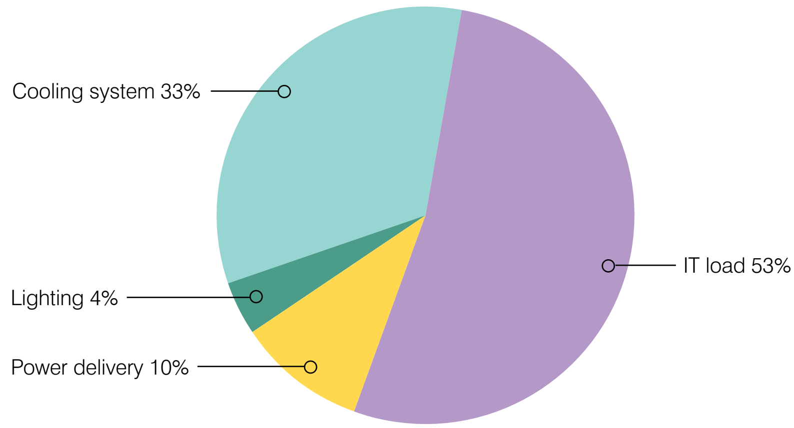
Businesses of all types have become increasingly dependent on information technologies (IT). Most businesses rely on IT to manage core business functions, such as account management, web presence and sales, as well as finances, human resources and email systems.

IT computing equipment has evolved from mainframe machines used only for specialized functions to ubiquitous servers. Since critical business functions depend on computing capacity, 24-7 server availability, or "uptime," is important. To help ensure maximum uptime and capture economies of scale, servers are commonly aggregated into data center facilities, also known as "server farms." Data center facilities are designed to supply reliable and high quality power to servers and keep equipment cool.

Unfortunately many organizations still have very decentralized IT equipment. It is not uncommon for operational servers to be located under IT staff member's desks or to be housed in converted janitorial or office supply closets (thus the origin of the term "IT Closet"). There is operational risk with this kind of IT equipment infrastructure since it is unlikely that these diverse systems are adequately backed-up or supplied with reliable power or cooling. Diverse IT equipment is also very hard to manage and keep track of. A complete inventory and review of all IT equipment and services should be the first step of any organization's IT reliability and energy management plan. Often, the logical next step is the removal and disposal of old or redundant equipment, followed by consolidation of remaining equipment into properly designed and managed data center facilities.

FIGURE 13.1

Estimated energy consumption of an average data center



Source: Rocky Mountain Institute estimate.

Some large organizations own their own data centers, while others outsource their IT functions or lease data center space managed by a hosting organization. Data centers that lease space are known as co-location centers, or "co-los."

A strong business case exists for making data centers more efficient. In a typical data center, less than 5% of the power consumed is used for computing operations. The other 95% is simply lost along the way—as heat in the servers, as conversion losses in power supplies, powering fans and lights, and in cooling systems required to remove all that waste heat.

Efficiency opportunities exist at each step of the system. In many cases, best practices are well known, as described below. Because increased energy use drives increases in both operating costs (electricity) and capital costs (for back-up generators, battery banks and cooling systems), efficiency measures in data centers generally cut costs quite dramatically and pay back relatively quickly.

More specifically, efficiency measures provide economic value in three main ways:

1. Saving energy reduces electricity costs required to power and cool servers.

2. Energy efficiency increases the number of servers that can be supported by existing data center infrastructure, delaying or eliminating demand for expensive new data centers.

3. In new data centers, designing more efficient systems can substantially reduce total capital outlays.

Energy efficiency improvements of 20–40% are typical in data centers, with savings over 50% possible in some cases.[1] Of course, costs and savings from efficiency measures vary among data centers. The savings and cost numbers in this chapter are *rough estimates*; they will need to be verified in order to be applied to specific data centers. Large energy and cost savings opportunities exist and are well documented, but unfortunately there are many organizational and risk management issues that have prevented most organizations form achieving those savings. Data centers are complex facilities, and efficiency potential depends on a wide range of factors. Data center decisions are subject to influence from many stakeholders—business executives, equipment purchasers, IT operators and facilities managers. Expertise and knowledge about the topics below is spread across this diverse group. Participation from a team of stakeholders is needed to evaluate efficiency potential and implement efficiency programs. Here is a list of organizational dynamics and considerations that can contribute to or impede the successful deployment of data center efficiency.

- Cost and environmental impact of IT electrical use must first be measured before it can be managed
- IT's focus on maximum uptime at any cost results in wasted capital investment and excess energy spends; it is a best practice to implement robust and resilient software that allows flexible and efficient physical environments
- Disconnect between who pays the costs of efficiency efforts (IT department) and who receives financial benefits (facilities department that pays utility bill)
- Treatment of physical IT hardware like capital assets (depreciation over time) rather than rapidly changing technology that for optimum financial return should be replaced every 18 months to two years
- Procurement and contract management and incentive programs that focus on lowest up-front purchase price while ignoring full life cycle cost of equipment decisions are a barrier to energy efficient projects
- Finance needs a way to transfer funds between budgets to allow utility savings to fund increased IT equipment (more refresh) and facility equipment investment

Additional information

For more information on data center energy use, see:

- Jonathan Koomey, "Growth in Data Center Electricity Use 2005 to 2010." Oakland, CA: Analytics Press. 2011. http://www.analyticspress.com/datacenters.html
- Uptime institute http://www.uptimeinstitute.org
- Green Grid http://www.thegreengrid.org

Information gathering guide

These questions will help to start the dialogue on data center efficiency:

- Is there a current and accurate inventory of the organizations IT equipment?
- Has an operational risk assessment and contingency evaluation been performed on the organizations critical IT infrastructure?
- Where are servers located? (In server closets in offices; in organization-owned data centers; or in leased data center space [co-location]?) Are IT services outsourced?
- What is the utilization of server capacity? Less than 5% indicates a large opportunity to increase hardware utilization; 30–50% is relatively good, but may still offer opportunities for improvement.
- What is the data center power utilization effectiveness (PUE, see description below)? A reasonable target for retrofit efforts is 1.5; industry average PUE is about 2.0. How frequently is PUE measured (ideal is continuously calculated)?
- Who (which department) pays for data center energy and operating costs?
- What is the organization's policy on IT equipment refresh? How much of IT hardware is older than three years (industry best practice is to replace equipment every two years due to

improved efficiency and performance, acceptable is 3-4 years, anything older than 4 years needs to be replaced).

- Is life cycle analysis (including direct and indirect energy use) performed when evaluating new equipment purchases, replacements or expansions?
- Who is responsible for IT strategy and data center investments?

Tactics for reducing energy use

1. Prerequisite: Monitoring and benchmarking

Although monitoring and benchmarking do not directly create energy savings, these low-cost measures inform efficiency programs and track their impact.

- **Calculate and monitor power utilization effectiveness.** The PUE is the ratio of total energy used by the data center to energy actually consumed by servers over a particular time period. An ideal data center would have a PUE of 1.0—all energy would be used to power servers. In reality, many data centers have a PUE of 2.0 or higher—the servers use just half of the energy. The rest is consumed by infrastructure systems to keep the data center environment cool and manage power quality. PUE can be calculated in different ways depending on where and how measurements are taken. An organization should establish guidelines on how PUE is calculated to ensure consistency. The PUE can change over time and throughout the year depending on server loads and outside temperatures, so it should be monitored regularly to track data center performance. Note that PUE is not a measure of data center overall efficiency or productivity since it does not measure the output produced by the IT equipment; it only compares the ratio of electricity use. For example a data center with newer IT equipment may have more production (processing or storage) and lower total energy use (thus more efficient), but a higher PUE than another data center that has older IT equipment but a lower PUE. EPA provides a Data Center benchmarking tool http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency
- **Track server utilization.** Average servers operate at less than 10% of their potential capacity, due to unpredictable loading patterns. Installing software that monitors server use helps to identify efficiency opportunities in underutilized servers as well as servers that are no longer being used at all.
- **Install sensors to monitor temperature and humidity.** Servers have specific temperature ranges (see Tactic 5). Improved monitoring can identify isolated “hot spots” within the data center where the air is significantly hotter than the average room temperature. This data can be used to focus cooling efficiency programs and allow more servers to be added to the data center without overheating. Note that only the air temperature at the INLET to the IT equipment matters—no action is needed to address “hot spots” that occur in the exhaust air from servers.
- **Use kW/ton metric to assess cooling system performance.** The ratio of power consumed by a cooling system (kilowatts) to heat removed (tons, equivalent to 12,000 Btu/hr) is a measure of the cooling efficiency. Optimized cooling systems may operate at 0.9 kW/ton or less. In many data centers, values are above 2.0 kW/ton, indicating a large potential for efficiency improvements.

2. Energy efficient software

The energy savings potential can be quite high for software measures, although the costs and expected savings of these measures will vary widely among organizations.

- **Design or purchase new software that minimizes energy use.** Energy use is rarely an important constraint for software developers. As a result, software often puts high demands on server hardware. More efficient software can accomplish the same task with less energy. Software efficiency is a complex issue, because efficiency measures are specific to individual programs and tasks. Incenting software designers to write more energy efficient code is an important first step for software created in-house. For purchased software, industry standards are still being developed to benchmark software energy performance.

- **Implement power management software.** Activating energy management programs can significantly reduce energy use. Like power save modes on desktop computers, servers can be programmed to go into idle mode when they are not being used.

3. Improved server utilization

"Server utilization" refers to the proportion of a server's processing capacity that is being used at any time. For most servers, energy use does not vary substantially based on the level of utilization. As a result, unused or underutilized servers use nearly as much energy as fully utilized servers. Significant efficiency gains can be accomplished by taking steps to reduce the number of servers running at low or zero utilization, and these steps can be taken at a comparatively low cost.

- **Unplug and remove servers that are not being used at all.** Surprisingly, a significant fraction of servers (in some cases, 20% or more) in many data centers are no longer being used. If an office employee quits, others would quickly notice if the unused desktop computer kept turning on every day. Servers are less obvious; they can run their operating systems and background applications invisibly for months or years before they are removed. To identify unused servers, run programs to monitor network activity over time. This effort will identify potential "zombie servers," which then must be individually investigated to determine whether they can safely be unplugged and removed.
- **Virtualize multiple servers onto single machines.** Virtualization simulates multiple "virtual" or "software" servers that allow multiple operating system copies and applications to run simultaneously on a single physical server. Virtualization offers large energy savings potential, because it consolidates several servers onto a single, more utilized server. Virtualization presents challenges, because operating systems and applications must be compatible and reliably managed to avoid interruptions to operations. However, the potential benefits are so great that many organizations are implementing virtualization initiatives. Virtualization potential is often quantified as 3:1 or 5:1, reflecting the number of servers that can be consolidated onto a single machine. In many cases, however, virtualization levels exceeding 20:1 are possible.
- **Consider advanced resource allocation through applications rationalization and cloud computing.** In addition to virtualization, new techniques are available that allow computing demands to be allocated to any server with capacity, without compromising security. Called cloud computing, these programs distribute loads among servers to optimize utilization levels. Unneeded servers may be shut down to conserve power until they are required to handle spikes in load.

4. Efficient server hardware design

Buying efficient hardware is a cost-effective way to capture major energy savings. Although efficient hardware sometimes costs more upfront, often there is no cost difference. Since most servers should be replaced ("refreshed") every three to four years, frequent opportunities exist to upgrade to more efficient equipment.

- **Purchase best-in-efficiency-class (BIEC) servers.** For a given level of performance (processing speed, RAM, etc.), servers on the market exhibit a wide range of energy demand. In other words, performance is only slightly correlated to energy. Despite this, most organizations' purchasing decisions do not consider energy efficiency. Working with IT and supply chain departments to prioritize energy efficient server models during normal refresh cycles has the potential to save up to 50% of server energy. And since efficient servers are not necessarily costlier, this is a low-cost opportunity.

- **Mandate efficient power supplies.** In recent years, efforts to raise power supply efficiencies have gained momentum. Server power supplies transform Alternating Current (AC) electricity to the low voltage Direct Current (DC) demanded by electronic components. Historically, many power supplies have operated at as low as 60% efficiency—meaning that only 60% of the input power (AC) is converted to DC power.
- **Many off-the-shelf servers today have power supplies certified by the 80 PLUS program, which demands at least 80% average efficiency.** In fact, power supplies with efficiencies over 90% are available (the 80 PLUS program and the Climate Savers Computing Initiative provide lists of manufacturers offering high efficiency power supplies).
- **Use power management equipment to shut down servers.** Many servers are not used for significant periods of the day. Often, unused machines remain on, even when their loads are predictable. Power management applications and hardware (smart "power distribution units") can be programmed to shut servers down and then bring them back online when needed. Since most servers use more than half of their total energy consumption when idle, power management measures have the potential to significantly reduce server energy use.

5. Cooling system optimization

Cooling systems account for less than half of data center energy use, but there are often efficiency opportunities that can be implemented with very reasonable payback periods.

- **Block excess holes in raised flooring.** Many data centers use an open **plenum** beneath a raised floor to distribute air to the server racks. Fans are used to pressurize the air in the plenum. Perforated tiles are positioned where cold air is needed (at the air intake side of server racks), which allows cold air to be pushed up into the room. However, in many data centers, floor tiles are removed to run wires or conduct maintenance and are never replaced. This allows cold air to escape and reduces the efficiency of the cooling system. An easy fix is to cut out small holes for cables and replace floor tiles to cover holes.
- **Bundle underfloor cables. In many data centers, airflow is restricted in the plenum by tangles of wires and cables.** Organizing underfloor cables can reduce fan energy use and improve cooling effectiveness, allowing more servers to be added to the data center.
- **Relax temperature and humidity constraints.** Allowable temperatures in data centers are typically restricted to narrow ranges in order to reduce risk of server failure. Many data centers adopt the "recommended range" from ASHRAE (a cooling industry organization) of between 64˚ and 80˚F. However, server manufacturers guarantee that their servers will operate reliably in significantly warmer temperatures. For example, a typical Sun server specifies 95˚F as the upper limit temperature.[2] Allowing warmer data center temperatures can reduce cooling energy use. The largest potential benefit of allowing broader environmental conditions is that it increases the opportunity to use air economization or "free cooling" where outside air is used to cool the data center partially or fully replacing the need for mechanical cooling, enabling that equipment to be turned off.
- **Enclose "hot" or "cold" aisles and block holes in racks with blanking panels.** To maximize efficiency of an air-cooled data center, cold supply air should be physically isolated from hot return air. The simplest way to achieve this is to encapsulate an aisle of server racks by adding end doors, roof panels over the racks and "blanking panels," which fit into the racks and block air from flowing through empty slots. When implemented, air flows from the cold aisle

through the servers to the hot aisle and exhaust air stream without "short-circuiting" (cold air bypassing servers and merging with hot exhaust air) or "recirculation" (hot air flowing back to the server inlets, leading to overheating problems).

- **Commission a facility audit.** Mechanical engineering auditors evaluate HVAC systems and operations. After spending time on-site, they can estimate energy savings and cost impacts of efficiency opportunities. In addition to the cooling system measures described above, they may recommend retrofits to use outside air for cooling, to optimize condenser water and chilled water temperature setpoints, and other retrofit measures.

6. Other loads: Power supply and lighting systems

- **Optimize power supply and conversion systems to maximize efficiency.** The **uninterruptible power supply (UPS)** typically uses a battery bank to ensure that no blips in power input result in server failure. However, the process of switching between voltages and alternating to direct current is only 85% efficient. Since all energy used by servers passes through the UPS system, 15% of all energy is lost. One way to improve UPS efficiency is to install a "Delta Conversion" system, which diverts most AC power flows around the AC/DC conversion and battery equipment, reducing conversion losses.

- **Reduce lighting energy use with automated controls and more efficient fixtures.** Lights are a small piece of data center energy use, but they can easily be improved. In many data centers, lights are glaringly bright, so that workers can see into the dark racks to configure servers. Furthermore, lights are often on 24-7, since a worker exiting a large data hall never knows if someone else is still at work. Occupancy sensors allow lights to turn off when the data center is empty, potentially saving 50% or more of the lighting energy. Lights can also be divided into separate banks, so that the entire space does not have to be lit when people are working in one area. Finally, the quality of light may be improved by using light-colored interior surfaces and server racks and by using indirect lighting fixtures.

Additional information

For more information on data center energy monitoring, see:

- Green Grid, "Data Center Power Efficiency Metrics: PUE and DCie," October 2007. http://www.thegreengrid.org/en/Global/Content/white-papers/the-Green-Grid-data-Center-power-efficiency-metrics-pUe-and-dCie

For more information on software efficiency, see:

- Intel, "Creating energy efficient software." October 2008. Accessible at http://software.intel.com/sites/default/files/m/d/4/1/d/8/developing_green_software.pdf

For more information on server utilization, download

- "Selecting the Right Virtualization Technology at: http://technet.microsoft.com/en-us/library/bb897468.aspx

For more information on efficient server hardware, see:

- Matt Stansberry, "The Green Data Center: Energy-efficient Computing in the 21st Century," Chapter 2: Energy-efficient Server Technologies. Accessible at http://wp.bitpipe.com/resource/org_1126901568_974/cassatt_ebook_9_14_v3.pdf
- Ecova plug load solutions, "80 PlUs power supplies." Accessible at http://www.plugloadsolutions.com/80PlusPowerSupplies.aspx
- Climate savers Computing initiative. Accessible at http://www.climatesaverscomputing.org

For more information on data center cooling systems, see:

- PG&E, "High performance data Centers," January 2006. Accessible at hightech.lbl.gov/documents/data_Centers/06_dataCenters-pGe.pdf

For more information on data center power supply systems, see:

- California energy Commission pier, "Uninterruptible power supplies: a data Center efficiency opportunity," September 2008. Accessible at http://esource.com/esource/getpub/public/pdf/cec/CeC-tb-45_UpsdataCenter.pdf

Notes

[1] Best Practices for Data Center Energy Efficiency Workshop, Data Center Dynamics, Dale Sartor, P.E. Lawrence Berkeley National Laboratory, May 25, 2012. http://hightech.lbl.gov/presentations/dc-dynamics-5-25-2012.pdf

[2] Sun Microsystems, Sun SPARC Enterprise T2000 Server, "Specifications." Accessible at http://www.sun.com/servers/coolthreads/se_t2000/specs.xml#anchor8

CHAPTER 14

Industrial facilities

Goals

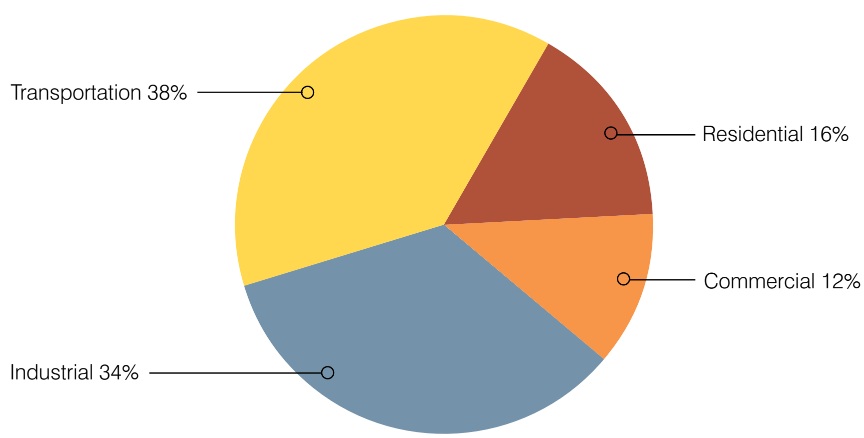
- Achieve an understanding of the characteristics of industrial and non-commercial facilities and how they are similar and different from commercial facilities
- Develop an overview of the types of equipment and systems common to industrial facilities and associated energy efficiency opportunities
- Develop an understanding of operations and business concerns at typical industrial facilities and how these may impact the ability to implement energy efficiency projects
- Develop some best practices for overcoming common barriers to implementing efficiency projects in non-commercial facilities

Overview

Industrial facilities include a wide range of sites ranging from oil refineries, steel and cement mills, airplane, auto and semiconductor factories (aka "chip Fabs"), to wineries, food processors, waste water treatment plants, coal, gas and nuclear power plants and many more. In general most facilities that are neither residential nor commercial can be considered "industrial"—a catch-all term for the "other" types of facilities that use energy. An industrial facility is typically

FIGURE 14.1

Percentage of 2011 U.S. energy sales by sector



Source: Lawrence Livermore National Laboratory and the U.S. DOE a manufacturing facility, where something is made or transformed, but often distribution centers or even pipeline pump stations are considered industrial facilities. It is difficult and risky to make generalities about such a diverse and large group, so when reviewing this chapter keep in mind that exceptions to this information may be common. The unique characteristics of each industrial facility should always be well understood and taken into consideration

According to the U.S. Department of Energy and the Energy Information Agency, industrial sites, as a group, use more energy in the United States each year than the residential and commercial sectors combined, and almost as much energy as all forms of transportation (see Figure 14.1).

Due to high energy use, industrial facilities have a large impact on national carbon emissions as well as most other waste streams. For specific industries a good resource are sector specific studies conducted but the U.S. Department of Energy at: http://www1.eere.energy.gov/manufacturing/resources/energy_analysis.html

Like commercial facilities, most industrial facilities will include lighting, HVAC and plug-load energy consuming systems. Some areas in industrial facilities, for example an office area that is part of a manufacturing site, may resemble commercial facilities and can have similar equipment and share many of the same possible energy efficiency opportunities. Generally, however, industrial sites are likely to have equipment or versions of systems that are significantly different from most commercial buildings. Some examples include:

- "High-bay" lighting (lighting for tall ceilings and large indoor open spaces)
- Large scale refrigerated rooms (whole buildings that are maintained at 35ºF or even –20ºF or colder)
- Large scale exhaust systems for smoke, fumes or dust
- "Steel shell buildings" (buildings with a roof and walls but open to outside air with no insulation or effort to isolate the internal environment from outside conditions)
- Large scale air-circulation pattern issues, i.e. internal "weather"

Another key characteristic of industrial facilities is that the vast majority of the energy used is often driven by the process rather than the building. This means that the equipment used directly in the manufacture of goods, or the systems that indirectly support the manufacturing equipment, often will use far more energy than the total energy used by the common commercial-like systems (lighting, HVAC and plug loads). For this reason it can be very hard to make noticeable reductions in energy consumption at an industrial facility by focusing exclusively on the support systems. To make significant impact on energy use and costs, changes need to be made to these core process systems.

Industrial energy using systems

Below is a list of the major energy-consuming systems that might be found at an industrial site. Most sites will have some of these systems, but few will have all of them. Some of these may also be found at commercial sites but at much smaller scale.

- Boilers and steam systems
- Process combustion (furnaces)
- Compressed air
- Motor driven equipment—fans, pumps, process equipment
- Chillers and process cooling systems
- Refrigeration systems

- Exhaust scrubbing and dust collection
- Waste water treatment
- Lighting
- HVAC

The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy provides extensive information, including case studies, calculation tools, technology summaries and research papers, on several of the energy-consuming systems listed above. Links to these are included in Additional Information at the end of this chapter. Industrial facilities may have the ability for fuel and feedstock flexibility because of multiple systems or the ability to reconfigure systems to take advantage of variable fuel costs (change between natural gas, fuel oil, bio-fuels, or process waste for heating). This allows the site to take advantage of cost savings due to changes in fuel market prices, but has the side impact of complicating the analysis of energy efficiency projects and site carbon emissions.

Self-generation and Combined Heat and Power (CHP) are sometimes found at industrial sites due to their constant operation (most run 24-7 × 365/yr), large energy use, and tendency to need simultaneous heating and cooling. These systems are complex but offer large opportunities for cost and carbon reductions and thus are a focus of major education and research efforts by the U.S. Department of Energy and EPA. See http://www1.eere.energy.gov/manufacturing/distributedenergy/ and http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf

While the energy use of a typical industrial site is often many times larger than a typical commercial facility, it is often not well-managed since it is typically a small fraction of the total cost of operation and operation, often coming in after raw materials, labor and capital equipment depreciation, and even often less than taxes, business overhead or finance interest charges. For this reason, large opportunities for energy efficiency improvement at industrial facilities are frequently overlooked or undervalued.

Production is the priority

An industrial facility exists for a primary function—to produce something. In general, the more the facility produces the more money it generates. Maintaining a high volume of production is the priority of almost everyone at an industrial facility. When production stops for any reason, the lost output is lost money.

This emphasis on maximizing production can be a barrier to energy efficiency projects for a number of reasons, many of which are similar to the barriers that face all organizations:

- **Lack of attention:** all time is focused on maximizing and maintaining production.
- **Lack of resources and funding:** financial budgets are prioritized for projects that will be able to increase production.
- **Lack of time:** when equipment fails, all effort is focused on getting the plant back into production as fast as possible (there is often not enough time to research or order more energy efficient alternative equipment).
- **Fear of negative impact to production:** a common (but often false) belief is that production and energy efficiency cannot both be optimized so that saving energy may impact production; the concern alone—without data or justification—may be enough to prevent energy efficiency efforts.
- **Fear of change:** optimizing operations for energy often requires changes of equipment and operating practices; this raises concerns that those changes could negatively impact production.

This often includes the implied/assumed reasoning that ANY impact to production would be a larger financial cost than whatever savings could result from energy efficiency (again this is often without data and often not the case).

While these barriers are often significant, they also represent opportunity for energy and cost savings. In almost all cases, facility staff finds that the changes made for energy efficiency efforts (either operational and maintenance procedure changes or new or upgraded equipment) often have a very positive impact in production due to higher volume, productivity, reduced waste, higher quality and reduced re-work.

Best practices for industrial energy efficiency

Since industrial sites are so diverse, there is no single method or solution for effectively implementing energy efficiency. Instead, like in the commercial segment, there are a number of best practices that can be effective. Consider the circumstances and existing conditions described below:

- **Start by evaluating current conditions and practices.** Have any energy projects been completed in the past? If so, how did they happen? Who drove them and why? What challenges were encountered? What was learned and can the lessons be applied?
- **Lighting and HVAC systems can be attractive.** These systems do not directly impact production so are less likely to be stopped by concerns about production impact. Upgrades are generally straightforward to analyze and plan. And there are also likely to be utility or government incentives and rebates available.
- **Create buy-in with critical personnel.** Identify key staff such as production supervisors or maintenance managers that are in roles that could veto or delay implementation of energy efficiency projects. Listen to their concerns, and include them in the solution development process. Work to have them feel ownership of the proposed energy efficiency project and receive credit when they are completed.
- **Identify, quantify and highlight non-energy benefits of energy efficiency projects.** Most energy projects will have other benefits such as reduced maintenance, lower down-time, increased production or quality, lower labor costs, etc. For an industrial site, energy waste is often a symptom of process and equipment inefficiencies so improved energy efficiency often improves other aspects as well. Be sure these are included and highlighted in any proposal.
- **Develop an energy management strategy and documented plan.** Develop a process for collecting and monitoring energy use data. Assign owners and goals for improving energy performance. Track actual performance compared to goals and historical trends. Identify major drivers for energy use and opportunities for improvement (see Energy Star for industry for an energy management program assessment tool: http://www.energystar.gov/index.cfm?c=guidelines.assess_energy_management
- **Commit and implement Superior Energy Performance** (http://www.superiorenergyperformance.net/index.html) **and / or ISO 50001** (http://www1.eere.energy.gov/energymanagement/pdfs/iso_50001_energy.pdf)
- **Identify and implement outside energy assessments (audits)** to provide a fresh perspective and ideas for energy efficiency opportunities.
- **Identify corporate and external resources (such as utilities, equipment vendors, energy efficiency consultants)** that can assist in identifying and implementing improvement projects at a facility when on-site staff does not have the time or knowledge to do so.

- **Develop a plan to document and quantify successes after projects are completed.** If some energy efficiency projects are completed (lighting, HVAC, motor VFDs, etc.) spend time to follow-up and document financial savings and non-financial benefits (increased lighting levels, better light color or consistency, better employee comfort). Often energy project financial return forecasts are met with skepticism because management has not seen the results of prior projects (often due to lack of time or resources to do post-project analysis).

Information gathering guide

The information below can be gathered from the plant engineer, production manager, finance analyst and maintenance manager (it is unlikely any one individual will have all of this).

- What is the overall facility production process flow? Where in the process is energy used? What are the key constraints (limits) to production volume and quality?
- Is there a list of major energy-using equipment with sizes and equipment specifications (motors, boilers, furnaces, compressors, chillers, etc.)?
- What systems or equipment have the largest cost or carbon impact? What portion of the plant total do these represent? What is the utilization of this equipment (how much is it actually used for production vs. how much capacity does it have)? What productivity improvement projects are being considered for this equipment/systems? What impact on energy do these proposals have? Is energy impact being considered in these proposals? Has a lifecycle-cost analysis been done on alternative options for these proposals?
- What is the budget and funding process for both maintenance repair projects and for capital projects? How does the organization differentiate between expense and capital projects? What are the criteria for prioritizing or approving projects?
- What process improvement efforts have been made in the past (Lean, Total Quality, etc.)? Was energy cost or carbon considered in these efforts? Who owns process improvement efforts?
- How is energy measured and monitored? What data are available at the system or equipment level? Can energy use be estimated for systems or equipment that are not directly monitored?
- What energy efficiency projects were proposed in the past? Where any completed? Why were some approved and others not? If completed, how did actual performance compare to projected performance?
- What non-energy factors are most important to the organization and key decision makers (different decision makers may prioritize factors differently)? How are these potential barriers to energy efficiency projects? Can they be leveraged to help achieve approval for projects?

Additional information

- Estimated U.S. energy use by source in 2011. Accessible at https://flowcharts.llnl.gov/content/energy/energy_archive/energy_flow_2011/LLNLUSEnergy2011.pdf
- U.S. Department of Energy, Energy Analysis by Sector. Accessible at http://www1.eere.energy.gov/manufacturing/resources/energy_analysis.html
- Department of Energy and Environmental Protection Agency report on Combined Heat and Power (CHP) as a clean energy solution. Accessible at http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf
- U.S. Department of Energy overview of Combined Heat and Power. Accessible at http://www1.eere.energy.gov/manufacturing/distributedenergy/

- U.S. Department of Energy Advanced Manufacturing Office projects, analysis, protocols and strategies to reduce industrial energy and carbon emissions in specific industries and technologies. Accessible at http://www1.eere.energy.gov/manufacturing/resources/industries_technologies.html
- U.S. Department of Energy initiatives, technology research, and implementation for manufacturing. Accessible at http://www.eere.energy.gov/topics/manufacturing.html
- U.S. Department of Energy Manufacturing Energy and Carbon Footprints. Accessible at http://www1.eere.energy.gov/manufacturing/resources/footprints.html
- Superior Energy Performance cm certification program for verifying energy performance improvements and management practices. Accessible at http://www.superiorenergyperformance.net/index.html
- ENERGY STAR for Industry. Acessible at http://www.energystar.gov/index.cfm?c=industry.bus_industry
- ENERGY STAR energy management program assessment. Acessible at http://www.energystar.gov/index.cfm?c=guidelines.assess_energy_management
- The Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) provides information on industrial energy-consuming systems:
    - Boiler and Steam Systems: http://www1.eere.energy.gov/manufacturing/tech_deployment/steam.html
    - Compressed Air: http://www1.eere.energy.gov/manufacturing/tech_deployment/compressed_air.html
    - Motors: http://www1.eere.energy.gov/manufacturing/tech_deployment/motors.html
    - Fans: http://www1.eere.energy.gov/manufacturing/tech_deployment/fans.html
    - Pumps: http://www1.eere.energy.gov/manufacturing/tech_deployment/pumps.html
    - Process heating: http://www1.eere.energy.gov/manufacturing/tech_deployment/process_heat.html

CHAPTER 15

Energy consumption of company vehicles

Goal

- Identify opportunities to reduce fuel consumption in corporate vehicles

Overview

Additional cost-effective energy efficiency gains can be made in organization vehicle fleets. Operating a cleaner, greener fleet means more than just counting the number of hybrids or alternative fuel vehicles on the road. Successful management means actively measuring and reducing greenhouse gas emissions. Many low-to-no-cost strategies are available to cut fuel consumption and emissions from corporate fleets. These include right-sizing vehicles and engines, reducing idling, reducing miles through improved routing, and reducing vehicle curb weight. To get the largest quantity of reductions, look first at the vehicles that comprise the largest segment of the fleet. A 3% efficiency improvement in 100 vehicles is usually more impactful than a 100% improvement in three vehicles.

Tactics for reducing fuel consumption

1. Improve vehicle selection

The most important environmental decision for a fleet is which vehicles to source. Relatively minor changes in vehicle selection can result in significant environmental—and financial—benefits over time. Consider the following strategies for improving vehicle selection:

- **Select the right size.** Analyze the operational needs of the fleet and eliminate excess vehicles. Match the duty requirements with the appropriate class and size vehicles. Special features, such as 4-wheel drive and 6- or 8-cylinder engines, can increase costs and emissions.
- **Choose "best-in-class."** Select vehicles with the highest fuel efficiency in their class that meet your organization's price and performance needs.
- **Evaluate total lifecycle costs.** Make vehicle selections based on costs over the full life of the vehicle, including acquisition, fuel consumption, depreciation and resale.
- **Use incentives.** Consider offering employees popular options such as interior upgrades, sunroofs and satellite radios as incentives to select more cost-effective, efficient vehicles.

2. Improve vehicle use

The way a vehicle is driven and maintained affects operating cost, fuel economy and greenhouse gas emissions. A few actions in this area can yield significant savings.

- Educate drivers. Teach drivers how to be more efficient on the road and drive fewer miles. Speeding, coupled with rapid acceleration and deceleration, for instance, can significantly increase fuel consumption. Idling is another inefficient practice—ten seconds of idling uses more fuel than re-starting the engine.
- Improve maintenance. Ramp up the vehicle maintenance program. Regular oil changes, proper tire inflation and other preventive maintenance practices increase fuel efficiency.
- Incorporate technology. Take advantage of new technologies, such as routing software, GPS systems and fuel management software to maximize efficiency. Telematics products allow for real time monitoring and data collection, which can increase safety, reduce idling, cut fuel consumption and decrease emissions.

Information gathering guide

- What are the main functions served by the fleet (i.e., delivering beverages, transporting sales staff, storing tools for technicians)?
- How many and what types of vehicles does the organization use?
- What is the average mileage driven per function?
- Are there more fuel-efficient vehicles that could do the job?
- What processes are in place for tracking fuel consumption?
- What efforts have been made to educate drivers about fuel efficiency?
- Are fleet emissions calculated at least annually?
- Is there currently an environmental program for the fleet? What are the goals?
- Does the organization self-manage the fleet or does it work with a fleet management company?

Additional information

- GHG management: EDF's Green Fleet Resources http://edf.org/greenfleet
- Vehicle selection: ACEEE Greener Cars http://www.greenercars.org
- Vehicle Use: U.S. DOE and EPA's Gas Mileage Tips http://fueleconomy.gov/feg/drive.shtml
- *Case Example, 2012 Annual Sustainability Report,* Organically Grown Company http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=VMC

CHAPTER 16

Demand response and smart grid

Goals

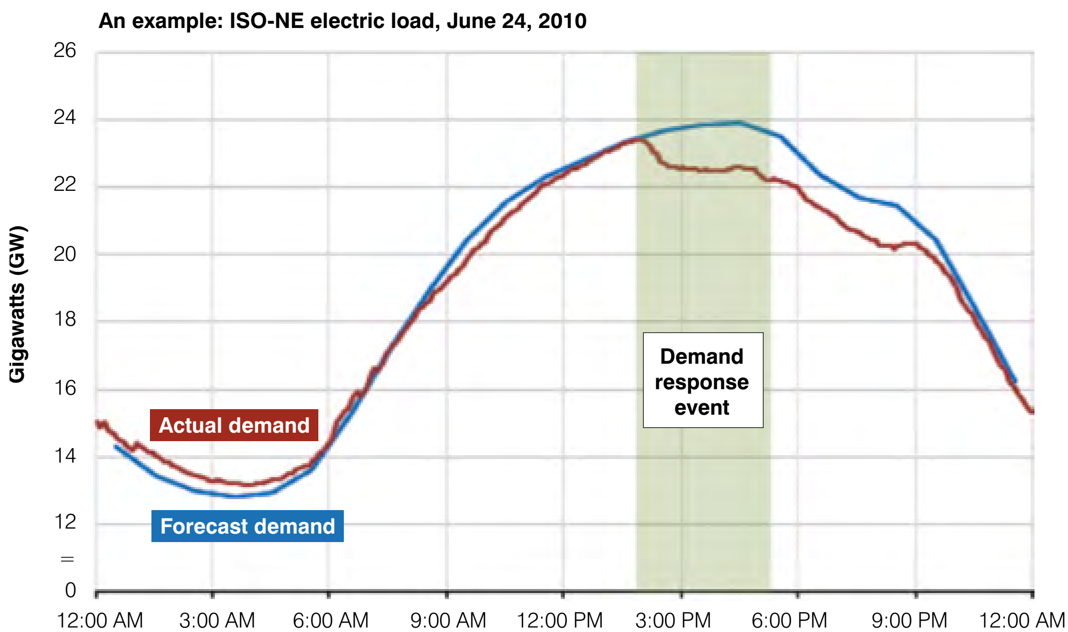
- Achieve a basic understanding of demand response (DR)
- Understand the components of DR agreement with a utility or curtailment service provider (CSP)
- Determine how to identify DR opportunities
- Understand how DR and smart grid are related
- Evaluate the potential energy savings and revenue from DR participation

Overview

Demand response (DR) is the action taken by end users (customers) of a utility to temporarily reduce their energy usage in response to either price or system reliability triggers. Reliability

FIGURE 16.1

Demand response event



Source: U.S. Energy Information Administration issues occur when the electrical grid is at peak capacity and at risk of brownouts or blackouts (demand response programs were originally used by grid system operators as a means of preventing these disruptions). Price triggers allow end users the option to reduce their electrical load based on high wholesale electricity prices. Demand response programs offer a unique opportunity for a customer to receive financial benefits for temporary reductions in energy usage.

DR programs can be administered by electrical utilities, independent system operators (ISO) or regional transmission organizations (RTO), but regardless they all have the same intent—to reduce energy demand during a brief period of time, based on a system reliability or price trigger. However, each program has its own requirements for establishing baselines, **measurement and verification (M&V)**, **generator emission allowance**, response time and payments.

Due to the complexity of these programs, companies will often work with a curtailment service provider (CSP) to administer the program. CSPs can provide services to help a customer participate in demand response and can act as a liaison to the utility/ISO/RTO. A CSP may provide necessary sub-metering, conduct an audit to identify load reduction opportunities and manage the relationship with the utility/ISO/RTO. Working with a CSP is an effective way to mitigate the risks of participating in a DR program; it can shield the customer from potential financial penalties for non-performance. For information on the components of an agreement between a commercial and a CSP or utility, consult Appendix H.

With increasing technologies demand response has become an important part of the trajectory to a **smart grid**. Smart grid refers to the use of communication and **information technology (IT)** within the electrical grid that improves the flow of data between utilities and end users. With the increase in energy sub-metering technology, system controls and integrated appliances, DR will expand beyond being a resource for grid and price instability, and become a critical component of the smart grid, enabling real-time signals between utilities and end users for targeting reductions in electricity consumption. smart grid will also be critical to the integration of renewable energy sources into the electrical transmission system, addressing the need to balance the intermittent nature of renewable energy (i.e. cloudy days for solar energy and low wind for wind turbines).

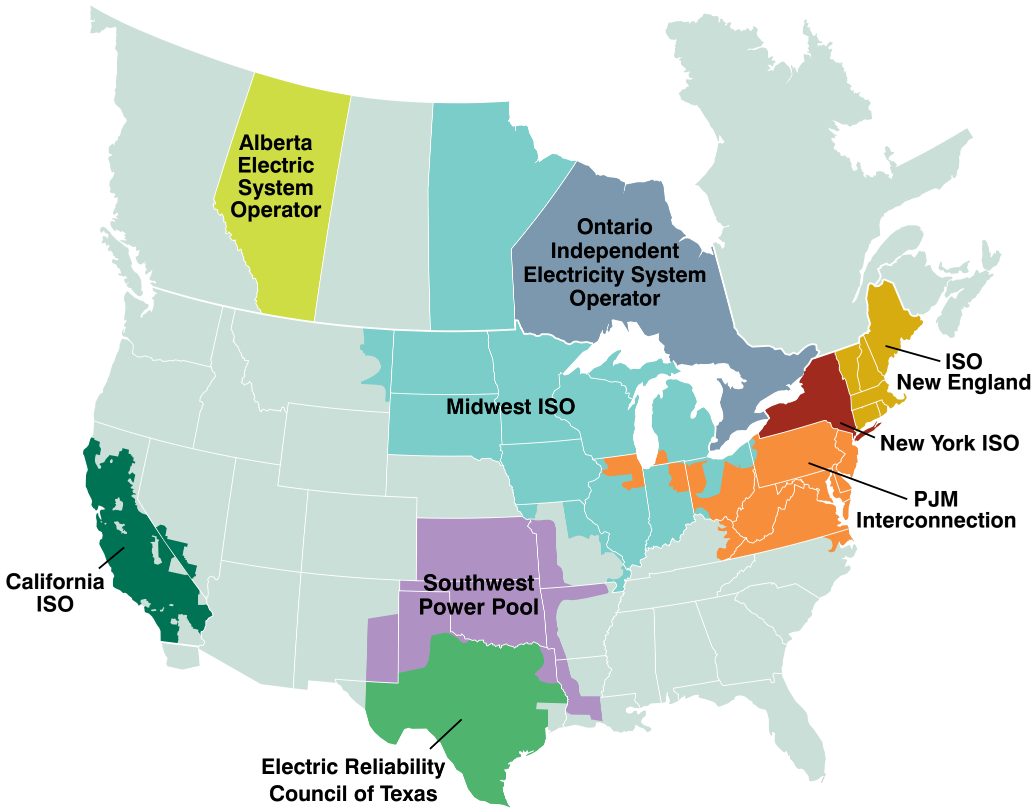
It is important to note that while DR is not typically viewed as an energy efficiency measure, it does provide an opportunity for energy cost savings and overall increased reliability of our electrical grid. For carbon and climate impact, some additional caution and analysis will be necessary as some DR measures (such as pre-cooling or thermal storage) actually result in increased total energy use (but may reduce costs).

Information gathering guide

- Determine what DR programs are available within your electrical service territory. Below is a map of the existing ISO/RTO organizations with mature Demand Response programs. Note that if your facility is not within an ISO/RTO service territory, the DR program may be offered through your local electrical utility.
- Determine the types of temporary electric load reductions that can be implemented at the facility and collect building system information to determine your load reduction potential. Tactics for reducing demand for building systems are included in the next section.
- Determine your sub-metering needs. DR programs require verification of the energy reductions using interval meters or other data collection devices. Consult with your specific DR program to determine the measurement and verification requirements.
- Develop a facility-level Demand Response Action Plan to prepare and inform building operators of the program features and actions to reduce electrical load for a given facility.

FIGURE 16.2

U.S. map of RTO/ISO Councils



Source: ISO/RTO Council

As part of a DR Action Plan, select key contacts within the organization. Demand response events are unpredictable and it is critical to have a communications protocol in place. The notice for DR events will come from the ISO/RTO or CSP via phone calls or email. Although the majority of DR is done by manual interventions, there are technologies that allow for automatic demand reductions. If a facility has the technology capability it may enroll in an Auto-DR program, in which the ISO/RTO/Utility can send a trigger for reduction to an automated load control system (i.e. using a building management systems (BMS) to reduce temperature set-points for a building).

- Determine what the average monthly electrical demand is for the facility. This information can be found on the utility bill. Electrical demand in measured in kilowatts (kW) and is different from electricity consumption measured in kilowatt-hours (kWh). Typically, the facility commits to a specific amount of demand reduction in kilowatts. Most DR programs have a minimum required kilowatt reduction for participation.

Tactics for reducing electrical load during a DR event

Lighting

- Reduce lighting in common areas. In addition to energy savings, reducing lighting in common areas can be used increase awareness among employees of the facility's efficiency efforts.

- Reduce or turn off all lighting in spaces with adequate natural lighting.
- Encourage employees to identify and reduce unnecessary lighting in their work spaces.

Heating ventilation and air conditioning (HVAC)

- Pre-cooling. Temporarily reduce the thermostat/chiller setpoint to 60° until 15 minutes before a DR event, and increase the temperature to 85° for the duration of the DR event.
- Thermostat setpoint adjustment. HVAC is one of the largest energy uses in commercial buildings. During a DR event, temporarily adjust the temperature setpoints either manually or through a building management system (BMS).
- Utilize window shading to reduce solar heat gain.

Plug loads

- Encourage occupants to reduce their plug loads during events. Common nonessential plug loads include TVs, space heaters, secondary monitors, electric ovens, fans and printers.

Vertical transportation

- Reduce the number of elevators and escalators operating.

Building controls

- Building controls allow building operators to reduce global temperature setpoints and reduce variable frequency drives (VFD) on fans and motors.
- Utilizing VFDs can result in significant demand reduction; a 10% reduction in motor/fan speed will decrease its power consumption by 27%.
- Facilities with sophisticated building management systems (BMS) can program reduction sequences, referred to as auto-demand response.

Process systems

- Process loads provide the greatest opportunity for industrial facilities to reduce loads, by reducing or shutting down large process loads (i.e. compressed air systems, large motors and other large machinery).

Employee engagement

- Communication is critical during DR events. Notifying facility occupants through email, signage and other efforts can be a powerful tool to ensure compliance and cooperation needed to impact reduction while also mitigating occupant complaints for possible disruptions during the DR event.

Distributed generation

- **Distributed generation (DG)** refers to electricity generated on site (i.e. diesel generators, solar panels etc.). In certain DR programs, the use of distributed generation can be used to reduce overall demand from the utility while minimizing the effects to the customer of reduced utility electrical supply. Before using DG in a DR Action Plan, know the local air emissions restrictions and generator emissions allowances for operating fossil fuel-powered distributed generation. Fossil Fuel DG also produces greenhouse gases.

Additional information

- Lawrence Berkley Lab—Demand Response Research Center. Accessible at http://drrc.lbl.gov/
- Federal Energy Regulatory Commission (FERC). Accessible at http://www.ferc.gov/industries/electric/indus-act/demand-response.asp
- Energy.gov—Office of Electricity Delivery & Energy Reliability. Acessible at http://energy.gov/oe/technology-development/smart-grid/demand-response
- ISO/RTO Council—North American Wholesale Electricity Demand Response Program Comparison. Accessible at http://www.isorto.org/atf/cf/%7B5B4E85C6-7EAC-40A0-8DC3-003829518EBD%7D/IRC%20DR%20M&V%20Standards%20Implementation%20Comparison%20(2012-01-20).xls

CHAPTER 17

Employee engagement

Goals

- Realize operational and behavioral opportunities to reduce energy consumption
- Create and maintain cultural values and norms that support energy efficiency and conservation
- Influence decision making and daily actions at all employee levels

Overview

Regardless of where or how energy consumption occurs in an organization, someone somewhere has affected that consumption through decision making and actions. Engaging employees throughout an organization in energy efficiency is key to effectively identifying, implementing and maintaining lasting efficiency and conservation efforts.

Commercial and industrial energy efficiency programs have traditionally focused almost exclusively on efficient equipment upgrades and purchases, energy management systems and controls, and changes to processes. Employee impact on energy consumption has often been overlooked as an energy reduction strategy because of the difficulty in measuring results, the perception that activities are generally low-impact, and the absence of well-defined actions. Over the past several years, however, there has been significant growth in interest and research focused on employee engagement, and the attendant tactics for raising awareness and motivating action, as a low-cost means to achieve reductions. Employee engagement initiatives are being deployed in a range of sectors and business types.

Employee engagement should be considered not only as one possible strategy, but as an important driver in achieving lasting energy efficiency success. As illustrated in the Virtuous Cycle of Organizational Energy Efficiency (see Chapter 5), the actions of individuals within the organization serve to reinforce one another over time. Employee engagement efforts can be utilized to formalize and sustain this reinforcement and to address organizational barriers as they arise.

Employee impact on energy use occurs through three main activities: decision making, influence and behavior. An effective employee engagement program should address all three of these activities, and focus on the individuals and groups where each is most significant.

Tactics for reducing energy use

Decision making

At some levels employees will have decision making authority that can affect efficiency efforts with strategic or far reaching impact. This includes those in leadership positions who make decisions about organizational goals and priorities, and those who make decisions about processes, investments and procedures. Many members of executive leadership and mid-level management fall into this category and can be instrumental in executing energy efficiency efforts when engaged. The most effective means of engaging these decision makers can include providing training and information (at an appropriate level of detail) and clearly connecting energy to their goals and key responsibilities (such as financial and operational efficiency). Additionally, the development of clear accountability and incentive metrics can greatly increase buy-in and alignment with efficiency goals, where these have been established.

Influence

Influence in organizations happens in a multitude of ways, on a number of levels. Identifying individuals and groups who will influence others to make decisions and take actions that affect efficiency efforts can be challenging. Looking for those who have influence in other areas of concern can be a good place to start. Understanding the audience to be influenced and identifying who can best reach that audience is also effective. When the influencers are identified, taking time to gain trust and buy-in is key, as is understanding how, why and what they need to influence the target audience. Creating a structured plan to first reach and then utilize the buy-in of key influencers can open up opportunities to affect and reinforce decision making and behaviors on a large scale.

Behavior

In many work settings, energy consumption is impacted significantly by the day-to-day actions of employees. Research on the impact of behavior based efficiency in the commercial and industrial sectors to date has been limited, but interest in this area is growing. Rates of efficiency impact are dependent on the way that the term behavior is defined (e.g. does it include behaviors such as purchasing decisions and formal operational changes, or does it simply address the way front-line employees interact with equipment and systems?). Additionally, isolating the impact that behavior focused efforts have on consumption can be difficult as other initiatives, such as system upgrades or operational changes that affect energy use tend to occur simultaneously.

It is important to consider several factors when assessing how and to what degree to engage employees in behavior based efficiency efforts.

The principal consideration will be the degree to which the employees can impact energy consumption. Understanding this is important to establishing the role of engagement and the desired results. In some settings, employees interface very little with equipment and system controls and have few other opportunities to affect consumption. A small box retailer with automated lighting and HVAC controls and with limited variations in operational procedures is an example. In this setting employees may only be able to effect consumption by keeping doors closed, turning off monitors and minimizing hot water use. They likely have little control over equipment selection or impact on investment and operational changes.

In others settings, opportunities exist to increase or decrease significant consumption through employee actions. For example, a hospital, hospitality or commercial kitchen setting all provide many opportunities for employees to impact consumption as they tend to have access to and more control over equipment, system controls and other operational considerations. They can run equipment too long or too hot for operating needs, can affect HVAC efficiency by adjusting setpoints inappropriately, can assist in keeping doors closed, lights off and equipment shut down and/or unplugged when appropriate. When this is the case, employee engagement efforts aimed at changing behavior can be very effective and beneficial.

Other details are also important to consider. For instance, the turnover of employees and the need to engage new employees will impact plans to maintain buy-in and successfully transfer information and norms among employees. Earlier successful programs or initiatives can provide an opportunity to gain insights into cultural considerations and communication and awareness barriers, and can reveal mechanisms for engagement that are already working.

Look for operation-critical initiatives such as health and safety and customer service and study these closely for lessons learned.

Top-down or bottom-up?

There are two principal dynamics by which energy efficiency initiatives begin in companies: top-down and bottom-up. Common to both is the observation that new initiatives always start with the actions of individuals. The most effective initiatives demonstrate elements of both approaches. In top-down approaches, management decides to make a strategic shift in the way the company captures value from wasted energy. This typically leads to investments in centralized resources or the establishment of new company policies and employee communication efforts. Top-down initiatives have the potential to create significant momentum for change through the actions of one or only a few key decision-makers, but organizational culture is a key concern here. Is the culture at the organization generally accepting of, and enthusiastic about, directives from "Corporate," or are grassroots efforts more often embraced? Regardless, the organizational change literature has shown that without effectively engaging the employee base to take ownership of the initiatives quickly, they can ultimately lose that initial momentum and fail to produce lasting improvements.[1]

Whether evaluating the impact of engagement through decision making, influence or behavior, when considering the value of any employee engagement effort, a vision for success and the metrics with which to measure performance should be established. As previously discussed, the value may be seen directly in relation to reductions in consumption, but the ability to measure that specific value can be exceptionally challenging. It can be difficult to isolate the consumption effects of changes in employee decisions and behavior from those provided by system upgrades, operational changes and many other factors that impact consumption. As noted above, employee engagement may provide value by advancing and reinforcing the value of top-down initiatives. Additionally, value may be found in less directly-related benefits, such as employee motivation and retention, which can result when employees feel the organization's value of stewardship aligns with their own, whether through public-facing or internal statements.

Employee engagement can be established and maintained through a number of tactics including:

1. **Communications campaigns** designed to increase awareness, provide motivation and deliver information on best practices, expected actions, corporate rationale and progress toward goals.

2. **Cross functional teams** can be utilized to optimize expertise and knowledge, decision making, capacity and influence. A cross functional energy management or "Green Team" should have a skilled facilitator, clear goals and appropriate resources at hand to meet those goals.

3. **Education/knowledge management** mechanisms can be put in place so that key individuals understand their roles and responsibilities and have access to appropriate knowledge and expertise to engage fully in a successful effort.

4. **Leadership development** provided at various levels of an organization can be a key element in a successful energy management program. Leadership in this case refers to those who take responsibility for integrating energy management into their work, are willing to innovate and share best practices and are, or can be placed in, a position to positively impact and reinforce the decisions and actions of others.

5. **Incentives and controls** on decision making and behaviors can be effective. Incentives take form through recognition programs, rewards and bonus structures as well as less formal

"pats on the back" for taking action and engaging in behaviors that result in reduced energy consumption. Controls can provide the accountability individuals and groups need to prioritize and maintain efforts that may otherwise be lost. The use of incentives and controls requires reliable mechanisms for assessing performance and reliable and consistent follow-though to be effective. Measurement does not need to be sophisticated, but the level of sophistication should match the level of reward or control applied to the measured result. For example, financial bonuses or formal discipline should not be applied to performance that can't be quantitatively measured with confidence.

Information gathering guide

- How much influence does employee behavior have on energy consumption in equipment and systems? Are there groups of employees with that are more capable of influencing energy consumption?
- Are there Energy Management Systems, Energy Information Systems or programmed/locked controls? How much interaction with equipment and system controls or building envelope, such as closing building doors and windows, do typical employees have?
- What other types of programs are successfully in place, such as health and safety or customer service, and how were they implemented?
- What have been the most effective channels for communicating information or educating employees? What non-energy value might an employee engagement program create, and how can this be measured?
- How involved are employees in driving other initiatives such as community service, health and safety, or internal waste management efforts?
- At what leverage points in the organization is employee engagement most valuable and what mechanisms and efforts will most effectively address these?
- What barriers to engagement may be encountered? How can they be addressed?
- What role might employee champions play in driving motivation, keeping information channels open, monitoring progress and reporting on barriers and successes?

Additional information

- Research and resources on behavior and energy from the Precourt Energy Efficiency Center. Accessible at http://peec.stanford.edu/behavior/foundational_readings.php
- Case example of Employee Engagement initiative: Raytheon Employee Engagement in Energy Conservation. Accessible at http://www1.eere.energy.gov/manufacturing/pdfs/webcast_20100805_achieving_total_employee_engagement.pdf
- 2012 ENERGY STAR National Building Competition: Battle of the Buildings resources for employee engagement activities. Accessible at http://www.energystar.gov/index.cfm?c=buildingcontest.battle_resources

Notes

[1] Kotter, J. P. 1996. Leading Change. Cambridge, MA: Harvard Business School Press. Senge, P., Kleiner, A., Roberts, C., Ross, R., Roth, G. & B. Smith. 1999. The Dance of Change: *The Challenges to Sustaining Momentum in Learning Organizations*. New York, NY: Doubleday

APPENDIX A

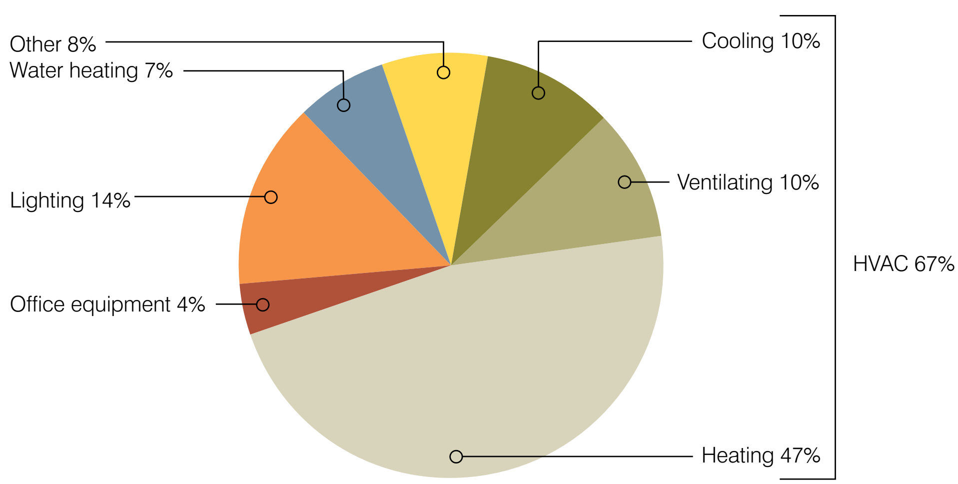
Energy consumption of U.S. commercial buildings by type

The U.S. Energy Information Administration conducts the Commercial Building Energy Consumption Survey every four years. The survey compiles data about energy use, expenditures and characteristics of commercial buildings in the U.S. This appendix includes figures detailing the end uses of energy in each commercial building type surveyed by the EIA: education, food sales, food service, healthcare, lodging, retail, office, public assembly, public order and safety, religious worship, service, warehouse, other and vacant. Each figure is accompanied by the text provided by the CBECS to define each building classification.

All data and accompanying text is sourced from the Energy Information Administration.[1,2]

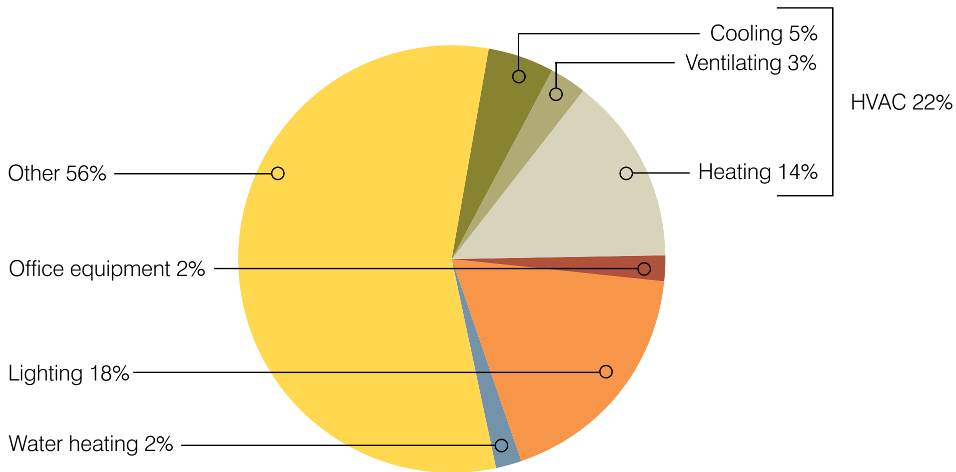
FIGURE A.1

Energy use for education buildings



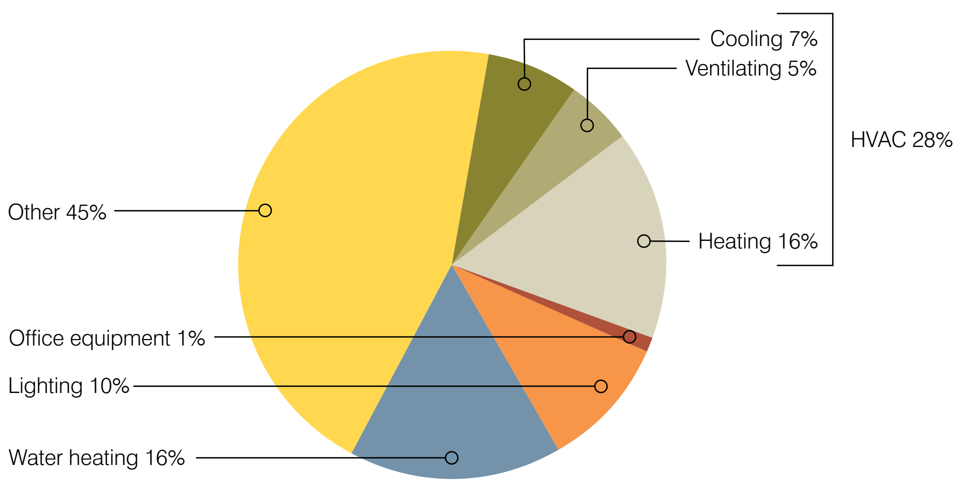
Buildings used for academic or technical classroom instruction, such as elementary, middle or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly." **Includes:** elementary or middle school, high school, college or university, preschool or daycare, adult education, career or vocational training, religious education.

FIGURE A.2
Energy use for food sales buildings



Buildings used for retail or wholesale of food. **Includes:** grocery store or food market, gas station with a convenience store, convenience store.

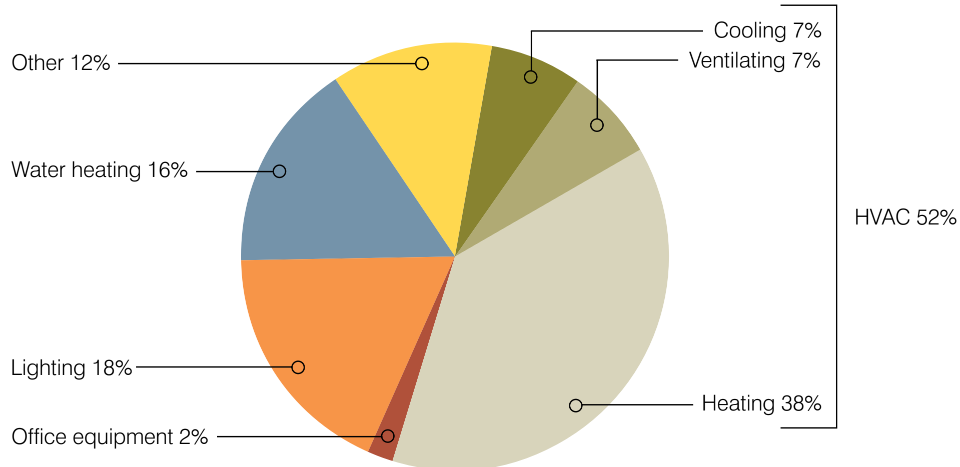
FIGURE A.3
Energy use for food service buildings



Buildings used for preparation and sale of food and beverages for consumption. **Includes:** fast food, restaurant or cafeteria.

FIGURE A.4

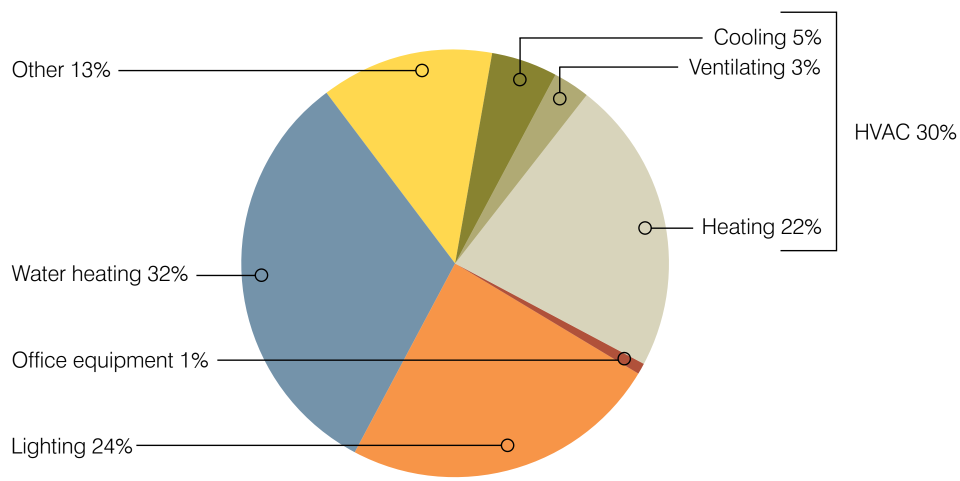
Energy use for healthcare buildings



Includes buildings used as diagnostic and treatment facilities for inpatient care, and buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment. **Includes:** hospital, inpatient rehabilitation, medical office with diagnostic equipment, clinic or other outpatient health care, outpatient rehabilitation, veterinarian.

FIGURE A.5

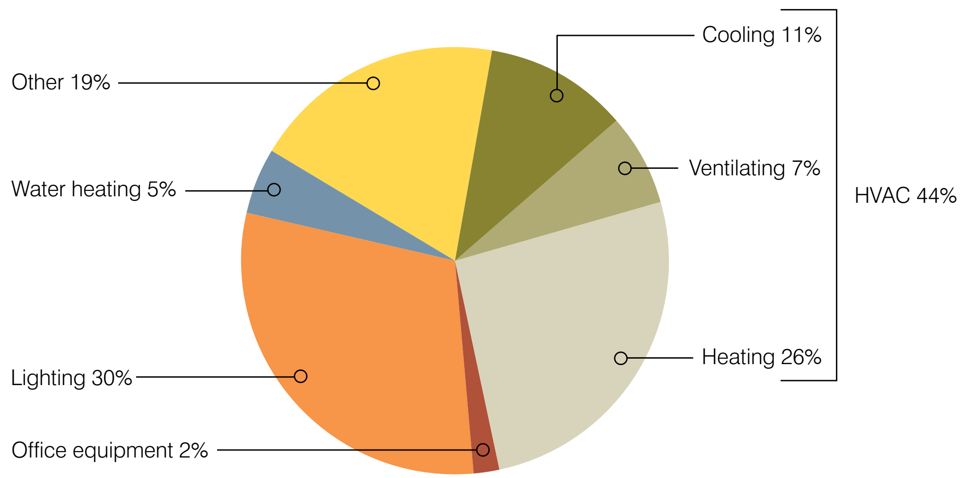
Energy use for lodging buildings



Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings. **Includes:** motel or inn, hotel, dormitory, fraternity or sorority, retirement home, nursing home, assisted living or other residential care, convent or monastery, shelter, orphanage or children's home, halfway house.

FIGURE A.6

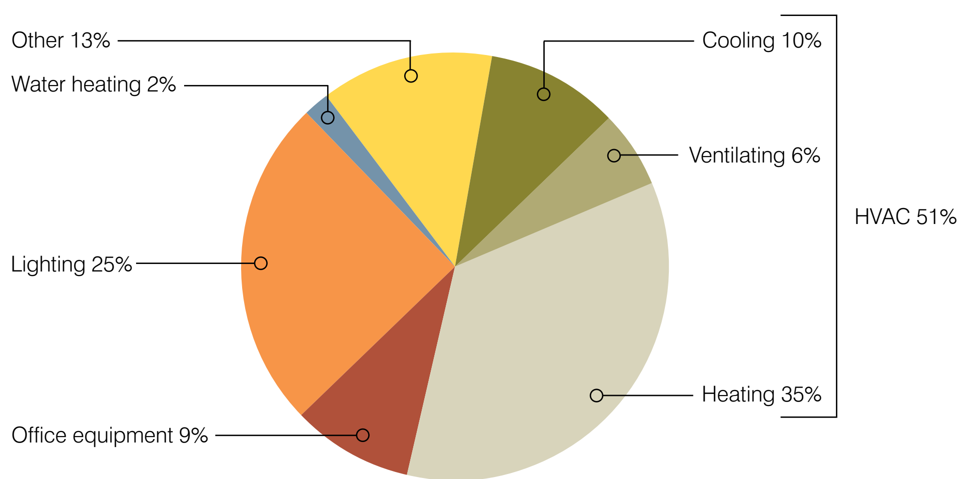
Energy use for retail buildings



Buildings used for the sale and display of goods other than food and shopping malls comprised of multiple connected establishments. **Includes:** retail store; beer, wine or liquor store; rental center; dealership or showroom for vehicles or boats; studio/gallery; enclosed mall; strip shopping center.

FIGURE A.7

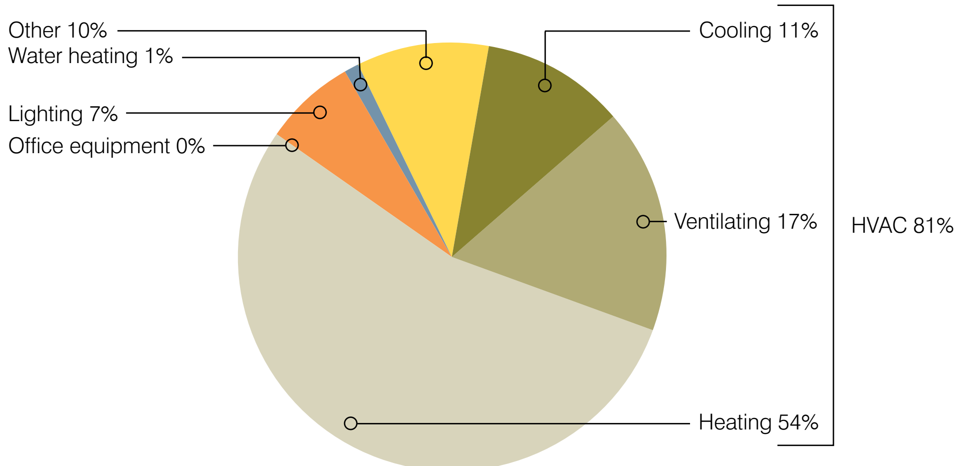
Energy use for office buildings



Buildings used for general office space, professional office or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building). **Includes:** administrative or professional office, government office, mixed-use office, bank or other financial institution, medical office without diagnostic equipment, sales office, contractor's office (e.g., construction, plumbing, HVAC), non-profit or social services, research and development, city hall or city center, religious office, call center.

FIGURE A.8

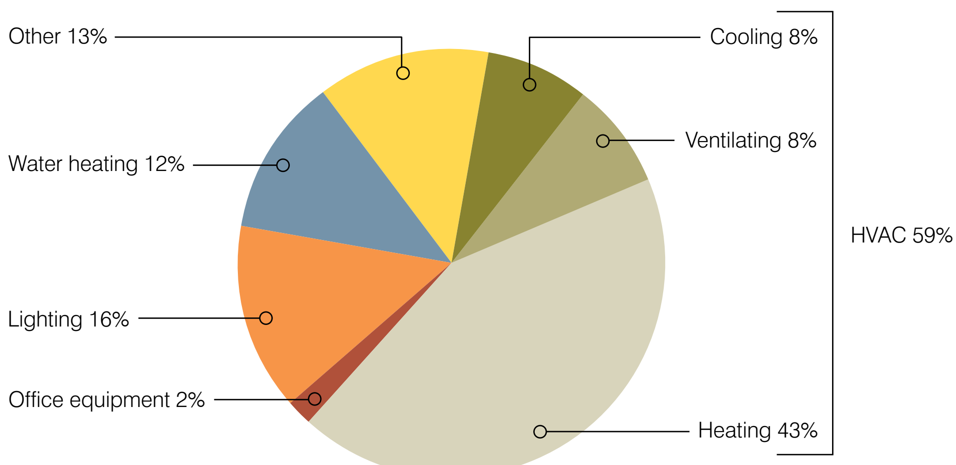
Energy use for public assembly buildings



Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls. **Includes:** social or meeting (e.g., community center, lodge, meeting hall, convention center, senior center), recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports), entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club), library, funeral home, student activities center, armory, exhibition hall, broadcasting studio, transportation terminal.

FIGURE A.9

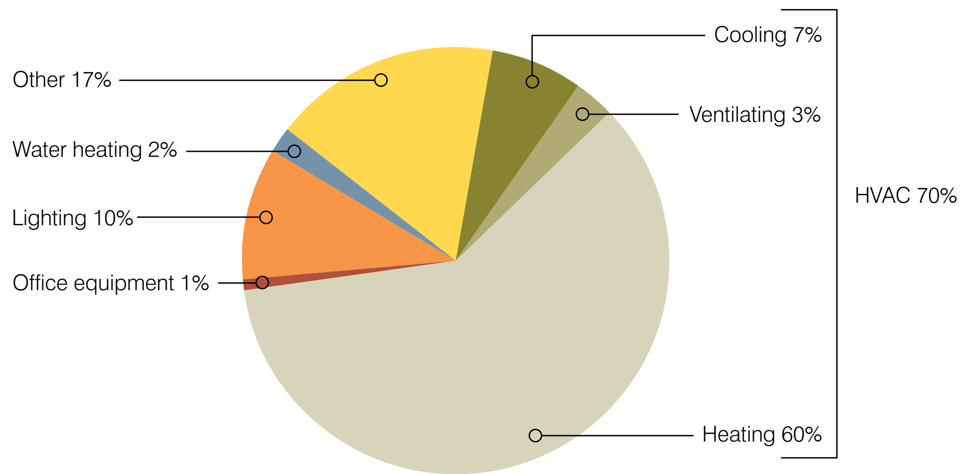
Energy use for public order and safety buildings



Buildings used for the preservation of law and order or public safety. **Includes:** police station, fire station, jail, reformatory or penitentiary, courthouse or probation office.

FIGURE A.10

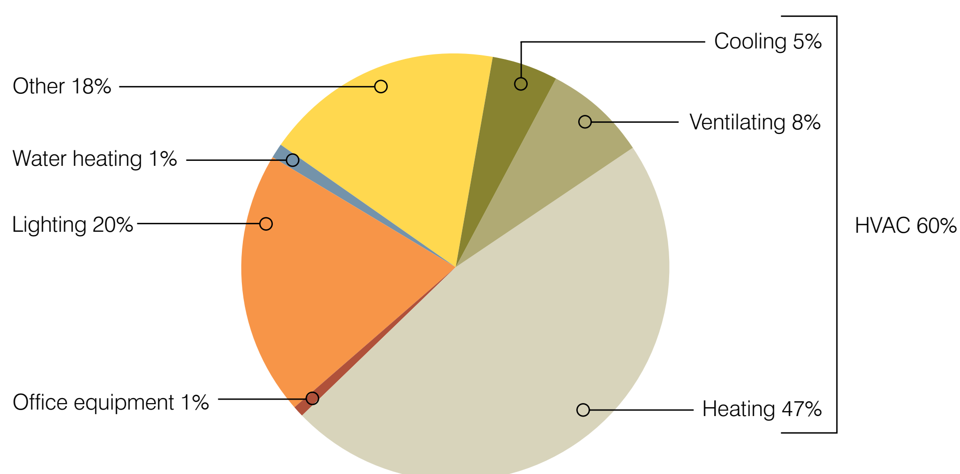
Energy use for religious worship buildings



Buildings in which people gather for religious activities. **Includes:** chapels, churches, mosques, synagogues, temples.

FIGURE A.11

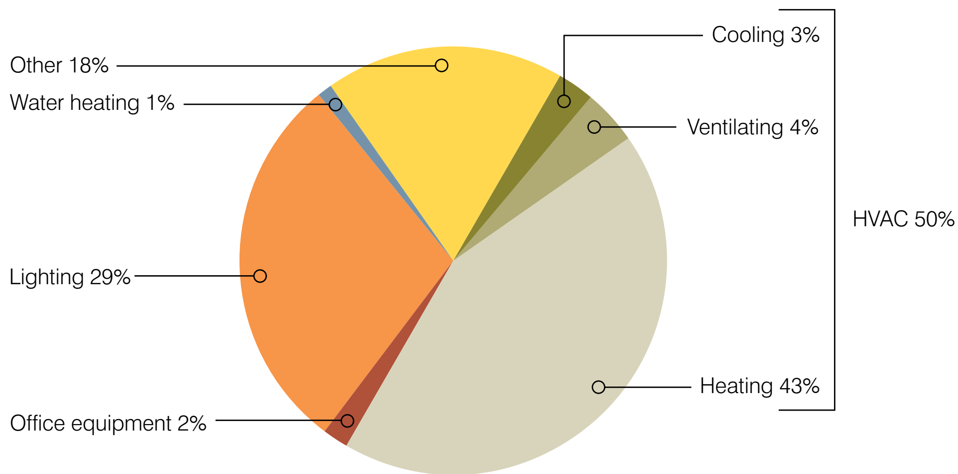
Energy use for service buildings



Buildings in which some type of service is provided, other than food service or retail sales of goods. **Includes:** vehicle service or vehicle repair shop, vehicle storage/maintenance (car barn), repair shop, dry cleaner or laundromat, post office or postal center, car wash, gas station, photo processing shop, beauty parlor or barber shop, tanning salon, copy center or printing shop, kennel.

FIGURE A.12

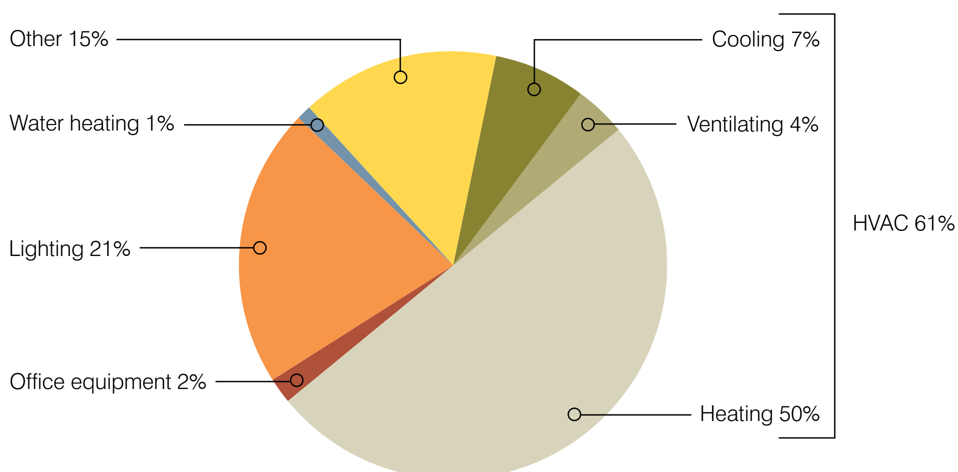
Energy use for warehouse and storage buildings



Buildings used to store goods, manufactured products, merchandise, raw materials or personal belongings (such as self-storage). **Includes:** refrigerated warehouse, non-refrigerated warehouse, distribution or shipping center.

FIGURE A.13

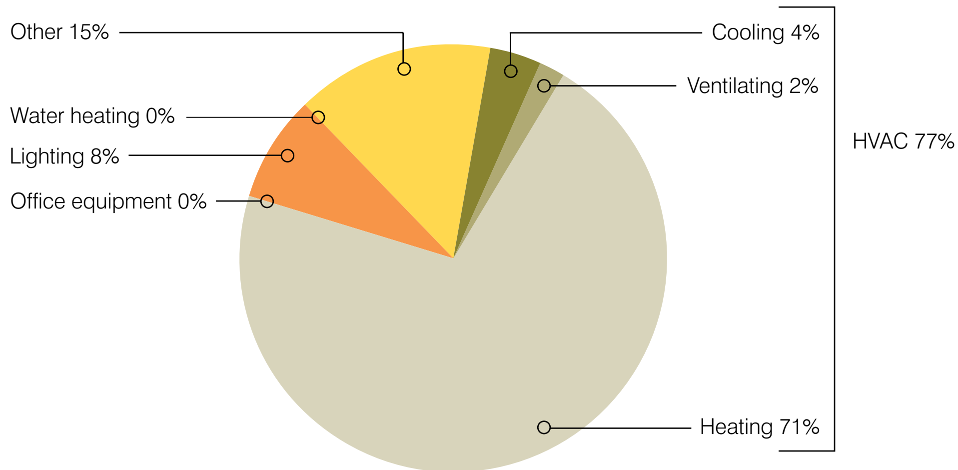
Energy use for other buildings



Buildings that are industrial or agricultural with some retail space; buildings having several different commercial activities that, together, comprise 50% or more of the floorspace, but whose largest single activity is agricultural, industrial/manufacturing or residential; and all other miscellaneous buildings that do not fit into any other category. **Includes:** airplane hangar, crematorium, laboratory, telephone switching, agricultural with some retail space, manufacturing or industrial with some retail space, data center or server farm.

FIGURE A.14

Energy use for vacant buildings



Buildings in which more floorspace was vacant than was used for any single commercial activity at the time of interview. Therefore, a vacant building may have some occupied floorspace.

Notes

[1] Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E1A. Major Fuel Consumption (BTU) by End Use for All Buildings," September 2008. Accessible at http://www.eia.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

[2] Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Description of CBECS Building Types," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/building_types.html

APPENDIX B
HVAC information

Packaged AC units vs. centralized HVAC systems

Commercial buildings smaller than 20,000 square feet typically use factory-built, air-cooled "packaged" HVAC equipment. Buildings larger than 100,000 square feet and multi-building campuses generally use site-assembled or engineered "centralized" HVAC systems. Buildings with a square footage between 20,000 and 100,000 square feet may employ a combination of multiple large packaged units (for example, one unit per wing of an office building) or small built-up systems. Performance comparisons between packaged and engineered systems, or among systems of either type, should consider the performance of the entire system, rather than just the chiller or boiler of a central chilled water/heating hot water plant or the chiller or the condensing unit.

The principal advantages of central HVAC systems are higher energy efficiency, greater load-management potential, fewer and higher-quality components that require less (but more skilled) maintenance and architectural and structural simplicity. The main advantages of packaged systems are lower initial costs, independent zone control, lower failure risk and less floor space occupied by a mechanical room, ducts and pipes, and less skilled maintenance.[1]

Performance measurements

There are a number of metrics that can be used to compare the efficiency performance of various HVAC systems. The Air-Conditioning & Refrigeration Institute (ARI) defines standardized test procedures to determine the efficiency metrics for a limited scope of HVAC systems.[2] The tests used to evaluate the performance vary based on the HVAC equipment being tested. The following list summarizes major HVAC performance metrics:

- **Cooling capacity** is rated as the amount of heat energy a cooling unit can remove from a space per hour, expressed in Btu per hour. (One ton of cooling capacity will remove 12,000 Btu of heat per hour.)
- **Energy Efficiency Ratio (EER)** is the ratio of the cooling capacity (Btu/hr) to the power input value (watts) at any given set of rating conditions expressed in Btu/watt-hour. The current standard, since 2010, is an energy efficiency ratio (EER) of 11.0 for systems with a capacity of 65 to 135 thousand-Btu per hour (kBtu/hr).
- **Coefficient of Performance (COP)** is defined differently depending on function. For cooling, COP describes the ratio of the rate of heat removal to the rate of energy input in consistent units, for a complete cooling system as tested under a nationally recognized standard. For heating, it is the ratio of the rate of heat delivered to the rate of energy input in consistent units, for a complete heat pump system as tested under designated operation conditions. COP is particular to heat pumps, whether water or air source. Heating efficiency is given in COP and the cooling efficiency is given in EER or SEER. Conversion: COP = EER * 3.4.

Note that both COP and EER are calculated under controlled laboratory conditions and usually do not reflect the efficiency of performance under actual use. The seasonal energy efficiency ratio (SEER) and the heating season performance factor (HSPF) address the need to reflect actual use by measuring efficiency in field situations.

Seasonal Energy Efficiency Ratio (SEER) is the total heat removed from the conditioned space during the annual cooling season, expressed in Btu, divided by the total electrical energy consumed by the air conditioner or heat pump during the same season, expressed in watt-hours. Federal appliance efficiency standards currently require minimum SEER ratings of 13. The highest efficiency models available can have SEER ratings up to 23 for central air units.

Heating Season Performance Factor (HSPF) is the total heat added to the conditioned space during the annual heating season (expressed in Btu), divided by the total electrical energy consumed by the air conditioner or heat pump during the same season (expressed in watt-hours).

Integrated Part-Load Value (IPLV) is a seasonal efficiency rating method for representative loads from 65,000 Btu per hour and up. This rating applies to units that have stated partial capacities, such as units with staged compressors. Units are tested at full capacity and at each stated partial capacity, and those values are then used to calculate IPLV. IPLV is usually for air- or water-cooled chillers that are serving large variable cooling loads.

Additional information

For more information on HVAC optimization, see:

- Nontechnical introduction to HVAC: "Energy Efficiency in Industrial HVAC Systems," 2003. http://www.p2pays.org/ref/26/25985.pdf
- Technical discussion of HVAC Systems: Benjamin, Reynolds, Grondzic, and Kwok. *Mechanical and Electrical Equipment for Buildings*, 10th Edition. John Wiley & Sons, Inc. New York.

Notes

[1] ERPI Office Complexes Guidebook, Innovative Electric Solutions. Chapter 6, Heating, Ventilating, and Air-Conditioning (HVAC). December 1997. tr-109450, p. 195. A

[2] Air Conditioning and Refrigeration Institute. 2006 Standard for Performance Rating of Unitary Air Conditioning Equipment and Air Source Heat Equipment.

APPENDIX C

Lighting information

Lighting functions

It is important to assess the function for which lighting is needed when considering options for efficiency improvements. Lighting functions include:

- **Ambient lighting** provides general illumination indoors for daily activities, and outdoors for safety and security.
- **Task lighting** facilitates particular tasks that require more light than is needed for general illumination, for example, desk lamps.
- **Accent lighting** draws attention to special features or enhances the aesthetic qualities of an indoor or outdoor environment, such as lights in lobbies and conference rooms.

Matching the amount and quality of lighting to the needed function is a key strategy to improving overall lighting environment and efficiency in any space. For example, using task lighting to reduce ambient lighting may not only reduce energy demand, but will also allow for greater flexibility and higher quality working conditions.

Light sources

Within the lighting industry, electric light sources are referred to as lamps, which include bulbs and tubes. Common light sources include:

- **Incandescent:** Incandescent lamps are one of the oldest electric lighting technologies available. Incandescent bulbs produce light by passing a current through a filament, causing it to become hot and glow (and also causing waste heat).
- **Tungsten halogen:** Tungsten halogen lamps are slightly more energy efficient and last longer than standard incandescents. One advantage of the tungsten halogen lamp is its controlled beam spread, which makes it ideal for accent lighting. Tungsten halogen lamps can be used in track, recessed, outdoor spot and floodlight settings.

Fluorescent

- **Fluorescent tube lamps:** Fluorescent tube lamps are very commonly used in business applications; these lamps are generally identified as T12 and T8, referring to the diameter of the tube. T12s are 12/8 of an inch in diameter, while T8s are 8/8, or one inch. Typically, T8s are more efficient than T12s.
- **Compact fluorescent lamps (CFLs):** CFLs have higher efficacy and longer life than comparable incandescent lamps. CFLs come in a variety of shapes and sizes and are compatible with most fixtures designed for incandescent bulbs.

- **Light emitting diodes (LEDs):** LEDs are a solid-state light source that delivers a direct beam of light at a very low wattage.

  The unique characteristics of LEDs, including compact size, long life, ease of maintenance, resistance to breakage and vibration, good performance in cold temperatures, lack of infrared or ultraviolet emissions, and instant-on performance are beneficial in many lighting applications. Recent advances in the technology allow LEDs to be dimmed and to provide color control, which are additional benefits. One of the defining features of LEDs is that they emit light in a specific direction. Since directional lighting reduces the need for reflectors and diffusers that trap light, well-designed LED fixtures deliver light efficiently to the intended location.

- **High-intensity discharge (HID):** HID lamps have a longer life and provide more light per watt than any other light source. HID bulbs are commonly used for outdoor security and landscape lighting. Mercury vapor lamps, which originally produced a bluish-green light, were the first commercially available HID lamps. Today, they are also available in a color-corrected, whiter light. Increasingly, the more efficient high-pressure sodium and metal halide lamps are replacing mercury vapor lamps. Standard high-pressure sodium lamps have the highest efficacy of all HID lamps, but they produce a yellowish light. High-pressure sodium lamps that produce a whiter light are now available, but their efficiency is somewhat lower than traditional high- pressure sodium lamps. Metal halide lamps are less efficient but produce an even whiter, more natural light. Colored metal halide lamps are also available.

Guidelines for lighting design

Seven steps should be considered when designing or renovating a lighting system. These steps are:

1. **Improve visual quality of the task.** Identify specific visual tasks and recommend appropriate luminance, including task lighting.

2. **Improve geometry of space and cavity reflectance.** Use the light and color of the room to increase the use of natural light; rearrange furniture for optimal lighting.

3. **Improve lighting quality.** Cut veiling reflections through more indirect light distribution and reduce glare.

4. **Optimize lighting quantity.** Balance levels of ambient and task lighting and ensure adequate light levels for tasks being performed.

5. **Harvest/distribute natural light.** Daylighting improves the visual environment and results in increased productivity and energy savings. It is important to shade windows to prevent glare and heat gain and to control the amount of daylight entering the building. Daylight can be redirected to where it is needed and be integrated with electric lights.

6. **Optimize technical equipment.** Lamps, ballasts , reflectors and other technology must be optimized for maximum performance.

7. **Control, maintain and educate.** Proper maintenance of equipment is a crucial component to keeping technology in the best shape possible.

Additional information

For more information on lighting design optimization, see:

- Mark S. Rea, Rensselaer Polytechnic Institute. Illuminating Engineering Society of North America Lighting Handbook. 2000.

APPENDIX D

Water heating information

A wide range of water heater types may be encountered in office buildings. The following is a description of water heater types excerpted from a Guide to Water Heating, published by the American Council for an Energy-Efficient Economy (ACEEE):[1]

Storage tank water heaters are the most common type of water heater in the U.S. today. Ranging in size from 20 to 80 gallons (or larger) and fueled by electricity, natural gas, propane or oil, storage water heaters heat water in an insulated tank. When you turn on the hot water tap, hot water is pulled out of the top of the water heater and cold water flows into the bottom. Without proper insulation, storage tank water heaters can be energy inefficient because heat is lost through the flue and the walls of the storage tank (this is called standby heat loss) even when no hot water is being used. New energy-efficient storage water heaters have higher levels of insulation around the tank and one-way valves where pipes connect to the tank, substantially reducing standby heat loss.

Demand water heaters, also known as instantaneous or tankless water heaters, eliminate the storage tank by heating water when hot water is needed. The energy consumption of these units is generally lower since **standby losses** are eliminated. Demand water heaters with enough capacity to meet household needs are gas or propane-fired. They have three significant drawbacks for some applications: (1) Large simultaneous uses may challenge their capacity; (2) They will not turn on unless the hot water flow is 0.5 to 0.75 gal/minute; and, (3) Retrofit installation can be very expensive.

Heat pump water heaters are more efficient than electric water heaters because the electricity is used for moving heat from one place to another rather than for generating the heat directly. The heat source is outside air or air where the unit is located. Refrigerant fluid and compressors transfer heat into an insulated storage tank. Heat pump water heaters are available with built-in water tanks called integral units, or as add-ons to existing hot water tanks. A heat pump water heater uses one-third to one-half as much electricity as a conventional electric resistance water heater, and in warm climates they may do even better. Unfortunately, there are few sources for these products.

Indirect water heaters generally use the boiler as the heat source. In boiler systems, hot water from the boiler is circulated through a heat exchanger in a separate insulated tank. In the less common furnace-based systems, water in a heat exchanger coil circulates through the furnace to be heated, then through the water storage tank. Since hot water is stored in an insulated storage tank, the boiler or furnace does not have to turn on and off as frequently, improving its fuel economy. Indirect water heaters, when used in combination with new, high efficiency boilers or furnaces, generally have the lowest operating costs among water heating technologies.

Solar water heaters use energy from the sun to heat water. Solar water heaters are designed to serve as pre-heaters for conventional storage or demand water heaters. While the initial cost of a solar water heater is high, it can save a lot of money over the long term. On a life-cycle cost basis, solar water heaters compete very well with electric and propane water heaters, though they are still usually more expensive than natural gas.

Central vs. distributed equipment

The decision to use a central or distributed water heating system impacts requirements for on-demand heaters, pipe insulation, application and building design.

Example: Central vs. distributed application

If a central hot water system is employed and hot water is needed in a bathroom that is 50 feet from the natural gas hot water storage tank, the 50 feet of water volume in the pipe will have to be drained in order to get to the hot water. If the pipe has a 3/4-inch diameter it will hold 4.6 gallons in 50 feet. If the water heater is set at a level of 120ºF and incoming water is 50ºF, the 4.6 gallons of wasted water will also waste 2,682 Btu when it is heated. One option around this loss would be the installation of tankless heaters adjacent to the hot water applications. This would avoid the loss of 4.6 gallons as well as the 2,682-Btu loss. However, if there is a large capacity need, the instantaneous demand for energy could lead to electric cost penalties or difficulty meeting large delivery needs. (Adapted from Stein, *Mechanical and Electrical Equipment Buildings*, 9th Edition., pp. 601–603.)

Additional information

For an introduction to facilities water management, see:

- James piper, maintenance solutions, "Water Use: Slowing the Flow," 2003 http://www.facilitiesnet.com/ms/article.asp?id=1969&keywords

Notes

[1] American Council for an Energy-Efficient Economy (ACEEE), "Consumer Resources: Water Heating." http://www.aceee.org/consumer/water-heating

APPENDIX E

Energy use by miscellaneous equipment

Depending on the equipment present in the host organization's building, there may be opportunities for energy savings in equipment beyond those discussed in Chapter 8. Lawrence Berkeley National Laboratory conducted an audit of 16 buildings and found that, in large offices (totaling 30,000 square feet or more), for every 2 kWh used by office equipment, another 1 kWh is used by miscellaneous equipment.[1] The following are the top ten users of energy in their survey:

TABLE E.1

Energy use by miscellaneous equipment

Rank	Miscellaneous equipment	Energy usage per year per unit (kWh/year)
1	Vending machine	3318
2	Commercial refrigerator	4300
3	Speakers	74
4	Ethernet switch	17
5	Commercial freezer	5200
6	Microwave oven	447
7	Fluorescent undercabinet lamp	33
8	Commercial coffee maker	1349
9	Coffee maker	450
10	Refrigerator (small)	277

Source: LBNL, 2007. Accessible at http://enduse.lbl.gov/info/LBNL-62397.pdf

If the host organization is using a significant number of these machines, it may be advantageous to replace equipment with more energy-efficient versions.

APPENDIX F

Fleet vehicle efficiency and driving tips

How to maximize your vehicle's fuel efficiency

Vehicle fuel consumption is greatly influenced by driving behaviors and maintenance practices. By following the tips below, you can maximize your vehicle's fuel efficiency and minimize its emissions of heat-trapping gases that contribute to global warming.

TIP 1: Avoid aggressive driving behaviors

A key to maximizing your vehicle's fuel economy and limiting its global warming emissions is to drive sensibly. Aggressive driving behaviors extract a high fuel penalty: up to 40%. You can avoid this penalty by:

- Obeying speed limits: Most vehicles reach their optimal fuel economy below 60 miles per hour. Above this speed, fuel economy can decrease quickly. According to some estimates, every five mph increase above 65 mph decreases your vehicle's fuel economy by 7%.
- Accelerating gradually: Higher RPM driving uses more fuel than lower RPM driving. By accelerating gradually, you can keep your vehicle's RPM lower and maximize fuel efficiency.
- Anticipating stops: By actively monitoring the traffic ahead, you will notice coming slow-downs or stops well in advance. When you see a need to stop up ahead, coast. Don't continue to accelerate and then brake at the last minute. Such action wastes fuel by converting energy from motion to brake heat.

TIP 2: Minimize idling

An idling vehicle wastes fuel and increases greenhouse gas emissions. In fact, ten seconds of idling uses more fuel than turning off the engine and restarting it. So, turn off the engine if you are not in traffic and are going to be stopped.

TABLE F.1

Increasing fuel economy through maintenance

Vehicle condition	Potential increase in fuel economy from correction of problem
Under-inflated tires	3–4%
Wheels out of alignment	4%
Malfunctioning oxygen sensor	40%
Improper weight of motor oil	2%

Source: U.S. DOE & U.S. EPA, "Gas Mileage Tips." http://fueleconomy.gov/feg/drive.shtml

TIP 3: Prepare before you go

There are several ways you can reduce fuel consumption before you even get in your car.

- Plan, plan, plan: The best way to reduce fuel consumption is to minimize your miles on the road. By optimizing routes, you will reduce fuel consumption and decrease the time spent behind the wheel. Before you head out on your way, ask yourself:
  - Do I know how to get where I want to go? Am I taking the most efficient route?
  - Can I combine another necessary stop into this trip and avoid a future trip?
  - Should I make this trip at a time when traffic will be lighter?
- Dump excessive cargo weight: Lugging around an extra 100 pounds of cargo weight can reduce fuel economy by 2%. Before you head out on your next trip, check the trunk and remove unnecessary items.
- Remove items that interfere with aerodynamics: Roof racks and other accessories that interfere with aerodynamics can cause up to a 5% decrease in fuel economy.

TIP 4: Keep your vehicle in good shape

In order for vehicles to perform at their best and maintain maximum resale values, they must be well maintained. Allowing a vehicle to fall out of shape can have significant impacts on fuel consumption and operating costs. Table F.1 presents a few examples.

TIPS 5: Employ other efficient driving techniques

By avoiding aggressive driving behaviors, minimizing idling, planning ahead and keeping up on maintenance, you will be on your way to maximizing your vehicle's fuel economy. Here are a few more ways to save:

- **Consider using cruise control:** On flat highways, cruise control helps to maintain a steady pace, which maximizes fuel economy. In hilly areas, however, it can cause rapid acceleration, which harms fuel economy.
- **Use overdrive:** Vehicles consume less gas at lower RPM. Using overdrive with automatic transmissions will cut back on fuel consumption when you are operating at a steady speed, such as on the highway. If you are driving a manual transmission, consider shifting sooner.

Notes

[1] M. Sanchez et al., Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, "How plugged in are Commercial buildings?" February 2007, p.11. http://enduse.lbl.gov/info/lbnl-62397.pdf

APPENDIX G

Energy efficiency case studies

This handbook includes three case studies detailing successful energy efficiency retrofit investments in commercial buildings:

1. Adobe Towers in San Jose (Adobe Systems)

2. 260 Townsend Street in San Francisco (Swinerton)

3. 100 Pine Street in San Francisco (Unico Properties)

Additional useful case studies on successful energy efficiency retrofits are available from the following source:

- California Energy Commission: http://www.energy.ca.gov/enhancedautomation

CASE STUDY 1: ADOBE TOWERS, SAN JOSE

Case study adapted from: *Adobe Systems Incorporated: Three Platinum Certified Green Buildings,* Adobe Systems internal report by George Denise, December 2006.

Beginning in 2001, Adobe Systems partnered with Cushman and Wakefield, a commercial real estate and services firm, to spearhead energy efficiency upgrades and produce highly sustainable returns.


Adobe

Adobe's headquarters consist of three high-rise office buildings located in downtown San Jose, California: East, West and Almaden Towers enclosing 325,421 square feet, 391,339 square feet, and 272,598 square feet, respectively. Combined, they total 989,358 square feet of office space, resting atop 938,473 square feet of enclosed parking.

From 2001–2004, Adobe undertook 30 energy conservation and related projects. They spent $888,912, earned rebates of $277,092 and reduced annual operating costs by $647,747, for a return on investment of 106%. In 2002, Cushman and Wakefield requested that all of its managers benchmark their properties with the EPA Energy Star® program. In 2004, following the labeling of all three buildings as Energy Star® compliant, the Adobe facilities team began the process of certifying the Towers as Green Buildings with the USGBC's Leadership in Energy and Environmental Design (LEED) program.

Adobe began the LEED certification process in mid-2005. From 2005–2006 Adobe completed 64 energy conservation and related projects, reducing annual operating costs by $1.2 million. These upgrades cost Adobe approximately $1.4 million, $389,000 of which was recovered in rebates from local and state agencies, for an impressive return on investment of 121% (a nine-month payback).

All three Adobe campus buildings—East, West and Almaden—have achieved LEED Green Building certifications with Platinum ratings, the highest rating possible. Additionally, Adobe

TABLE G.1

Project categories of energy efficiency upgrades at the Adobe Towers

Description	No. projects	Cost	Rebate	Savings	ROI
Load management	26	$445,248	$205,437	$729,185	304.00%
Lighting	19	$300,701	$44,918	$155,616	61.00%
Equipment	6	$298,439	$122,575	$107,976	61.00%
Monitor and controls	1	$39,472	$11,000	$12,001	42.00%
Total	**52**	**$1,083,860**	**$383,930**	**$1,004,778**	**144%**

TABLE G.2

Selected energy efficiency upgrade projects at the Adobe Towers

Effort category	Energy efficiency measure	Capital cost (US$)	Annual cost savings (US$)	Annual energy savings (kWh)	Payback period	ROI
Lighting	Provided surge protectors and motion sensors for every office	$104,750	$65,887	43522	5 months	253%
	Retrofitted garage lighting	$157,775	$138,544	91516	10 months	118%
	Reprogrammed garage lighting	$55,267	$34,037	22483	11 months	115%
	Changed corridor lighting override to control and program	$4,500	$27,327	210207	2 months	607%
	Retrofitted indoor lamps	$21,088	$52,530	34700	5 months	249%
HVAC	Modified cooling tower staging and sequencing	$575	$12,272	94400	immediate	2134%
	Modified boiler control programming	$600	$41,779	27597	immediate	6963%
	Corrected chilled-water pump controls	$1,200	$43,000	28400	immediate	3583%
	Provided motion sensors for HVAC in all conference rooms	$37,500	$40,357	90984	8 months	140%
	Installed VFD on chiller	$65,000	$38,719	25576	7 months	163%
Monitor and control	Added real-time electric meters	$19,696	$39,938	26381	6 months	203%

has earned the EPA ENERGY STAR® label for each of its three buildings, with scores of 78, 84 and 87 (on a scale of 100).

The impressive financial returns from Adobe's energy efficiency returns are matched by notable environmental improvements. Since upgrading the energy efficiency of its campus buildings, Adobe has made significant reductions to its environmental footprint in the following areas:

- 16% reduction in CO_2 emissions
- 35% electricity savings per occupant
- 41% natural gas savings per occupant

CASE STUDY 2: 260 TOWNSEND, SAN FRANCISCO

In 2002, the building contractor Swinerton began efforts to retrofit its own newly purchased San Francisco headquarters to serve as a model energy-efficient retrofit project. Swinerton's office space at 260 Townsend, San Francisco was originally built in 1984 with 67,000 square feet of office space, 28,000 square feet of covered parking and 19,000 square feet of terraces.

Retrofit improvements undertaken at 260 Townsend included the installation of a new digitally controlled building management system (BMS), efficiency upgrades to lighting and equipment commissioning.

The retrofit project allowed 260 Townsend to exceed California's Title 24-2001 commercial building energy standard by 12%, with a final building energy use intensity of 16 kWh/ft^2/year As a result of the efficiency improvements, 260 Townsend earned a gold level certification through Leadership in Energy and Environmental Design for Existing Buildings (LEED EB). As a result of the retrofit project, Swinerton's headquarters achieved:

- 50% reduction in energy bills
  - 1,072,000 kWh saved annually
  - 2,700 Btu saved annually
- 30% drop in occupant water use
- 60% drop in irrigation water use

Swinerton

Building management system

Prior to the Swinerton retrofit, the building management system (BMS) at 260 Townsend was nearly 20 years old. Although still functioning, the system was far from optimal. Swinerton replaced the system with an Emcor BMS with direct digital controls. The new BMS enabled remote monitoring of temperature, CO_2, humidity and energy demand, and allowed Swinerton to automatically adjust HVAC and lighting systems for optimal performance and efficiency. The BMS system also collects data on systems performance and energy consumption and helps to identify equipment malfunctions, which enables optimally efficient operation and increased equipment lifetime. The energy costs savings achieved by the BMS at 260 Townsend allowed for a payback of installation costs in just 1.7 years.

Swinerton's BMS is designed to sub-meter each floor and track energy usage data on a floor-level basis, enabling the company to pass energy costs on to specific groups based on usage.

This detailed metering allows teams to recognize their role in the energy consumption of the facility, and has helped create an atmosphere of individual accountability and commitment to energy savings at Swinerton.

Lighting retrofit

Swinerton also implemented lighting retrofits throughout its office space and covered parking structure. Daylighting was increased by reducing the number of private offices around the perimeter of the building, allowing natural light to penetrate further into interior workspaces. Exit signs were also upgraded to more efficient models.

In the parking garage, lights were changed from T12 fluorescent fixtures to metal halide fixtures, reducing total demand by 7,950 watts. The metal halide fixtures were outfitted with motion sensors to minimize their operation time.

Transportation

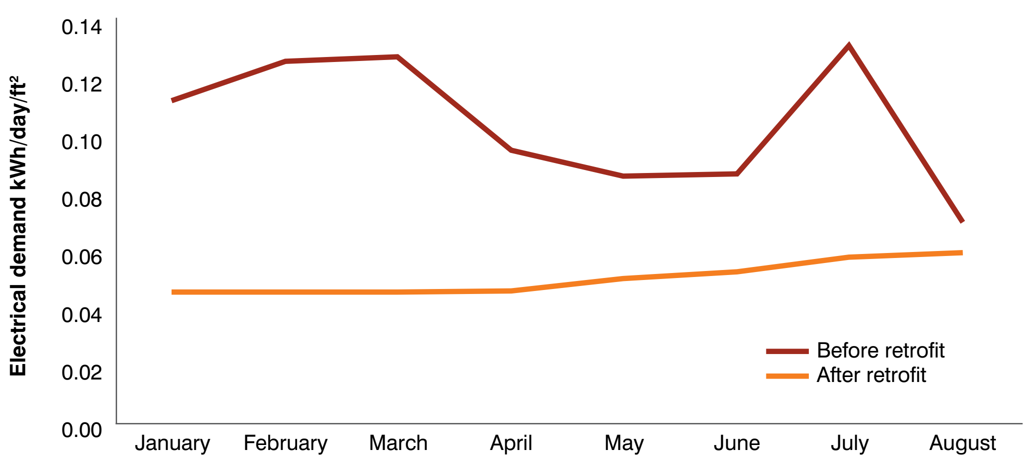
Swinerton's headquarters at 260 Townsend has access to a variety of public transportation options. It is located next to six bus stops, the Municipal Railway ("Muni") N-Judah Train and the Southbay commuter rail CalTrain. Alternative transportation is further encouraged by reserved access to parking for vanpools, carpool, hybrid and electric vehicles. Additionally, there is a secure bicycle storage and shower facility available to employees as well as two bicycles and one electric vehicle available for use around the city. All of these efforts reduce individual driving to the workplace and around the city. Moreover, these efforts may have value-added health benefits such as reduced stress and improved fitness.

Water efficiency

Indoor and outdoor efforts contributed to the water savings achieved by Swinerton. Outdoors, native vegetation was planted along with high-efficiency irrigation equipment. Indoors, all showerheads and faucets were retrofitted with low-flow aerators. Additionally, toilets that utilized five gallons per flush were replaced with toilets that use only 1.5 gallons per flush,

FIGURE G.1

Before retrofit and after retrofit electrical demand for 260 Townsend



a 70% reduction of water use per flush. These steps combined to reduce Swinerton's water consumption 30% per occupant and to achieve a full 60% reduction in irrigation water use.

CASE STUDY 3: 100 PINE STREET, SAN FRANCISCO

The building at 100 Pine Street in San Francisco is a 36-story high-rise with 402,534 rentable square feet. The high-rise is partially owned and fully managed by Unico Properties, Inc. Efficiency improvements at 100 Pine have allowed Unico Properties to increase its net operating income and win plaudits for improved environmental performance.

California's energy crisis of 2001 kick-started efficiency efforts at 100 Pine, leading the building management to hire an energy consultant to evaluate the building's systems. Efficiency improvements were achieved though equipment upgrades, as well as through policy and behavioral changes that transformed the entire building's staff culture around attention to energy usage.


Mathew Grimm

Initial efficiency upgrade investments focused on retrofits to the lighting and HVAC (Heating, Ventilation and Air-Conditioning) systems, garnering savings through reduced steam usage in the HVAC system and reduced electricity load for lighting.

In addition to technological efficiency upgrades, 100 Pine has accomplished significant efficiency gains through policy changes and by motivating a culture shift around energy efficiency in the building. The building management added a section on "Energy & Efficiency" to the tenant handbook. Some of the topics covered are:

- Turning off computers at night
- Using Energy Star® rated office machines
- Reducing the cooling load in a building through more efficient office equipment
- Recommending the purchase of office occupancy sensors

These simple and low-cost measures have netted savings throughout the building. A summary of efficiency improvements achieved to date at 100 Pine:

- A reduction of 1,200,000 kWh between the years 2000 and 2002 through fluorescent lighting upgrades and improved usage of the building EMS (energy management system)
- A reduction of 22.7%, or 5 million pounds, of steam between 2001 and 2002
- An Energy Star® score of 76 out of 100 in 2003

Looking forward, 100 Pine is seeking further environmental benefits and financial savings to increase profitability. These measures are displayed in Table G.3. Each of the four improvements being considered have paybacks between 1.3 and 3.1 years, with estimated total annual cost savings of over $500,000 plus incentives from the local utility (PG&E).

TABLE G.3

Projected benefits of planned efficiency improvements at 100 Pine

Energy efficiency measure	Annual energy savings			Annual cost savings (US$)			Incentive	Adjusted payback
	kWh	kW	MMBTU	Electric	Steam	Total	US$	Years
Install lighting occupancy sensors in all offices	121,493	22	0	$16,061	$0	$16,061	$6,075	2.0
Install variable speed drives on chilled water pumps and condenser water pumps/fans	288,049	46	139	$38,080	$3,482	$41,562	$23,044	1.9
Convert constant volume HVAC system to variable air volume system, and install variable speed drives on supply fans	1,277,962	203	12,184	$168,947	$304,610	$473,557	$178,915	1.3
Install carbon monoxide controllers for garage ventilation fans	26,766	11	0	$3,539	$0	$3,539	$2,141	3.1
Totals	**1,714,270**	**282**	**12,323**	**$226,627**	**$308,092**	**$534,719**	**$210,175**	**1.38**

APPENDIX H

Demand response agreements

Below are the most common components of a demand response contract agreement between the business customer and DR program administrator (**ISO/RTO**/Utility) or a **curtailment service provider (CSP)**.

- Term of the contract expressed in years or periods (i.e. summer or winter periods)
  - **DR program specifics**, including but not limited to the following:
  - **DR program description.**
  - **Program period.** Typically DR events are called within a specific date/time frame (i.e., June 1-September 30; 12:00pm–8pm weekdays)
  - **Demand reduction commitment.** Also referred to as "capacity," is expressed in terms of kilowatt (kW). Registration of the committed reduction to the appropriate ISO/RTO/Utility
  - **Notification protocol.** Details on how an event will be initiated and the protocol for getting that message to the customer
  - **Event frequency and duration** (i.e., maximum of ten (10) DR events ranging from one (1) to a maximum of six (6) hours
  - **Demand response test.** A DR test may be conducted in compliance with certain DR programs to demonstrate the facility's ability to meet their committed demand reduction
  - **Payment information.** A specific $/kW amount or for a CSP agreement, the payment is a percentage of the capacity payment
- **Confidentiality of energy information**
- **Opt-out/termination clause**
- **CSP services.** These would be services that a CSP provider may offer as part of their relationship with the customer:
  - Sub-metering installation to capture electrical consumption
  - Development of a curtailment plan

Glossary

accent lighting: Lighting that draws attention to special features or enhances the aesthetic qualities of an indoor or outdoor environment, such as lobbies and conference rooms.

air economizer: A component of an HVAC system that provides cooling without the use of mechanical refrigeration or air conditioning. An economizer saves energy by regulating dampers when the outdoor air temperature and ambient conditions are sufficient to provide the heating and cooling needs of the building interior.

ambient lighting: The general base-level illumination of space.

automated demand response (ADR): The use of controls and communications to automate the specific actions that reduce electrical demand during a **demand response** event.

ballast: Electrical or magnetic devices that provide appropriate voltage when a fluorescent light is turned on to limit and stabilize the amount of current flowing to the lamp during operation. Fluorescent tube lights require ballasts to operate. Compact fluorescents lamps (CFLs) do not.

BAS: See **building automation system**.

BMS: See **building automation system**.

boiler: Pressure vessel designed to transfer heat produced by combustion or electric resistance to a fluid. In most boilers, the fluid is water in the form of liquid or steam.

British thermal unit (Btu): Unit of energy used commonly for heating and air conditioning. Btu per hour (Btu/hr) is also used to describe the power of heating and cooling systems. A Btu is defined as the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

Btu: See **British thermal unit**.

building automation system (BAS): A system of automated controls for a range of building systems. Building automation systems range in degree of complexity, but are typically less sophisticated than energy management systems (EMS). May also be referred to as a building management system (BMS).

building envelope: The outer shell of a building, including walls, roof, windows and doors.

building management system (BMS): See **building automation system**.

chiller: Mechanical device that cools liquid, which is then circulated through cooling coils to cool the air supplied to a building.

commissioning: A process by which newly installed equipment is tested to make sure it performs according to design intent. When a building is initially commissioned it undergoes an intensive quality assurance process that begins during design and continues through construction, occupancy and operations. Commissioning ensures that the new building operates initially as the owner intended and that building staff are prepared to operate and maintain its systems and equipment. Retro-commissioning is performed on previously installed equipment and should be performed periodically on HVAC systems, Building Automation Systems and lighting systems.

compact fluorescent lamp (CFL): Fluorescent lamps suitable for use in fixtures designed for standard incandescent bulbs. CFLs have a longer life and lower energy usage than comparable incandescent bulbs.

CSP: See **curtailment service provider**.

curtailment service provider (CSP): An entity authorized to act as an interface between the ISO and energy market participant to deliver demand response capability.

demand: The rate at which energy is delivered to loads and scheduling locations by generation, transmission or distribution facilities. For a utility, it is the level at which electricity or gas is delivered to users at a point in time.

demand charge: Fees levied by a utility for electric demand. Demand charges are set based on a customer's peak demand.

demand response (DR): Demand response is the action taken by end users (customers) of a utility to temporarily reduce their energy usage in response to either price or system reliability triggers.

depreciation: A noncash expense that reduces the value of an asset as a result of wear and tear, age, or obsolescence. Most assets lose their value over time (they depreciate), and must be replaced once the end of their useful life is reached.

diffuser (lighting): A device that distributes light produced by lamps into a space.

dimmer: See **dimming controls**.

dimming controls (lighting): A device that varies the voltage running to a lamp in order to reduce or increase lighting intensity. Dimming controls can be manually operated or automated.

direct meter: A utility payment configuration in which a tenant contracts with and is billed by the utility.

discount rate: Rate used to calculate the present value of future cash flows.

distributed generation (DG): Also called on-site generation, generates electricity from many small energy sources. Distributed generation allows collection of energy from many sources and may give lower environmental impacts and improved security of supply.

DR: See **demand response**.

efficacy: The ratio of lamp lumen output to total lamp power input expressed in lumens per watt.

energy information system (EIS): A platform that communicates with external and internal signals of a building, such as electricity prices, weather and power quality. An EIS can also provide a gateway to the energy management system as well as analyses of various levels of data.

energy management system: A set of computer-aided tools designed specifically for the automated control and monitoring of electromechanical facilities in a building which yield significant energy consumption such as heating, ventilation and lighting installations. The scope may span from a single building to a group of buildings such as university campuses, office buildings, retail stores networks or factories. Most of these energy management systems also provide facilities for the reading of electricity, gas and water meters. The data obtained from these can then be used to perform self-diagnostic and optimization routines on a frequent basis and to produce trend analysis and annual consumption forecasts.

energy use intensity (EUI): A unit of measurement that describes a building's energy use. EUI represents the energy consumed by a building relative to its size.

fixtures: A light fixture, or luminaire, is an electrical device used to create artificial light or illumination.

fluorescent tube lamp: A tubular electric lamp, common in commercial and office spaces, that is coated on its inner surface with a phosphor and that contains mercury vapor whose bombardment by electrons from the cathode provides ultraviolet light which causes the phosphor to emit visible light either of a selected color or closely approximating daylight. See also, **T5**, **T8** and **T12**.

generator emission allowance: The air emission allowances from fossil fuel burning generators set by local, state and federal environmental entities.

green revolving fund (GRF): The fund gets its name from the revolving aspect of loan repayment, where the central fund is replenished as individual projects pay back their loans, creating the opportunity to issue other loans to new projects.

HID: See **high-intensity discharge**.

high-intensity discharge (HID): A term for mercury vapor, metal halide, and high- pressure sodium lamps and fixtures. Similar in design to an incandescent bulb, but instead of a filament, current is passed through a capsule of gas.

hurdle rate: Minimum acceptable rate of return on a project.

HVAC: heating, ventilation and air conditioning.

incandescent: One of the oldest electric lighting technologies available. Incandescent bulbs produce light by passing a current through a filament, causing it to become hot and glow (also causing waste heat).

incentives: Incentives are government or utility financing tools to help offset costs of and promote the adoption of energy efficiency improvements. In some context, incentives refer to a tax incentive or tax credit whereas rebates refer to a cash reimbursement. In this Handbook, incentives are a general term encompassing all of these unless otherwise distinguished.

independent system operator (ISO): A federally regulated organization that is tasked with monitoring and coordinating the operation of the electrical grid within a specific geographical region.

information technology (IT): Term used to describe computing equipment and services. Servers, desktop computers, printers, phones and software are all considered IT.

internal rate of return (IRR): Discount rate at which investment has zero present value.

IRR: See **internal rate of return**.

ISO: See **independent system operator**.

IT: See **information technology**.

key performance indicator (KPI): Key performance indicators help organizations achieve organizational goals through the definition and measurement of progress. The KPIs selected must reflect the organization's goals, they must be key to its success, and they must be measurable.

kilowatt (kW): 1,000 watts, is a rate and a measure of power similar to horsepower. It is the power you are consuming at one instance. To use an automotive analogy, it is equivalent to how fast you are driving. In industry, kW is referred to as power.

kilowatt-hour (kWh): kWh, or kilowatt-hours, is a quantity of energy—the amount of energy equivalent to the power of one kilowatt running for one hour. To get kWh from kW, simply multiply your kW by the number of hours applicable. If you consume 20 kilowatts for two hours, you will use 40 kilowatt-hours. It is the amount of energy you have consumed after a given amount of time (such as, a month or twenty minutes). To use an automotive analogy, kWh is like the number of miles you have driven. Electricity use for a building or a home is measured in kWh. In industry, kWh is referred to as energy.

KPI: See **key performance indicator**.

kW: See **kilowatt**.

kWh: See **kilowatt-hour**.

LED: See **light emitting diode**.

lens (lighting): Cover for a light fixture; acts as a diffuser.

life cycle cost: Also called **total cost analysis**. The total cost of owning an asset over its entire life. Whole life cost includes all costs such as initial cost, installation cost, operating costs (utility costs, maintenance costs), associated financing costs, depreciation and disposal costs. Life cycle costs often also include environmental and/or social costs. When comparing investment decisions, LCC provides a more accurate picture of the true costs and benefits of an investment opportunity.

life cycle costing (LCC): See **life cycle cost**.

light emitting diode (LED): A solid-state light source that delivers a direct beam of light at a very low wattage.

load: The amount of electric power supplied to meet one or more end user's requirements. May also refer to an end-use device or end-use customer that consumes power. **Related terms:** load curtailment.

load curtailment: Steps taken to reduce power demand at peak load times or to shift some of it to off-peak times, using techniques including back-up emergency generators, switching electric cooling onto other systems, cycling of loads to maintain a process but reduce usage, and shutting down processes.

lumens: The unit of luminous flux, a measure of the perceived power of light. A standard 100-watt incandescent light bulb emits approximately 1,700 lumens in North America.

lumens per watt (LPW): A measure of lighting efficiency calculated by dividing the number of lumens produced by the number of watts used.

luminaire: Complete lighting unit, consisting of one or more lamps together with a housing, the optical components to distribute the light from the lamps and the electrical components (ballast, starters, etc.) necessary to operate the lamps.

measurement and verification (M&V): A term used to refer to the methodology for quantifying the energy savings from a specific energy reduction measure.

megawatt-hour (MWh): Unit of energy measurement equal to 1,000 kilowatt-hours (kWh).

MWh: See **megawatt-hour**.

net present value (NPV): The difference between the present value of the future cash flows from an investment and the amount of investment. Present value of the expected cash flows is computed by discounting them at the required rate of return.

NPV: See **net present value**.

off-peak: The time during a particular period when electrical demand is relatively low. If a utility uses time-of-day pricing, electric prices will be highest during periods of peak load.

peak demand: See **peak load**.

peak load: The highest electrical demand within a particular period of time. Daily electric peaks on weekdays occur in late afternoon and early evening. Annual peaks occur on hot summer days.

photo sensor: A device that responds electrically to the presence of light.

plenum: An open space in buildings usually between floors that is used to distribute cold air or collect hot air (as opposed to ducts). Data centers typically use under-floor plenums to supply air to server aisles.

power management settings: A feature of some electrical appliances, especially copiers, computers and computer peripherals such as monitors and printers, that turns off the power or switches the system to a low-power state when inactive.

power utilization effectiveness (PUE): Ratio of total data center power consumption to server power consumption. A measure of data center system efficiency.

rebate: A cash reimbursement from a utility or government entity to offset costs and create demand for energy efficiency improvements. See **incentives**.

recommissioning: Another type of commissioning that occurs when a building that has already been commissioned undergoes another commissioning process. The decision to recommission may be triggered by a change in building use or ownership, the onset of operational problems, or some other need. Ideally, a plan for recommissioning is established as part of a new building's original commissioning process or an existing building's retrocommissioning process.

reflector: A device installed in luminaries used to direct light from a source via specular or diffuse reflection.

regional transmission operation (RTO): A federally regulated organization tasked with coordinating the movement of high-voltage electricity across large geographical area, including across state borders.

rent inclusion: A utility payment configuration in which payment for a service is bundled in with rent, usually as a fixed amount per square foot.

return on investment (ROI): A performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. To calculate ROI, the benefit (return) of an investment is divided by the cost of the investment; the result is expressed as a percentage or a ratio.

RTO: See **regional transmission operation**.

simple payback: The length of time required for the net revenues or accumulated savings of an investment or energy efficiency project to return the cost of the investment.

smart grid: The term referring to the incorporation of digital technologies and automated controls into the electricity distribution system to improve operation, increase efficiency and improve reliability.

social network analysis: Social network analysis is based on an assumption of the importance of relationships among interacting units. The social network perspective encompasses theories, models and applications that are expressed in terms of relational concepts or processes.

standby loss: A measure of efficiency of commercial water heaters that is a measure of the percentage of heat lost per hour once water is heated. Standby loss is expressed as a percentage, typically ranging from 0.5–2.0% (the lower the value, the more efficient the heater).

submeter: A utility payment configuration in which a tenant pays the landlord based on the meter as well as a "handling fee" that will vary based on negotiations, but is typically not more than 12%.

sub-metering: Hardware and software equipment that is used to capture, monitor and analyze electrical consumption that can be installed either on individual equipment or at the "main feed" to monitor overall building consumption.

T5: A linear fluorescent lamp with a diameter of 5/8 of an inch.

T8: A linear fluorescent lamp with a diameter of 8/8, or one inch in diameter.

T12: A linear fluorescent lamp with a diameter of 12/8 of an inch.

task lighting: Facilitates particular tasks that require more light than is needed for general illumination, for example, desk lamps.

tax shield: The reduction in income taxes that results from taking an allowable deduction from taxable income.

therm: Unit of energy equal to 100,000 Btu. Natural gas consumed for energy is typically measured in therms.

thermal efficiency percentage: A measure of efficiency of commercial water heaters that represents the percentage of energy from the fuel or electric heating element that is transferred to the water being heated (ranges from 0–100%; the higher the value, the more efficient the heater).

three-phase: A wiring system suitable for installations involving large motors. The system consists of three hot wires and one ground wire.

time clock: Lighting controls scheduling program to turn lights on within a facility on a predetermined schedule rather than switching lights on all at once throughout the space. May also integrate occupancy sensors and photocells to further increase energy savings by only activating scheduled lighting during periods of occupancy and when natural lighting alone is not sufficient.

tungsten halogen: An updated version of a traditional incandescent bulb. It contains halogen gas and uses a tungsten filament.

uninterruptible power supply (UPS): Technology designed to ensure that power does not cut out unexpectedly in a data center, resulting in server failure. UPS systems commonly use batteries to back up the electric power supply.

virtualization: Consolidation of multiple copies of an operating system onto a single server. The operating systems can run simultaneously, dramatically increasing the utilization of the server.

watt: See **kilowatt**.

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