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Climate Corps Handbook

Energy Efficiency Investment Opportunities in Commercial Buildings / FOURTH EDITION

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Fourth Edition

Environmental Defense Fund

Environmental Defense Fund is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic and social support because they are nonpartisan, cost-effective and fair.

The Environmental Defense Fund Climate Corps Program places trained MBA fellows into companies to capture unrealized financial and environmental gains through the identification and implementation of cost-effective energy efficiency improvements.

This Handbook is intended for use as a reference manual for identifying, analyzing and prioritizing energy efficiency investments in commercial buildings. For more information about the Climate Corps Program, please contact Victoria Mills at climatecorps@edf.org.

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Acknowledgements

Thanks to Andy Wunder for research support, to Jacob Hiller, Andrew Mulherkar, and Emily Reyna for edit support and to Laurie Hunter, Allison Cobb, Jennifer Coleman, Christina Baute and Bonnie Greenfield for production.

Cover photo: The Environmental Defense Fund San Francisco offices were designed to maximize energy efficiency. Photo by César Rubio.

Printed on totally chlorine-free 100% post-consumer recycled content paper.

The complete report is available online at edf.org/climatecorps.

Table of contents

CHAPTER 1

Introduction

Climate Corps Program objective

The Climate Corps Program places trained Master of Business Administration (MBA) fellows in companies to help capture unrealized financial and environmental gains. Climate Corps fellows identify and prioritize cost-effective investments that result in energy savings for building owners or leaseholders, and they develop plans to fund and implement those projects.

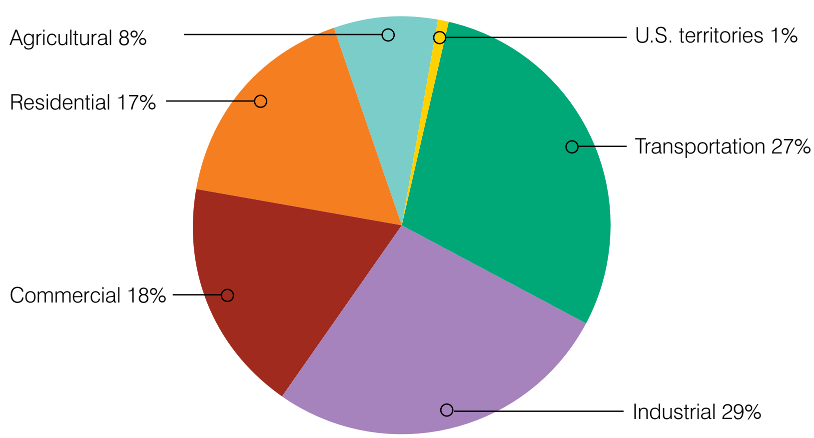
Energy efficiency matters

Increasingly, companies 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 it "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 2007, the energy used by residential and commercial buildings accounted for 35 percent of U.S. GHG emissions.[1] California's energy efficiency outreach campaign, "Flex Your Power," estimates that most commercial buildings could cut energy use by 30 percent through investments in improved efficiency.[2]

FIGURE 1.1

Sources of greenhouse gas emissions in the United States



Data source: U.S. EPA, "Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009," Table ES-8, February 2011. Accessible at http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

Along with cutting GHG emissions, efficiency improvements could translate into major savings for the companies operating those buildings. The U.S. commercial sector spends $108 billion each year on energy bills for buildings. Over 75 percent of this spending goes towards electricity.[3] According to Flex Your Power, a 50,000-square-foot office building of average operating efficiency can reduce costs by $40,000 per year just through no-cost and low-cost efficiency upgrades.[4] Energy efficiency upgrades can also bring long-term benefits to building owners, as asset value typically increases by an estimated $3 for every $1 invested in energy efficiency.[5] A 2008 study by the CoStar Group found that Energy Star certified buildings sell for an average of $61 per square foot more than their peers, and LEED certified buildings sell for $171 per square foot more than uncertified buildings.[6]

Barriers and overlooked opportunities

Despite the opportunities, few companies have fully invested in cost-effective energy efficiency improvements. Even companies 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 companies from identifying or approving smart efficiency investments.

Some barriers are organizational: for example, facilities 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 facilities 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.

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 companies may impose an overly stringent hurdle rate (e.g., a one-year payback) that prevents many smart, low-risk investments from being approved. (For more detail on these problems, see Chapter 5: Barriers to energy efficiency.)

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

Notes

1 This statistic was derived by combining the commercial and residential sectors' GHG emissions (with electricity-related emissions distributed), which are attributable to building energy consumption. Data source: U.S. EPA, "Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009," Table ES-8, February 2011. Accessible at http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

2 Flex Your Power, "Commercial Sector." Accessible at http://www.fypower.org/com.

3 Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table C2A. Total Energy Expenditures by Major Fuel for All Buildings, 2003," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html.

4 Flex Your Power, "Commercial Sector." Accessible at http://www.fypower.org/com.

5 Flex Your Power, "Best Practice Guide: Commercial Office Buildings." Accessible at http://www.fypower.org/com/bpg.

6 Miller, N., Spivey, J., and Florance, A. "Does Green Pay off?" July 2008. Accessible at http://www.usgbc.org/ShowFile.aspx?DocumentID=5537.

CHAPTER 2

Trends in commercial building energy consumption

Energy consumption in commercial buildings

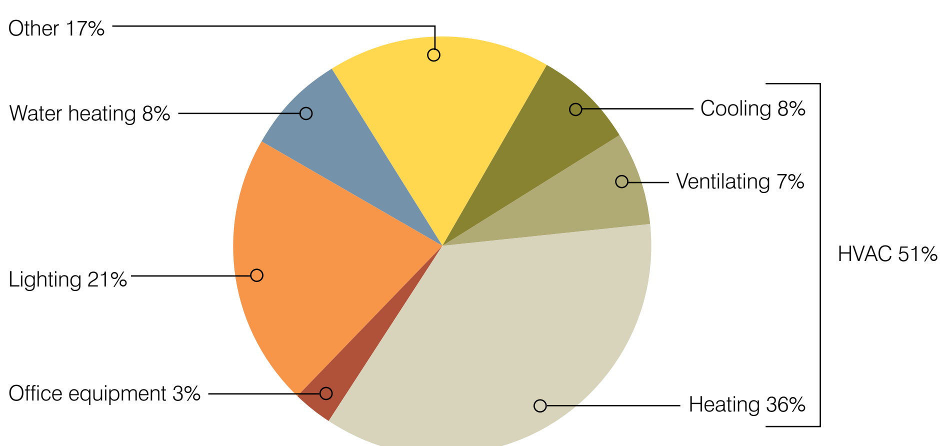
A first step in identifying opportunities to improve energy efficiency is to understand how energy is used within a building. Though different types of buildings serve very different purposes, there are common systems that most commercial buildings share. The systems that consume significant portions of energy in an average commercial building include: heating, air conditioning and ventilation (51% together), lighting (21%), office equipment and computers (3%) and water heating (8%) (see Figure 2.1). Efficiency opportunities for each of these systems will be explored in detail in subsequent chapters.

Energy consumption and energy intensity vary 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 2.2). If every office building in the country achieved the thirty percent cut

FIGURE 2.1

Estimated energy consumption of U.S. commercial buildings



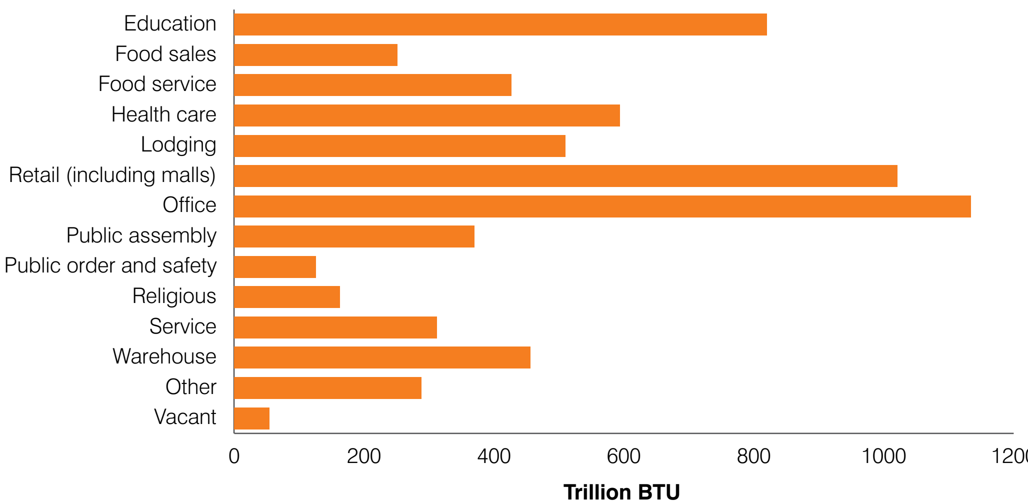
Data source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E1A. Major Fuel Consumption (BTU) by End Use for All Buildings," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html.

in energy use that Flex Your Power estimates is possible, the combined annual reduction in U.S. energy use would total over 340 trillion BTU.[1] That's enough energy to power over 638 thousand homes for a year.[2]

Another important measure in understanding variations in energy consumption across building types is energy intensity. Energy intensity is the amount of energy a building uses per square foot. Among commercial buildings, food sales and service buildings have the highest

FIGURE 2.2

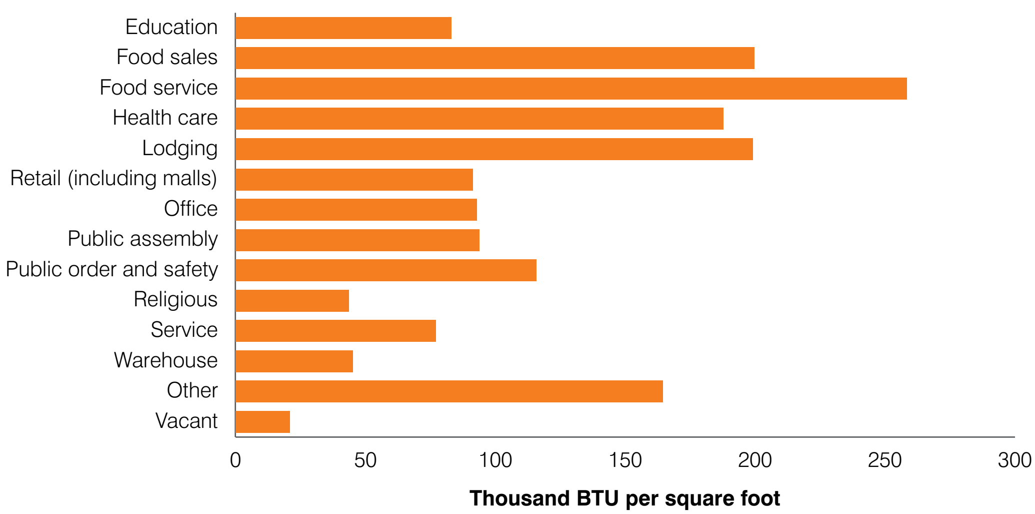
Estimated total fuel consumption by end use for all U.S. commercial buildings



Data 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 2.3

Estimated energy intensities for U.S. commercial buildings



Data 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 intensity—each uses more than twice the energy per square foot of a typical office building (see Figure 2.3). Energy 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 6: Interpreting electricity bills and benchmarking energy use.

For additional information on energy use patterns in a range of specific building types, consult Appendix A: Energy consumption of U.S. commercial buildings by type.

Notes

1 This statistic was derived from the Flex Your Power estimate that commercial buildings can reduce energy consumption by 30 percent and Energy Information Administration data on the total energy consumption of office buildings. Data sources: Flex Your Power, "Commercial Sector." Accessible at http://www.fypower.org/com and 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_2003/2003set19/2003pdf/e01a.pdf.

2 This statistic was derived using the Environmental Protection Agency's Interactive Units Converter to calculate kilowatt-hours from BTUs and the Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator to calculate household energy consumption from kilowatt-hours. Data sources: U.S. EPA, Coalbed Methane Outreach Program, "Interactive Units Converter." Accessible at http://www.epa.gov/cmop/resources/converter.html and U.S. EPA, "Greenhouse Gas Equivalencies Calculator," March 2010. Accessible at http://www.epa.gov/cleanenergy/energy-resources/calculator.html.

CHAPTER 3

How to use this handbook

This handbook is a reference manual for identifying, analyzing and prioritizing energy efficiency investments in commercial buildings. The handbook contains a set of chapters focusing on areas of a typical company's energy use and associated energy savings opportunities—lighting, HVAC (heating, ventilating and air conditioning), office equipment, water heating and vehicles. Each chapter provides an overview of steps that a company can take to reduce energy use, from policy changes to efficient use adjustments and equipment replacement. Additional chapters detail the energy savings potential of installing or upgrading an energy management system (EMS) and the efficiency opportunities that exist in data center facilities.

Chapters are also devoted to additional concepts that will be useful to Climate Corps fellows: traditional barriers to energy efficiency investment, how to interpret office energy bills, basic energy efficiency finance and additional non-financial considerations. Each chapter contains a set of goals, a topical overview and an "Information Gathering Guide," which outlines information a Climate Corps fellow should collect from the host company and outside engineers. The handbook contains extensive references for a reader who may want to delve deeper into a particular practice or technology. Additional background information is included in the appendices, and the vocabulary terms that are in **bold color** throughout the text are defined in the glossary.

The chapters contain rough estimates of costs, typical energy savings and expected returns on investment for a number of the suggested efficiency upgrades. Potential utility rebates for many of the measures are also listed. This rebate information is based on the rebates offered by Pacific Gas & Electric in Northern California; rebate information for other areas should be available from regional utilities. For HVAC and EMS upgrade measures, where energy savings and expected returns range broadly depending on building specifics, the chapter text includes short financial case studies to illustrate potential savings. In conjunction with the handbook, Environmental Defense Fund has developed a companion Financial Analysis Tool 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 savings and **payback** times specific to the conditions of a particular building. The savings estimates can be used as the base of a business case for the host company.

Another useful approach when presenting companies with a business case for investment in energy efficiency is to cite relevant case studies from companies that have made successful investments. In addition to the short case studies in the text of the HVAC and EMS chapters,

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

three complete case studies are included as appendices to the handbook, along with a reference list of other useful published case studies.

Although the challenge of greatly 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 efficient technology options. The energy reduction tactics in each chapter are presented in order from simplest and lowest cost (e.g., policy and process changes) to more complex and cost-intensive (e.g., equipment replacement).

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

This handbook focuses primarily on the final stage, operations and facilities management, and suggests measures that are suitable for retrofitting or replacing existing building technologies. The following text outlines the basic steps for identifying and prioritizing energy efficiency opportunities. Note that Climate Corps fellows will be primarily involved in steps 4–6.

1. Estimate baseline energy use intensity. High-level calculations of baseline energy use intensity (EI) can be performed by dividing annual purchased electricity and fuel by square footage. In order to perform this analysis, obtain documentation of purchased energy (e.g., monthly electric and natural gas bills) from the previous fiscal year and square footage figures for the space. Baseline estimates of EI can be compared to benchmark energy use intensity figures to provide a rough estimate of possible gains to be accomplished through energy efficiency measures. For more information on estimating baseline energy use and benchmarking, see Chapter 6: Interpreting energy bills and benchmarking energy use.

2. Commission an energy audit. If initial energy 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 is likely to 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. For more information on energy audits, consult the Flex Your Power energy audit guide at http://www.fypower.org/bpg/module.html?b=offices&m=Planning_an_Energy_Program&s=Energy_Audits.

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. For example, efficiency upgrades to a lighting system will result in reduced releases of heat and will lower the cooling load of the air-conditioning (AC) system. The energy efficiency engineer(s) should be able to provide good estimates of the probable collateral effects of a given efficiency upgrade, and these should be factored into financial analysis and prioritization.

4. Perform financial analysis of possible efficiency investments. For each potential project, one should forecast the initial incremental investment plus the expected annual savings and costs. Reduction in energy usage will likely be the main financial driver, but changes in labor and replacement costs may also be significant. Tax incentives and utility rebates should also be included in the calculation. The Climate Corps Financial Analysis Tool 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 the size of the initial investment and feasibility. 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 14: Energy efficiency finance). The best option for a given company will depend on the company's cash position, budget cycle, availability of incentives 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 companies after six, twelve and twenty-four months to monitor progress and reductions in energy usage.

CHAPTER 5

Barriers to energy efficiency

If energy efficiency makes economic sense, then why have companies not already made these rational investments? There are a host of structural and organizational barriers impeding investment.

Structural barriers

- Split incentives occur when benefits from an investment made by tenants accrue to the landlord or vice versa. For example, if the tenants' electricity is included in the rent, they have little incentive to reduce their electricity use. If the tenants are **sub-metered** or pay for electricity directly, however, the incentive to make changes is strong.

- Short or imminent lease schedules also impose financial constraints. Few tenants would invest in projects with a five-year **payback** if they may depart within three years.

Organizational barriers

- Scarce resources mean there is limited time to evaluate and implement efficiency investments. Other, more immediate tasks are given higher priority.

- "Language barriers" between finance and facilities make it difficult for facilities managers to develop and present a solid business case in appropriate financial terms. The consulting firm GreenOrder argues that companies also "separate capital and operating expenses in such a way that it is difficult to justify a capital expense that reduces operating expenses."[1]

- Coordination challenges across finance, human resources and facilities make it time consuming to implement efficiency improvements such as **HVAC** or lighting upgrades while also ensuring that worker comfort and productivity are not affected.

- Limited accountability for green initiatives means that no one department may be responsible for getting initiatives funded and implemented. For example, funding for software to reduce energy consumption in personal computers (PCs) may come out of an IT budget, whereas the energy savings benefit is reflected in the facilities budget.

Financial barriers

- Many companies impose overly stringent **hurdle rates**. A McKinsey study estimated that only 25% of companies would invest in efficiency measures with paybacks longer than two years.[2] This means that the majority of companies will turn down energy efficiency investment with an internal rate of return (IRR) of over 40%.

- Efficiency investments often feature a significant up-front investment, followed by years of stable and predictable savings. Lack of available cash or financing can impede this investment. Budget cycle may also dictate timing of investments.

- Companies may not be aware of opportunities for tax incentives or utility subsidies that improve the IRR of energy efficiency investments.

Notes

[1] Andy Frank, GreenOrder, "Possible and Profitable: Energy Efficiency Investments in the Building Sector." Accessible at http://www.greenbiz.com/news/2007/08/20/possible-and-profitable-energy-efficiency-investments-building-sector.

[2] Florian Bressand et al., McKinsey Global Institute, "Wasted Energy: How the US Can Reach its Energy Productivity Potential." June 2007, p. 16. Accessible at http://www.mckinsey.com/mgi/reports/pdfs/wasted_energy/MGI_wasted_energy.pdf.

CHAPTER 6

Interpreting electricity bills and benchmarking energy use

Goals

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

Overview

Tenants can pay for electricity through one of three ways:

- **Direct meter:** The tenant contracts with, and is billed by the utility.
- **Sub-meter:** 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 a company is **direct 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 company's monthly utility bills. However, if a company 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 companies pay at the end of each billing period is based on an energy charge and a **demand charge**. 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 company's equipment, normally recorded over a 15-minute time interval each month.The demand charge is significant because it sets the amount of generation 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. As a result, utilities try to control customer load growth to defer building new generation capacity for as long as possible through demand charges and conservation programs.

$$\text{Electric bill} = (\text{energy charge} \times \text{energy usage}) + (\text{demand charge} \times \text{maximum load})$$

Therefore, in order to reduce electric bills, companies must either reduce the amount of electricity they use or reduce the maximum amount of electricity they use at any one time.

TABLE 6.1

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.)

Data source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table C21. Electricity Consumption and Conditional Energy Intensity by Building Size and Table C31. Natural Gas Consumption and Conditional Energy Intensity by Building Size," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html.

- **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, 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 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.

Additional information

For further information on billing structure and demand response programs, consult regional utilities.

For more information on energy use intensities by climate zone and region, see:

- Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS)," September 2008. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html.

Benchmarking energy usage

The energy 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 intensity values to known benchmarks for the building type and geographic area. If a given building has energy intensity values that are higher than the benchmarks, there likely will be significant potential for cost-effective energy efficiency improvements.

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.
- How many meters are in the building? What portion of the facilities do they cover?
- Does the firm pay the utility directly for energy use or are payments made to the landlord or management company?
- What is the host company'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 the space?

CHAPTER 7

Lighting

Goals

- Identify locations in the building that are overlit, unoccupied locations that are lit and areas where lighting sources can be replaced with lower wattage alternatives

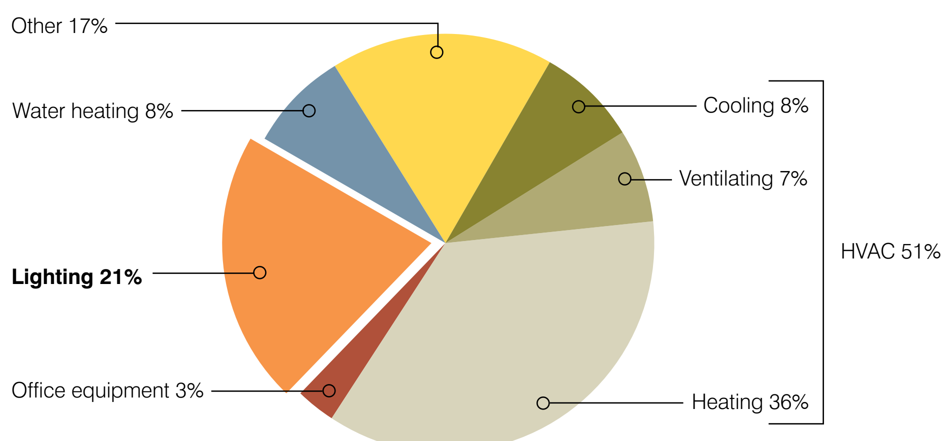
- Develop estimates of energy usage and calculate the estimated savings potential of installing improved lighting controls and/or more efficient lighting sources

Overview

On average, lighting consumes 21% of the energy used by commercial buildings in the U.S.[1] Many commercial buildings operate with highly inefficient lighting systems, with lighting that stays on when spaces are vacant, daylit spaces that are artificially lit all day and outdated lighting source technologies. In addition to having a high energy demand, inefficient lighting systems release a large portion of drawn electricity as waste heat, adding to a building's cooling load and requiring additional energy expenditure for air-conditioning. As a result, increasing lighting efficiency not only decreases energy costs associated with lighting, but may also reduce energy costs associated with HVAC.

FIGURE 7.1

Estimated energy consumption of U.S. commercial buildings



Data 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 efficiency of a lighting system can be increased through:

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

Information gathering guide

It is important to consider a number of questions about the building before assessing its lighting efficiency potential, including:

- Does the host company own or lease the space?
- If the host company leases space, does the company pay the utility bill or is it included in the rent? (See Chapter 6: Interpreting electricity bills and benchmarking energy use.)
- Is the landlord (if not the host company) interested in pursing efficiency reductions for tax credits or other financial incentives?
- Who in the host company's organizational structure makes 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 outdoor lighting is required for security?
- Are there any official lighting policies? (e.g., lights are dimmed after 6:30 pm)
- How are lights controlled? Which systems are automated and which are manually controlled?
- What are the responsibilities of cleaning staff with regard to lighting? Is cleaning staff receptive to requests?

In addition, a rough estimate of lighting savings potential can be calculated simply by walking through the office during workday hours and then again after office hours and noting lighting levels. A blueprint of the floorspace is useful for this exercise. During a walkthrough, the following questions should be considered:

- For each room or zone, are the lights on during the day/evening? When rooms are unoccupied? Is the lighting adequate? Excessive?
- What is the type and wattage of lamps used in the building?

A lighting engineer can offer more detailed assessment capabilities as well as a broader range of solutions.

Tactics for reducing energy use

1. Policy and process changes

- **Train/educate staff to turn off lights.** One of the simplest efficiency upgrades a company can make is to institute policies and processes that prevent lights from being left on when space is vacant. Determine which users of the space should have primary responsibility for turning

TABLE 7.1

Lighting maintenance checklist

Description	Comment	MAINTENANCE FREQUENCY Daily	Weekly	Monthly
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.			✓

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

lights on and off at different times of the day and week and make sure that those responsibilities have been adequately communicated. Increased coordination among players, from office managers to office occupants and cleaning crews, can often result in decreased energy draw from lighting. Installing a master switch that can simultaneously turn off all lights on a floor will make it easier for the last who leaves to ensure that all lights are out.

- **Separate task lighting and ambient lighting.** Separating **ambient lighting** from **task lighting** will give employees the flexibility to choose appropriate lighting levels for their workspaces, improving lighting quality and reducing unnecessary lighting. Increasing available task lighting and providing individual dimming and on/off controls will allow the users to control and balance the luminance ratios for their tasks.

- **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 7.1 for the Federal Energy Management Program's recommended maintenance schedule for commercial lighting systems.

2. Lighting control efficiency measures

There are two types of lighting control devices: devices that enable occupants to control their lighting environments and devices that are designed to take the place of occupant actions.

Manual control devices, such as light switches, manual dimmers and window blinds can be directly accessed and controlled by occupants. Automatic control devices, such as occupancy sensors, timers and photosensors, are designed to take the place of occupant actions.

Tactics for reducing energy use

1. Policy and process changes

- Train/educate staff to turn off lights
- Separate task lighting and ambient lighting
- Practice regular lighting maintenance

2. Lighting control efficiency measures

- Install time clocks to automatically shut off lights after hours
- Install occupancy sensors
- Install dimmable ballasts and dimming controls in indoor daylit zones
- Install photosensors in indoor daylit zones
- Install time clocks or photosensors to control outdoor lighting

3. Lighting source efficiency upgrades

- Replace T12 linear fluorescent lamps with T8 linear fluorescents lamps that have reflectors (for detail on lighting types, consult Appendix B: Lighting background information)
- Replace incandescent bulbs with comparable compact fluorescent lamps (CFLs)
- Install LED exit signs
- Upgrade outdoor lighting to high-pressure sodium fixtures or metal halide fixtures

- **Install time clocks to automatically shut off lights after hours.** Installing time clocks to turn lighting on and off eliminates the inefficiency of 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 which time clocks are appropriate for which types of spaces, 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.

TABLE 7.2

Costs and rebates

Technology	Materials	Labor	Total cost	PG&E rebate
Time clock, 24-hour mechanical	$40	$90	$130	$36[a]
Time clock, 7-day digital	$30	$70	$100	$36
Time clock, 7-day electromechanical	$110	$90	$200	$36
Time clock, 7-day electromechanical, 3-phase[b]	$300	$90	$390	$36

Data source: California Energy Commission, "Technical Options Guidebook," p. 11. Accessible at http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF.

a For details, consult PG&E's Business Rebates & Incentives Information at http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

b For use with HVAC equipment as well as lighting.

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

- **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 hours of 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 7.3

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

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

TABLE 7.4

Costs and rebates

Technology	Materials	Labor	Total cost	PG&E rebate
Wall-mount occupancy sensor	$50	$10	$60	$20–$55[a]
Ceiling-mount occupancy sensor	$100	$50	$150	$35–55

[a] For details, consult PG&E's Business Rebates & Incentives Information at http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

Payback period: According to the State of California's Green California initiative, the typical **payback** period for occupancy sensors (before rebates) is two to three years.[2]

Additional information

For more information on occupancy sensors, see:

- Wisconsin Public Service, "Lighting: Occupancy Sensors." Accessible at http://www.wisconsinpublicservice.com/business/esource/DisplayESource.aspx?page=_escrc_0013000000DP22YAAT-2_BEA1_PA_PA_Lighting_PA-10.html.
- FPL Business Energy Advisor, "Buying Equipment: Lighting: Occupancy Sensors." Accessible at http://www.fpl.com/business/energy_saving/energy_advisor.shtml.
- Lighting Research Center, "Controls." Accessible at http://www.lrc.rpi.edu/researchAreas/controls.asp.

- **Install photosensors, dimmable ballasts and dimming controls in indoor daylit zones.** Photosensors 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 varying amounts of daylight throughout the day, photosensor controls can adjust artificial light levels as necessary to supplement available natural light. A continuous dimmer controlled by a photosensor 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. **LED** lamps require a dimming power supply in combination with LED dimming controls.

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

The installation of photosensors 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 photosensor installation plus the incremental cost of dimming ballasts and controls over standard ballasts and controls.

TABLE 7.5

Costs and rebates

Technology	Materials	Labor	Total cost	PG&E rebate
Daylight photosensor	$10–50	$60	$70–110	—
Fluorescent dimming ballasts	$50–75	$10–200	$85–275	—
HID hi-lo ballasts	$50–100	$100–150	$150–250	—
Dimmer (per fixture, assuming two fixtures/circuit)	$440	$270	$710	—
Dimmer (per fixture, assuming ten fixtures/circuit)	$175	$110	$285	—

Data source: California Energy Commission, Technical Options Guidebook, p. 11. Accessible at http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF.

Payback period: In a theoretical building with 40 daylit lighting zones and 20 linear fluorescent lamps per zone, installation of dimming ballasts and dimming controls during a simultaneous lighting retrofit would cost an additional $20,200 and would save an additional $3,634 annually in electricity costs, for an adjusted payback period of 5.6 years (assuming a 35% reduction in energy draw by lighting due to dimming controls, an electricity cost of $0.12/kWh and a labor cost of $60/hr).[3]

Additional information

For more information on dimmable ballasts, see:

- Lawrence Berkley National Lab, "Retrofit Fluorescent Dimming with Integrated Lighting Control—Economic and Market Considerations." Accessible at http://lighting.lbl.gov/pdfs/economic_considerations.pdf.
- Washington State University,
  - "Energy Efficiency Fact Sheet: Daylight Dimming Controls." Accessible at http://www.energy.wsu.edu/ftp-ep/pubs/building/light/dimmers_light.pdf.
  - "Energy Efficiency Fact Sheet: Dimmable Compact Fluorescent Lamps." Accessible at http://www.energy.wsu.edu/ftp-ep/pubs/building/light/compact_fluor.pdf.
- University of California, Berkeley, "Field Experience with High Frequency Ballasts." Accessible with subscription at http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=96972.

- Lighting Controls Associations, "The next generation of electronic lighting systems:smaller, smarter and greater energy savings." Accessible at http://lightingcontrolsassociation.org/.

For more information on photosensors, see:

- Lighting Controls Association, "Linear Fluorescent Dimming Ballasts—Technology, Methods, Protocols." Accessible at http://www.lutron.com/Education-Training/LCE/Pages/DimmingBasics.aspx.
- Washington State University, "Energy Efficiency Factsheet—Daylight Dimming Controls." Accessible at http://www.energy.wsu.edu/ftp-ep/pubs/building/light/dimmers_light.pdf.
- FPL Business Energy Advisor, "Buying Equipment: Lighting: Lighting Controls." Accessible at http://www.fpl.com/business/energy_saving/energy_advisor.shtml.

- **Install time clocks or photosensors to control outdoor lighting.** Energy savings can also be achieved through greater efficiency in outdoor lighting. Time clocks or photosensors that turn outdoor lighting on at dusk and off at dawn can avoid energy waste from unnecessary lighting.

TABLE 7.6

Costs and rebates

Technology	Materials	Labor	Total cost	PG&E rebate[c]
Daylight photosensor[a]	$50	$60	$110	$11
Time clock, 24-hour mechanical	$40	$90	$130	$36
Time clock, 7-day digital	$30	$70	$100	$36
Time clock, 7-day electromechanical	$110	$90	$200	$36
Time clock, 7-day electromechanical, 3-phase[b]	$300	$90	$390	$36

a California Energy Commission, Technical Options Guidebook, p. 11. Accessible at http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF.

b For use with HVAC equipment as well as lighting.

c PG&E offers rebates of $11.00 for photosensors installed to control outdoor lighting (no rebates currently available for indoor photosensors). For details, consult PG&E's Business Rebates & Incentives Information at http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

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

3. Lighting source efficiency upgrades

Upgrades to more efficient lighting sources (i.e., lamps, light fixtures, etc.) often yield the most significant efficiency gains in lighting systems. Look for opportunities to replace outdated lighting sources (e.g., **incandescents**, **T12** linear fluorescents) with modern, more efficient sources (e.g., **compact fluorescent lamps (CFLs)**, **T8** linear fluorescents, LED, HID). For background information on lighting types, consult Appendix B: Lighting background information.

- **Replace T12 linear fluorescent lamps with T8 linear fluorescents lamps with reflectors.** T8 linear fluorescents (narrower in diameter and more efficient than T12 linear fluorescents) are the standard lighting source used in most recently constructed buildings. In older buildings, however, inefficient T12 lamps may still be in use, and an upgrade to T8s should be undertaken.

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.

T8 lamps with reflectors and electronic ballasts are about 30% more efficient than T12 lamps with magnetic ballasts (see Table 7.7). 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 more efficient than T8s, but typically require the replacement of a building's entire lighting system because the lamps are a different standard length than T8s and T12s. T5 fluorescents should be considered if building space is being renovated, but will not likely be cost effective as a retrofit.

TABLE 7.7

T12 and T8 Comparison—4 ft. lamps with comparable light output

	T12 LAMPS WITH MAGNETIC BALLAST		T8 LAMPS WITH ELECTRONIC BALLAST	
Number of lamps	Input watts	Efficacy (lumens/watt)	Input watts	Efficacy (lumens/watt)
2	72	73	58	94
4	144	73	112	97

Data source: Alliant Energy, "Lighting: T8 Fluorescents". Accessible at http://www.alliantenergy.com/UtilityServices/ForYourBusiness/EnergyExpertise/EnergyEfficiency/012398.

TABLE 7.8

Costs and rebates

Technology	Materials (incremental)	Labor (incremental)	Total cost	PG&E rebate[b]
4-foot T8 lamp	$0[a]	$0[a]	$0	$5.50
Electronic ballast	$10	$10	$20	NA

a T8 lamp has no incremental cost over T12 lamp; incremental labor cost is $0 with the assumption that T12 lamp is due to be replaced.
b Rebate is for both lamp and ballast. For details, consult PG&E's Business Rebates & Incentives Information at http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

Incentives are also available for "delamping" (permanently removing unnecessary light fixtures). 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. A 10% delamping is typically possible following a T12 to T8 retrofit. An additional benefit of delamping is reduced heat produced from lamps, which lowers building cooling load and energy costs. PG&E provides an incentive of $8.00 for every 4-foot fluorescent lamp that is permanently removed.[4]

Payback period: In a theoretical building where 1,000 4-foot T12 lamps are replaced with 900 4-foot T8 lamps, installation would cost $5,500 and would save $2,958 annually in electricity costs, for an adjusted payback period of 1.9 years (assuming PG&E rebates of $5.50 per 29W T8 lamp installed and $8 per 32W T12 lamp removed, an electricity cost of $0.12/kWh and a labor cost of $60/hr).[5]

- **Replace incandescent bulbs with comparable compact fluorescent lamps (CFLs).** In a typical incandescent bulb, 95% of energy is released as waste heat. CFLs are designed to be compatible with traditional incandescent fixtures, but are 60–75% more efficient than comparable incandescent lamps (see Table 7.9) and have an expected life of up to 10,000 hours vs.

about 1,000 hours for an incandescent. Replacing incandescent lamps with CFLs will save on maintenance and cooling costs in addition to lighting energy costs.

TABLE 7.9

Estimated cost savings of replacing an incandescent bulb with a CFL of comparable output in lumens

Incandescent	CFL	Lumens	Cost savings[a] ($.10/kWh)
40W	11–14W	>490	$39–$44
60W	15–19W	>900	$62–$68
75W	20–25W	>1,200	$76-$83
100W	26–29W	>1,750	$76-$83
150W	38–42W	>2,600	$163–$169

Data source: Environmental Defense Fund, "Make the Switch." Accessible at http://www.edf.org/cflguide.
[a] Savings from reduced lighting electricity; does not include additional savings from reduced cooling load and maintenance.

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

TABLE 7.10

Costs and rebates

Technology	Materials (incremental)[a]	Labor (incremental)[b]	Total cost	PG&E rebate[c]
CFLs with reflectors (screw-in, 14-28W)	$7–$8	$0	$7-$8	$7
Standard CFL (screw-in, 14–28W)	$1–$2	$0	$1–$2	—

[a] Incremental lamp cost assumes $1.00 per incandescent bulb.
[b] Incremental labor cost is $0 with the assumption that incandescent bulb is due to be replaced.
[c] For details, consult PG&E's Business Rebates & Incentives Information at http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

Payback period: Typical payback for replacement of incandescent bulbs with comparable CFLs is under six months.

To generate more specific payback estimates for CFL installation, consult the EPA Energy Star® calculator available at http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorCFLs.xls.

Additional information

For more information on CFLs, see:

- Alliant Energy, "Lighting: Compact Fluorescent Lamps." Accessible at http://www.alliantenergy.com/UtilityServices/ForYourBusiness/EnergyExpertise/EnergyEfficiency/012396.
- CFL purchasing tips: 'Make the Switch,' Environmental Defense Fund. Accessible at http://www.edf.org/cflguide.

● **Install LED exit signs.** Although exit signs draw a relatively low wattage, they run continuously. A typical incandescent exit sign has an annual energy draw similar to that of a desktop PC. LED exit signs are more energy efficient than incandescent or fluorescent exit signs.

TABLE 7.11

Exit sign comparison

	Incandescent	Fluorescent	LED
Input power (watts)	40	11	2
Yearly energy (kWh)	350	96	18
Lamp life (years)	0.25–0.5	1–2	10+
Estimated energy cost per year ($0.10/kWh)	$35	$9.60	$1.80

Data source: Alliant Energy, "Lighting: LED Exit Signs." Accessible at http://www.alliantenergy.com/UtilityServices/ForYourBusiness/EnergyExpertise/EnergyEfficiency/012397.

TABLE 7.12

Costs and rebates

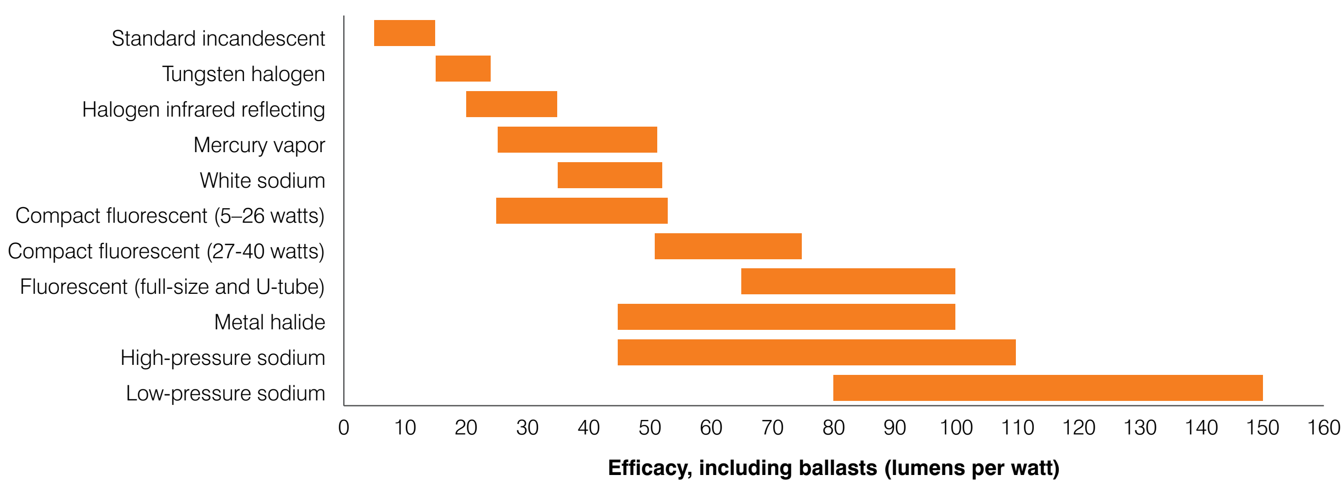
Technology	Materials	Labor	Total cost	PG&E rebate[b]
LED exit sign	$17–95	$30	$47–125	$15-$27 [a]

[a] PG&E will rebate $27 per sign for LED exit signs that replace incandescent exit signs and $15 per sign for replacing fluorescent exit signs. For details, consult PG&E's Business Rebates & Incentives Information at http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

Payback period: In a theoretical office where ten incandescent exit signs are replaced with ten LED exit signs, replacement would cost $430 and would save $4,448 annually in electricity costs, for an adjusted payback period of one year (assuming an incremental cost of $40 per sign, a PG&E rebate of $27 per sign, an electricity cost of $0.12/kWh and a labor cost of $60/hr).[6]

FIGURE 7.2

Efficacy of available lighting technologies



Efficacy: a measure of lighting efficiency. The amount of light output per unit of electrical input, or lumens per watt (also known as LPW), is a common measure of lighting efficiency. The value of lumens per watt is always greater than one, so lamps with higher LPW values are said to have higher efficacy. This figure shows lighting efficacies of the different types of lighting technologies. Data source: FPL Business Energy Advisor, "Buying Equipment: Lighting: High-Intensity Discharge Lamps." Accessible at http://www.fpl.com/business/energy_saving/energy_advisor.shtml.

• **Upgrade outdoor lighting to high-pressure sodium fixtures or metal halide fixtures.** High intensity discharge (HID) lamps provide energy savings of 50–90% over incandescent sources and are well suited to outdoor applications.

Costs and rebates: HID prices vary broadly depending on application, but are generally significantly more expensive than comparable incandescent bulbs.

PG&E rebates $15–$150 for replacing an incandescent fixture with an HID lamp. For details see: http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

Payback period: Despite the high incremental cost of HID lamps, the wattage reductions achieved when replacing incandescent lamps with HID lamps are significant enough that payback is usually under one year.

Additional information

For more information on HID outdoor lighting, see:

• FPL Business Energy Advisor, “Buying Equipment: Lighting: High-Intensity Discharge Lamps.” Accessible at http://www.fpl.com/business/energy_saving/energy_advisor.shtml.

• Gardco Lighting, “Saving Energy in Outdoor Lighting.” Accessible at http://www.sitelighting.com/brochure/g-e_energy_brochure.pdf.

• Los Alamos National Laboratory, “Los Alamos National Laboratory Sustainable Design Guide,” Chapter 5. Accessible at http://apps1.eere.energy.gov/buildings/publications/pdfs/commercial_initiative/sustainable_guide_ch5.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. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html.

[2] Green California, “Building Maintenance—Lighting and Occupancy Sensors.” Accessible at http://www.green.ca.gov/EPP/building/sensors.htm.

[3] Estimate generated using Environmental Defense Fund Climate Corps Financial Analysis Tool.

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

[5] Estimate generated using Environmental Defense Fund Climate Corps Financial Analysis Tool.

[6] Estimate generated using Environmental Defense Fund Climate Corps Financial Analysis Tool.

CHAPTER 8

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

Goals

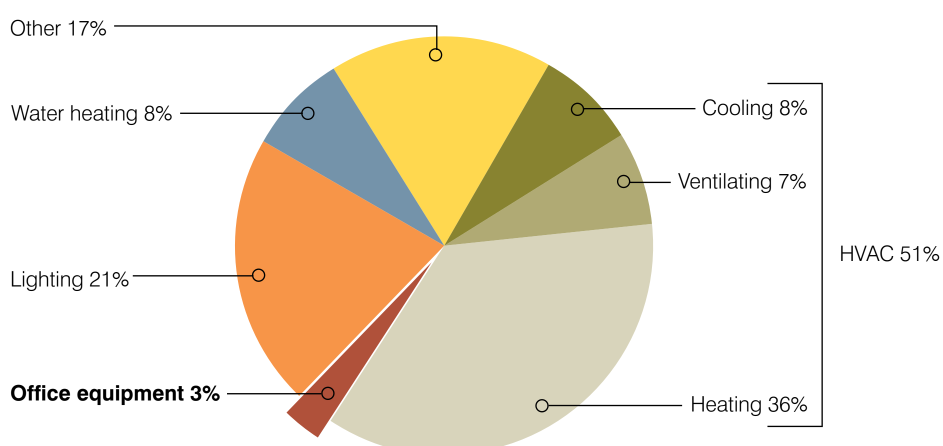
- Develop an inventory of current office equipment and document usage patterns
- Understand life-cycle of equipment from purchase/lease decision to initial configuration and ongoing maintenance
- Develop estimates of energy usage from office equipment and calculate estimated savings potential of efficient-use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

Overview

In a typical commercial building in the U.S., 3% of energy is used for office equipment like computers, printers and copiers. In an office building, however, office equipment accounts for a larger portion of energy consumption—9% on average.[1] Waste heat from inefficient office machines can also increase a building's cooling load, which adds to the energy requirements of the **HVAC** system. Potential to increase efficiency exists across office equipment, from PCs to copiers and vending machines (see Table 8.1).

FIGURE 8.1

Estimated energy consumption of U.S. commercial buildings



Date 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.

This chapter presents a combination of strategies for reducing the power draw of typical office equipment. These strategies include increasing the efficient use of existing 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

TABLE 8.1

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/bulk_purchasing/bpsavings_calc/Calc_office_eq.xls.

[f] Derived from Energy Star Vending Machine Savings Calculator. Accessible at http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Vend_MachBulk.xls.

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.[2] Activating these power management settings is perhaps the easiest step that can be taken 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. For PCs and monitors, installing centralized power management software that can 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 of more efficient equipment. The 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 manager.

- How many PCs, laptops, copiers, printers and vending machines are in use at the host company? 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?
- Who is in charge of configuring and maintaining office computers? Has the company explored installing auxiliary computer power management software (e.g., EPA's EZ Save, 1E Nightwatch, Verdiem SURVEYOR, DesktopStandard's PolicyMaker)?
- 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

Efficient use of office technologies lowers the energy usage of existing equipment, typically 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, Desktop Standard's Policy Maker on PC networks). Centralized power management software sets power settings of all networked PCs and monitors to minimize energy waste. The software increases efficiency by allowing central controls to override individual user power settings. If company 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.).

Tactics for reducing energy use

1. Efficient use of office technologies

- Install supplemental computer power management software
- Install energy savings devices on vending machines or ask vendor to provide more efficient vending machines

2. Equipment replacement/purchasing

- Purchase Energy Star® certified PCs and servers with 80 Plus® certified power supplies (converter cords) for PCs and servers
- Purchase Energy Star® certified printers, copiers and monitors
- Purchase high-speed, duplex-capable laser printers and make duplex printing the default print setting

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

A number of power management software vendors will perform a free audit of network PC energy use and conduct an analysis of energy savings and payback time.[3] Consult vendors for more information.

TABLE 8.2

Costs and rebates

Technology	License (annual per computer)	Installation	Total cost	PG&E rebate
PC power management software	$0-$40	$0	$0-$40	$15[a]

[a] For details, consult PG&E's Business Rebates & Incentives Information at http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

Payback period: Typical payback for purchase and installation of supplemental power management software on PCs is six months to one year.[4]

- **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. These devices reduce the energy consumption of vending machines by about 50% on average, while maintaining proper temperature and necessary illumination.[5]

TABLE 8.3

Costs and rebates

Technology	Equipment cost	Installation	Total cost	PG&E rebate
Energy saving device for vending machines	~$165	$30	$195	$100[a]

[a] For details, consult PG&E's Business Rebates & Incentives Information at http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

Payback period: At Tufts University, where Vending Misers® were installed on all campus vending machines, the payback period for the units was between one and two years.[6]

2. Equipment replacement/purchasing

● **Purchase Energy Star® certified PCs and servers with 80 Plus® certified power supplies (converter cords) for PCs and servers.** The 80 Plus® performance standard requires that power supplies be at least 80% efficient at 20%, 50% and 100% of rated load. PCs with 80 Plus® certified power supplies are estimated to be ~33% more efficient than those without.[7] The Energy Star® Version 4.0 specifications for desktop computers, which went into effect in July 2007, require that PC power supplies meet 80 Plus® performance standards.

A list of PC models with 80 Plus® certified power supplies can be accessed at http://www.plugloadsolutions.com/80PlusPowerSupplies.aspx.

Costs and rebates: There is little to no incremental cost for Energy Star® certified PCs and servers. Savings calculators for Energy Star® office equipment can be accessed at http://www.energystar.gov/index.cfm?c=bulk_purchasing.bus_purchasing.

● **Purchase Energy Star® certified printers, copiers and monitors.** Energy Star® printers, copiers and monitors 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.[8]

Costs and rebates: There is little to no incremental cost for Energy Star® certified printers, copiers and monitors. Savings calculators for Energy Star® office equipment can be accessed at 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.[9]

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.

Duplex printing reduces the cost of paper and paper disposal by up to half. A reduction in paper use will also lower the company's upstream greenhouse gas footprint. For more information, see: www.edf.org/papercalculator/.

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.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html.

2 Sanchez, M. et al., Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, "How Plugged in are Commercial Buildings?" February 2007. Accessible at http://enduse.lbl.gov/info/LBNL-62397.pdf.

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

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

5 Tufts Climate Initiative, "Vending Misers: Facts and Issues." Accessible at http://sustainability.tufts.edu/downloads/VendingMiserHandout-updated020310.pdf.

[6] Tufts Climate Initiative, "Vending Misers: Facts and Issues." Accessible at http://sustainability.tufts.edu/downloads/VendingMiserHandout-updated020310.pdf.

[7] Ecos Plug Load Solutions, "80 PLUS Benefits Fact Sheet." Accessible at http://www.plugloadsolutions.com/docs/collatrl/print/80plus_benefits.pdf.

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

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

CHAPTER 9

HVAC (heating, ventilating and air-conditioning)

Goals

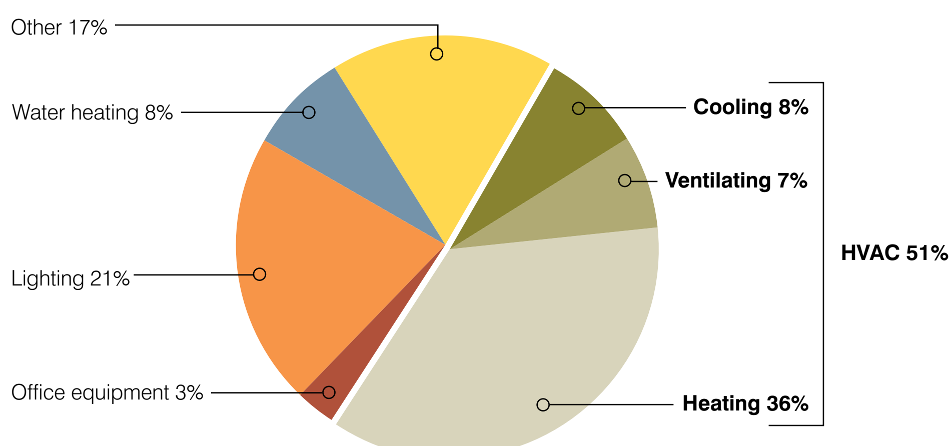
- Survey current **HVAC** system, operating procedures and maintenance schedule
- Analyze results of energy audit for HVAC system (performed by an HVAC professional)
- Perform due diligence and conduct financial analyses on recommendations of energy auditors

Overview

Building heating, ventilating 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% ventilating, 8% cooling).[1] 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

FIGURE 9.1

Estimated energy consumption of U.S. commercial buildings



Data 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.

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 a company'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. Alternative "passive" cooling technologies are more rare, but are typically much more energy efficient. These technologies include: natural ventilation, evaporative cooling systems and radiative 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 reducing 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; 3) calibrate and tune system controls; and 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 company own or lease its building space?
- Does the host company pay the utility bill or is it included in the rent?
- Is the landlord (if not the host company) interested in pursing efficiency reductions for tax credits or other financial incentives?
- What type of HVAC system is in place? For example, is the system unitary or centralized, and who is in charge of operating the system? (For a description of HVAC system types, see Appendix D: HVAC background information.)
- When was the existing HVAC system installed?
- How do building managers control the HVAC system? Which controls are manual? Which controls are automated?
- What data on building temperature and energy consumption do 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 **commissioning**?

● 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 Cushman and Wakefield at Adobe Towers in San Jose 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

Tactics for reducing energy use

1. Maintenance and commissioning
- Verify regular maintenance schedule
- Determine frequency of HVAC commissioning

2. Efficiency tune-ups
- Complete envelope upgrades
- Tune/install thermostat controls

3. Equipment replacement/purchasing
- Install outside air economizers
- Correctly size and retrofit HVAC fan systems
- Measure existing heating/cooling loads and correctly size HVAC heating and chilling components

chilled-water pump controls cost $1,200 and netted $43,000 in annual energy savings (see Case Study 1, p.83).

Additional information

For more information on maintenance and commissioning, see:

- U.S. EPA, "Energy Star® Building Upgrade Manual—Recommissioning," December 2004. Accessible at http://www.energystar.gov/ia/business/BUM.pdf.
- Ellicott and Rothstein, National Conference on Building Commissioning, "Procuring Commissioning Services—Who, When, and How," 2005. Accessible at http://www.peci.org/ncbc/proceedings/2005/11_Ellicott_NCBC2005.pdf.

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 seven 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** time of less than two years.[4]

- **Tune/install thermostat controls.** An HVAC engineer should compare the host company building's heating/cooling patterns with its occupancy schedule to determine whether controls should be adjusted to reflect occupancy. Additional savings can be accomplished through the installation of combined automated control systems for HVAC and lighting (see Chapter 11: Energy management systems). HVAC and lighting can then be continuously monitored and adjusted based on occupancy and environment.[5] An HVAC engineer should evaluate the feasibility of preheating or precooling 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.[6]

Additional information

For more information on building envelope upgrades, see:

- U.S. EPA, "Energy Star® Building Upgrade Manual—Supplemental Load Reduction," December 2004, pp. 73–95. Accessible at http://www.energystar.gov/ia/business/BUM.pdf.

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:

- Improved year-round occupant comfort and convenience
- Higher energy efficiency with lower operational costs[7]

● **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.[8] Air-side economizers can also be used to precool 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 heating/chilling components. Fans are often oversized—a recent EPA study found that 60% of U.S. office buildings had fan systems that were at least 10% oversized, with an average oversizing of 60%. In general, correctly sizing a fan system results in a 50% decrease in energy drawn by the fan system.[9]

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%.[10]

A VAV system can be retrofit to control fan speed using a variable-speed drive (VSD). VSD devices vary fan speed according to need, resulting in energy savings from reduced fan speeds. A recent EPA study found that installing a VSD in an existing VAV system achieved a mean savings of 52% in fan system energy requirements.[11] (For more information on VSDs, see Energy Star® Building Upgrade Manual, pp.107–108.)

Once energy requirements of fans have been reduced, an engineer can determine whether downsizing fan motors to more efficient sizes is appropriate.[12]

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 (See Appendix G).

Financial case study: A variable frequency drive 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.[13]

● **Measure existing heating/cooling loads and correctly size HVAC heating and chilling components.** An HVAC engineer should remeasure 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 "multizone 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.[14,15]

Additional information

For more information on heating and cooling systems, see:

• U.S. EPA, "Energy Star® Building Upgrade Manual—Heating and Cooling System Upgrades," December 2004, pp. 116–142. Accessible at http://www.energystar.gov/ia/business/BUM.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. Accessible at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html.

2 U.S. EPA, "Energy Star® Building Upgrade Manual—Recommisioning," December 2004, p. 36. Accessible at http://www.energystar.gov/ia/business/BUM.pdf.

3 U.S. EPA, "Energy Star® Building Upgrade Manual—Load Reduction Strategies: Window Films," December 2004, pp. 85-87. Accessible at http://www.energystar.gov/ia/business/BUM.pdf.

4 Clear Innovations, Case Study—One Market. Accessible at http://clearinnovations.net/case_history.html.

5 Flex Your Power, "Best Practice Guide—Commercial Office Buildings, Central HVAC System." Accessible at http://www.fypower.org/bpg/module.html?b=food_and_bev&m=Central_HVAC_System.

6 Flex Your Power, "Best Practice Guide—Commercial Office Buildings, Heating Subsystem." Accessible at http://www.fypower.org/bpg/module.html?b=offices&m=Central_HVAC_System&s=Heating_Subsystem.

7 "ERPI Office Complexes Guidebook, Innovative Electric Solutions," Chapter 6: Heating, Ventilating, and Air-Conditioning (HVAC), December 1997, TR-109450, pp. 208, 191–215.

8 U.S. EPA, "Energy Star® Building Upgrade Manual—Fan System Upgrades," December 2004, p. 109. Accessible at http://www.energystar.gov/ia/business/BUM.pdf.

9 U.S. EPA, "Energy Star® Building Upgrade Manual—Fan System Upgrades," December 2004, p. 98. Accessible at http://www.energystar.gov/ia/business/BUM.pdf.

10 U.S. EPA, "Energy Star® Building Upgrade Manual—Fan System Upgrades," December 2004, p. 102. Accessible at http://www.energystar.gov/ia/business/BUM.pdf.

11 U.S. EPA, "Energy Star® Building Upgrade Manual—Fan System Upgrades," December 2004, p. 107. Accessible at http://www.energystar.gov/ia/business/BUM.pdf.

12 U.S. EPA, "Energy Star® Building Upgrade Manual—Fan System Upgrades," December 2004, p. 106. Accessible at http://www.energystar.gov/ia/business/BUM.pdf.

13 Flex Your Power, "Case Study—Adobe Systems Incorporated and Cushman & Wakefield." Accessible at http://www.fypower.com/bpg/case_study.html?b=offices&c=Adobe_Systems_Incorporated_and_Cushman_%26_Wakefield.

14 Flex Your Power, "Case Study—Glenborough Realty Trust." Accessible at http://www.fypower.org/bpg/case_study.html?b=offices&c=Glenborough_Realty_Trust.

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

CHAPTER 10

Water heating

Goals

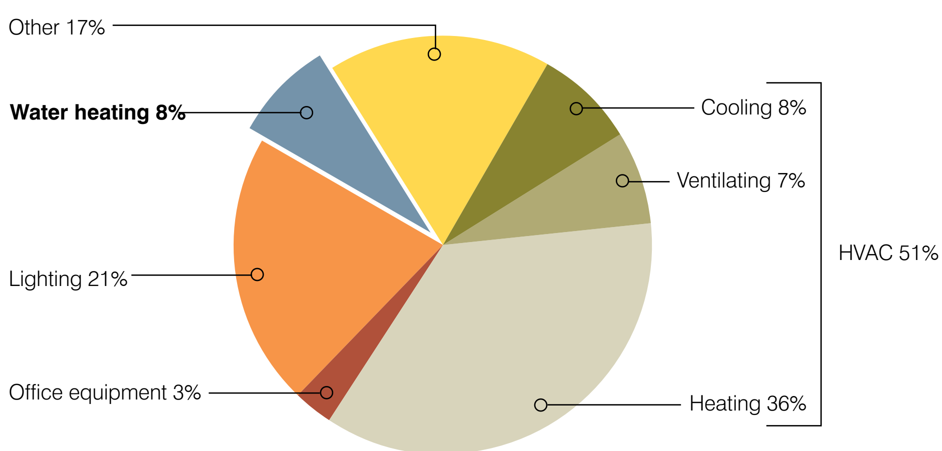
- With the aid of an energy efficiency engineer, determine whether the host company has potential to benefit from reduced energy costs through increases in water heating efficiency
- With the aid of an energy efficiency engineer, determine whether the water heating system is aligned correctly with hot 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 companies 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, inefficient and unnecessary use of water heaters releases waste heat that must be countered by increased cooling, resulting in additional wasted energy.

FIGURE 10.1

Estimated energy consumption of U.S. commercial buildings



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 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 2% 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 companies 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 company?)
- **Costs:** Who is financially responsible for the water heating and how is it billed? How much does the host company 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

Tactics for reducing energy use

1. Efficient use adjustments and upgrades

- Set water heater temperature appropriately
- Install tank insulation
- Install pipe insulation
- For electric heaters: heat water at night using off-peak electricity
- Install low-flow fixtures and automatic sensor controls

2. Equipment upgrades

- Correctly size the water heater for company needs
- Purchase a water heater with higher thermal efficiency

18% of water heating energy and a 10°F thermostat reduction can save 6% of water heating energy.[2] Table 10.1 gives an estimate of temperatures required for a range of applications.

TABLE 10.1
Hot water temperatures required for given activities

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

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

● **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.**

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 office 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 per 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.

Additional information

For more information on low-flow fixtures and automatic sensor controls, see:

- James Piper, Maintenance Solutions, "Water Use: Slowing the Flow," 2003. Accessible at http://www.facilitiesnet.com/ms/article.asp?id=1969&keywords.

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 company needs.** The host company 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%.[9] Electric water heaters typically have a thermal efficiency of 98%.[10] 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).[11] 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 company. 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.[12]

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.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html.

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

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

4 Mike Opitz, U.S. Green Building Council, "Efficient Plumbing Fixtures—Saving Water at a Profit." Accessible at http://www.fmlink.com/article.cgi?type=Sustainability&title=Efficient%20Plumbing%20Fixtures%20%26%23151%3B%20Saving%20Water%20at%20a%20Profit&pub=USGBC&id=40639&mode=source.

5 Greener Buildings, "Water Use Backgrounder." Accessible at http://www.greenbiz.com/business/research/report/2004/05/11/water-use-backgrounder.

6 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). *1995 ASHRAE Handbook: HVAC Applications*.

7 PG&E, Business Rebates & Incentives Information. Accessible at http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

8 Flex Your Power, "Water Heaters." Accessible at http://www.fypower.org/com/tools/products_results.html?id=100208.

9 Flex Your Power, "Water Heaters." Accessible at http://www.fypower.org/com/tools/products_results.html?id=100208.

10 Flex Your Power, "Water Heaters." Accessible at http://www.fypower.org/com/tools/products_results.html?id=100208.

11 U.S. DOE Office of Electricity Delivery & Energy Reliability, "Overview of the Electric Grid." Accessible at http://nomoretowers.org/Documents/GridWorks%20Overview%20of%20the%20Electric%20Grid.htm.

12 PG&E, Business Rebates and Incentives Information. Accessible at http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/.

CHAPTER 11

Energy management systems (EMS)

Goal

- Determine whether host company could benefit from an energy management system (EMS) installation or upgrade

Overview

An energy management system (EMS) allows for centralized monitoring and control of energy use 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., **photosensor**-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 can be configured to work with most existing sensors and controls and with any new monitoring points and control points that are added.

In recent years, EMS technologies have become more affordable and more widely used. According to the California Energy Commission, 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) and 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.

A BMS or BAS typically includes 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)

Most EMS have the capability to record and track the real-time energy usage of a building or floor, and to store that information for later analysis. Increasingly though, **energy information systems** (EIS) are being used to supplement the energy monitoring and tracking of EMS with functions including weather information, pricing structures and more sophisticated real-time energy usage data. An EIS can enable a company to further reduce energy costs by integrating factors such as weather and energy prices into energy management decision making. An EIS also enables companies 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 company's facilities manager, and consideration should be given to whether a building can benefit from an EMS installation or upgrade.

Questions for the host company's facilities manager

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

Questions for an EMS installation engineer

- Is the host company's building 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 company's building currently employ? Can an 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, 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 company 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 company's operations staff. Clearly, a company should not invest in a system with features it is unlikely to fully utilize. The best EMS for a given company 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 company 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 company.

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 11.1 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, PG&E 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 moved into a 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 (**sub-metering**) and to 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]

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

TABLE 11.1

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

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

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. Accessible at http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF.

- California Energy Commission, "Enhanced Automation: Business Case Guidebook." Accessible at 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. Accessible at http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF.

Notes

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

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

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

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

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

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

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

CHAPTER 12

Data centers and IT equipment

Goals

- Investigate energy used in company'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

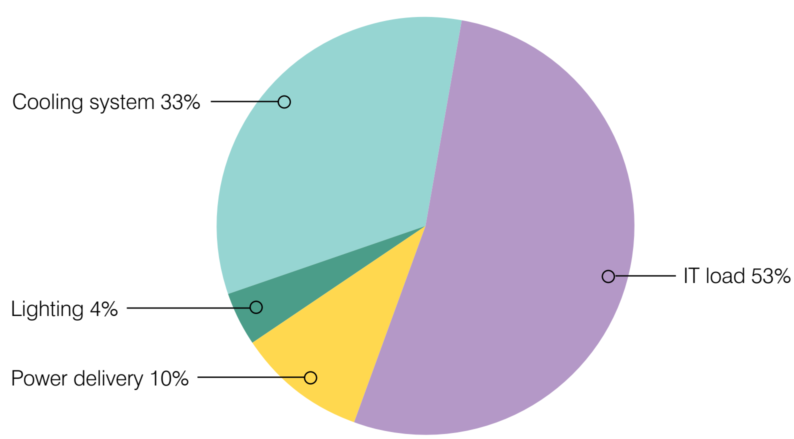
For many companies, data centers are major contributors to total operating costs and environmental impact. Data centers typically have been designed and operated with little consideration for energy efficiency. As a result, there are many efficiency opportunities with exceptionally strong business cases, 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.

FIGURE 12.1

Estimated energy consumption of an average data center



Data source: Rocky Mountain Institute estimate.

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 maximize 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 high quality power to servers and keep equipment cool.

Some large companies own their own data centers, while others outsource their IT functions or lease data center space managed by a hosting company. Data centers that lease space are known as co-location centers, or "co-los." It is also common for companies to set aside space in their office buildings for servers, commonly known as server closets.

Data centers are major energy users

Servers are major consumers of electricity. An individual server uses about 300 W of power, equivalent to three bright (100 W) incandescent light bulbs. Like an incandescent bulb, servers convert much of their energy to heat. However, since servers run constantly throughout the year, their energy use and heat production are much higher than any light bulb.

In many data centers, cooling systems and other infrastructure—power reliability equipment and lighting—use as much energy as the servers themselves. As a result, a single server with support systems has an annual footprint of more than five tons of carbon dioxide, the equivalent of a typical minivan driven 12,000 miles per year.[1] Large data centers commonly house 10,000 or more servers. For many non-manufacturing companies, data centers are major contributors to the corporate environmental footprint.

Data centers have become significant power users in the United States. In 2006, the EPA estimated that 1.6% of electricity was consumed by data centers, a number projected to double by 2011.

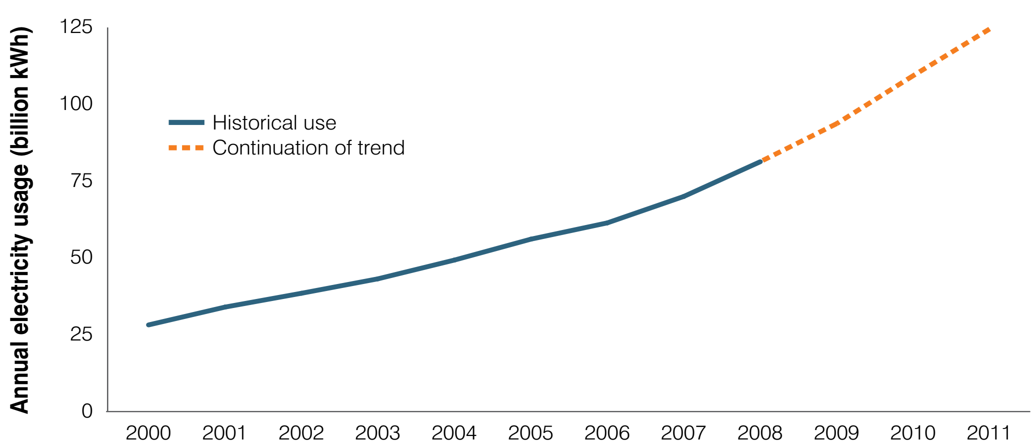
A strong business case exists for making data centers more efficient

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.[2]

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),

FIGURE 12.2

Growth in energy use by data centers



Data source: U.S. EPA. "Report to Congress on Server and Data Center Energy Efficiency," August 2007. Accessible at http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency_study.

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:

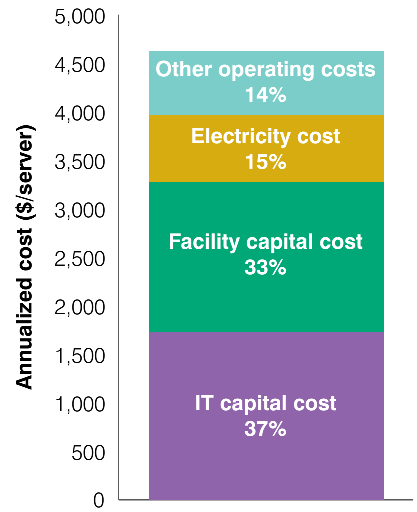
- Saving energy reduces electricity costs required to power and cool servers;
- Energy efficiency increases the number of servers that can be supported by existing data center infrastructure, delaying or eliminating demand for expensive new data centers;
- In new data centers, designing more efficient systems can substantially reduce total capital outlays.

IT hardware and software efficiency measures may reduce server energy use by 90%. When coupled with the 40% efficiency potential of cooling system retrofits, an optimized data center system may reduce energy demand per computing operation by 92%.[3]

Of course, costs and savings from efficiency measures vary among data centers. The savings and cost numbers in the rest of this chapter are *rough estimates*; they will need to be verified in order to be applied to specific data centers.

FIGURE 12.3

Cost of ownership for server in a data center



Data source: Koomey, Jonathan, Uptime Institute, "A Simple Model for Determining True Total Cost of Ownership for Data Centers," October 2007. Accessible at http://www.uptimeinstitute.org/wp_pdf/(TUI3011C)SimpleModelDetermingTrueTCO.pdf.

Additional information

For more information on data center energy use, see:

- U.S. EPA, "Report to Congress on Server and Data Center Energy Efficiency," August 2, 2007. Accessible at http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency_study.
- McKinsey & Company, "Revolutionizing Data Center Energy Efficiency," July 2008. Accessible at http://www.mckinsey.com/clientservice/bto/pointofview/pdf/Revolutionizing_Data_Center_Efficiency.pdf.
- Uptime Institute (http://www.uptimeinstitute.org).
- Green Grid (http://www.thegreengrid.org).

Information gathering guide

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.

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

- Where are servers located? (In server closets in offices; in company-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; 20–30% is relatively good, but may still offer opportunities for improvement.

- What is the power density (W of IT equipment per square foot (SF)) of data center space?
  - Less than 100 W/SF indicates server densities are low. More servers could likely be added through retrofit programs.
- What is the data center **power utilization effectiveness** (PUE, see description below)?
  - 1.5 is a reasonable target for retrofit efforts; industry average PUE is about 2.0.
- Who (which department) pays for data center energy and operating costs?
- 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.

Tactics for reducing energy use

1. Prerequisite: Monitoring and benchmarking

- Calculate and monitor power utilization effectiveness (PUE)
- Track server utilization
- Install sensors to monitor temperature and humidity
- Use kW/ton metric to assess cooling system performance

2. Energy efficient software

- Design and purchase new software that minimizes energy use
- Implement power management sotware

3. Improved server utilization

- Unplug and remove servers that aren't being used at all
- Virtualize multiple servers onto single machines
- Consider advanced resource allocation through applications rationalization and cloud computing

4. Efficient server hardware design

- Purchase best-in-efficiency-class (BIEC) servers
- When custom-building new servers, eliminate unnecessary components and use efficient power supplies, fans and hardware
- Mandate efficient power supplies
- Use power management equipment to shut down servers

5. Cooling system optimization

- Block holes in raised flooring
- Bundle underfloor cables
- Relax temperature and humidity constraints
- Enclose "hot" or "cold" aisles and block holes in racks with blanking panels
- Commission a facility audit

6. Other loads: Power supply and lighting systems

- Optimize power supply and conversion systems to maximize efficiency
- Reduce lighting energy use with automated controls and more efficient fixtures

• **Calculate and monitor power utilization effectiveness (PUE).** 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. 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.

• **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.

• **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.

Additional information

For more information on data center energy monitoring, see:

• Green Grid, "Data Center Power Efficiency Metrics: PUE and DCiE," October 2007. Accessible at http://www.thegreengrid.org/en/Global/Content/white-papers/The-Green-Grid-Data-Center-Power-Efficiency-Metrics-PUE-and-DCiE.

• Steve Greenberg et al., "Best Practices for Data Centers: Lessons Learned from Benchmarking 22 Data Centers," 2006. Accessible at http://eetd.lbl.gov/Emills/PUBS/PDF/ACEEE-datacenters.pdf.

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 companies.

• **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.

Alternative performance metrics

PUE is the most widely used metric to compare data center efficiency to a baseline. However, two other metrics are increasingly being used:

- **DCiE (Data center infrastructure efficiency):** The inverse of PUE, DCiE is the ratio of server energy use to total facility energy use. It represents the fraction of energy consumption that is actually being used to power servers. An average value is 50%, but the best data centers may operate at nearly 90% efficiency.
- **CADE (Corporate average data efficiency):** CADE is a more advanced metric that considers the energy use by the server equipment as well as the facility efficiency. It is the product of facility energy efficiency, facility utilization, IT utilization and IT energy efficiency. Since IT efficiency is difficult to quantify, the metric is still being developed. Nonetheless, it is helpful because it considers all of the relevant factors in data center efficiency.

Additional information

For more information on software efficiency, see:

- Intel, "Creating Energy Efficient Software," October 2008. Accessible at http://software.intel.com/en-us/articles/creating-energy-efficient-software-part-1/.

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, 10%) 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.** New technologies have been developed in the last five years that allow multiple operating system copies to run simultaneously on a single server. This process is known as **virtualization**. Virtualization offers large energy savings potential, because it consolidates several servers onto a single, more utilized server. Virtualization presents challenges, because entire operating systems must be transferred from one server to another. However, the potential benefits are so great that many companies are now rushing to implement 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

TABLE 12.1

Server utilization efficiency costs and benefits

	IT energy savings (%)	Cost per server ($)	Payback (years)
Turn off unused servers	10%	$1000	1–2
Virtualize	75%	$1500	2
Advanced allocation	Varies	Varies	—

Data source: Rocky Mountain Institute analysis, 2008.

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. In addition, applications rationalization measures may be implemented on a single server to allow multiple copies of an application to run simultaneously. In this way, one or more servers may be consolidated onto a single machine.

Additional information

For more information on server utilization, see:

- CiRBA, "How to Choose the Right Virtualization Technology for Your Environment," November 2007. Accessible at http://www.cirba.com/forms/12f_how-to-choose-the-right-virtua.htm.
- Richard Martin and J. Nicholas Hoover, Information Week, "Guide to Cloud Computing," June 21, 2008. Accessible at http://www.informationweek.com/news/services/hosted_apps/showArticle.jhtml?articleID=208700713.

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, when the "lifecycle cost of ownership" is considered, Information Week, the energy savings over time more than pay back the extra cost. Since most servers are 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 companies' 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.

- **When custom-building new servers, eliminate unnecessary components and use efficient power supplies, fans and hardware.** Some companies custom design the servers used in their data centers. This opens the door to a variety of efficiency measures that save capital costs and energy. The first step is to eliminate unneeded components that come standard in many servers. Items such as disk drives and graphics cards may be unnecessary depending on the server's function. Next, efficiency of specific components should be considered as part of the purchasing decision. Power supplies, fans, chips and storage drives offer potential efficiency gains. To realize these opportunities, analyze how decisions are made for server components and ensure that energy use is a metric.

- **Mandate efficient power supplies.** In recent years, efforts to raise power supply efficiencies have gained momentum. Server power supplies transform electricity to the low voltages demanded by electronic components. Historically, many power supplies have operated at as low as 60% efficiency—up to 40% of energy consumed by the server is lost as heat immediately. 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 of 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.

TABLE 12.2

Server hardware efficiency costs and benefits

	IT energy savings(%)	Cost per server ($)	Payback (years)
Purchase BIEC	40%	$0–100	<1
Optimize custom builds	Varies	Varies	—
Power supplies	20%	$0–100	<1
Advanced allocation	Varies	Varies	—

Data source: Rocky Mountain Institute analysis, 2008.

Additional information

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.
- Ecos 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.

5. Cooling system optimization

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

- **Block 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 allow 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 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. Companies including KoldLok also market "brushes" and other floor cover materials as inexpensive options.

Building an ultra-efficient new data center

This chapter deals primarily with existing data centers. However, when a new data center is built, an even wider suite of efficiency measures should be considered. In addition to the IT hardware and software measures discussed in this section, innovative strategies for cooling and power supply may be adopted. For example:

- **Air side economizer.** Design the data center to directly use outside air for cooling when the temperature is low enough. This is similar to opening the window of a house to cool a room rather than using an air conditioner.

- **Remove server fans.** If a centralized fan system is used to pressurize the cold aisles, it may be possible to remove the inefficient fans in each server.

- **Direct liquid cooling.** Pipe coolant directly to the IT hardware; liquid is a much more effective remover of heat than air.

- **Dynamic UPS.** Instead of a large battery bank to provide uninterruptible power, use a rotating flywheel system.

These strategies can reduce PUE to below 1.2, enabling major operating cost savings at little or no additional capital cost.

- **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.[4] Allowing warmer data center temperatures reduces cooling energy use and allows more servers to be added to the data center. For this measure, implementation is simple—raising temperature setpoints requires only a modification of controls. Getting buy-in from IT systems operators is the primary barrier to adoption.

- **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

TABLE 12.3

Cooling system efficiency costs and benefits

	Cooling energy savings (%)	Cost per server ($)	Payback (years)
Block holes	Up to 5%	$5	1
Bundle cables	2%	$1–5	<1
Temperature constraints	Varies	$0	Varies
Aisle containment	Up to 25%	$40	2
Facility audit	Varies	Varies	Varies

Data source: Rocky Mountain Institute analysis, 2008.

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). Implementing aisle containment measures can disrupt data center operations if racks need to be repositioned, but can enable up to 25% cooling energy savings.[5]

- **Commission a facility audit.** Mechanical engineering auditors evaluate HVAC systems and operations. After spending a day 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.

Additional information

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.
- Matt Stansberry, "The Green Data Center: Energy-Efficient Computing in the 21st Century," Chapter 3: Data Center Infrastructure Efficiency, February 2009. Accessible at http://wp.bitpipe.com/resource/org_979246117_954/Green%20data%20center%20ch3%200109_v9.pdf.
- ASHRAE, "2008 ASHRAE Environmental Guidelines for Datacom Equipment," August 2008. Accessible at http://tc99.ashraetcs.org/documents/ASHRAE_Extended_Environmental_Envelope_Final_Aug_1_2008.pdf.

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, greatly 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 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] Rocky Mountain Institute analysis. Assumptions: 400 W server, 20.5 mpg average vehicle efficiency, 12,000 miles driven per year (U.S. average), 1.64 lb CO_2/kWh (U.S. average).

[2] Rocky Mountain Institute analysis, 2008.

[3] Rocky Mountain Institute analysis, 2008.

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

[5] Rocky Mountain Institute analysis, 2008.

CHAPTER 13

Company-owned and company-leased vehicles

Goal

- Identify opportunities to reduce fuel consumption in corporate vehicles.

Overview

Additional cost-effective energy efficiency gains can be made in company 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.

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 company 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 company self-manage the fleet or does it work with a fleet management company?

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.

Additional information

For more information on vehicle efficiency, see:

- 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 & EPA's Gas Mileage Tips http://fueleconomy.gov/feg/drive.shtml.

CHAPTER 14

Energy efficiency finance

Goals

- Develop a financial analysis method that reflects the company's investment analysis framework

- Develop a plan recommending which energy efficiency investments should be made and how they can be either paid for out of existing department budgets, budgeted for next year or financed through other means

Overview

Each potential energy efficiency project will require a forecast that includes the initial incremental investment, annual savings and costs. Energy cost savings will likely be the main financial driver, but changes in labor and replacement costs of equipment may also be significant.

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

The Financial Analysis Tool calculates **net present value (NPV)**, the sum of forecasted discounted cash flows minus the initial investment, as the primary measure of a project's attractiveness. Using NPV properly positions energy savings opportunities as an investment, not as an expense.

There are several variables included in the Financial Analysis Tool that affect the calculation (discount rate, tax rate, and depreciation).

Discount rate: As a default, the **discount rate** in the Financial Analysis Tool should be set as the host company's internal **hurdle rate**. Discount rates reflect both the time value of money and the risk involved in a specific project. Typically, energy efficiency investments have much lower risk than other investments that companies choose to pursue. From a strictly financial perspective, efficiency investments should therefore be evaluated using correspondingly lower discount rates. However, 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, then it may be worth presenting a sensitivity analysis using multiple discount rates.

Note that the EPA uses a 4% real discount rate in its Energy Star® efficiency investment calculators.[1] In one report, the California Public Utilities Commission uses an 8.15% nominal rate for energy efficiency investments; assuming 2.5% inflation, this implies a real discount rate of 5.5%.[2] $[(1+\text{inflation rate})*(1+r_{real})=(1+r_{nominal})]$

Tax rate: Some companies will want to look at investments on a pre-tax and some on a post-tax basis. Whereas post-tax 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 so tax and depreciation effects can be included at one's discretion. The default marginal tax rate is 35%.

If the financial manager at the host company wants to look at the analysis post-tax, it is important to speak with the finance department to understand 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]

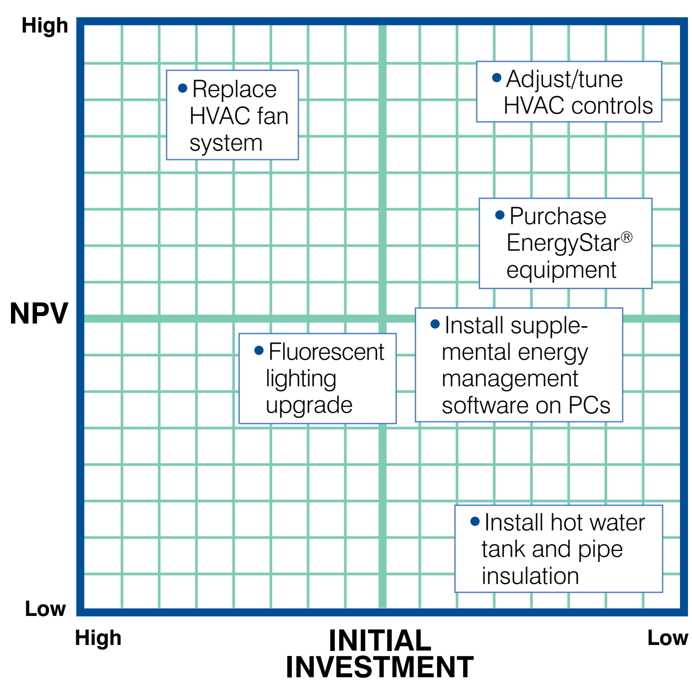
Depreciation: Companies will vary in which assets they depreciate. Based on IRS guidelines, the Financial Analysis Tool assumes five years for computers, copiers and printers, seven years for office **fixtures** and equipment and 39 years for HVAC systems.[4,5] If taxes are not included in the financial analysis, including or excluding depreciation will have no effect on the analysis as there will be no tax shield.

Payback is the time required for accumulated savings to equal the initial investment. This metric is frequently used in energy efficiency investments. It is simple to understand and can be powerful when the payback period is one to three years. In most variants, however, paybacks ignore cash flows after the payback period and time value of money, thus underestimating the value of a longer-term investment. Again, if this metric is used, it should be accompanied by an NPV calculation.

The internal rate of return (IRR) is closely related to NPV and is used by corporations with similar frequency. 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.

FIGURE 14.1

Example prioritization matrix for potential energy efficiency investments



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 size of the upfront investment does have an impact on the decision, one way to present this information may be a matrix with NPV and initial investment on each axis.

Investments with relatively low initial investments and high NPV or energy savings potential should obviously be pursued first.

Financing investments

Once investments are prioritized, the next challenge is to determine how they will be paid for. There are four broad categories of payment structures, including cash, loan, leasing or performance contracts.

Cash: Paying with cash is ideal if the investment is relatively small and the firm has a strong balance sheet. It also allows the firm to depreciate the investment. If the firm does decide to pay in cash, no adjustments need to be made to the base NPV analysis.

Loan: Depending on the cash position of the host company and the size of the required investments, a loan may be required. It may be useful to identify whether there are any below market rates available for specific investments. The value created by a subsidized loan (to be used only if the loan is sizable and the analysis includes taxes) can be calculated using the adjusted present value (APV) method, which estimates the value created by the operations and the financing separately. With this methodology, one can calculate the NPV using the project-specific discount rate and add the value of the subsidized loan.

Table 14.1 sets out an example of how to calculate the value of a $100 subsidized loan offered at a below market interest rate of 9% when the market interest rate is 12% and tax rate is 35%.

TABLE 14.1

Example calculation of value of a subsidized loan

Loan type	Unsubsidized	Subsidized
Loan amount	100	100
× Interest rate	0.12	0.09
Loan payment	12	9
× Marginal tax rate	0.35	0.35
Annual tax shield	4.2	3.15
After tax payment (Loan payment – shield)	7.8	5.85
Value created (subsidized vs. unsubsidized)		**1.95**

Lease: This financing vehicle is not very common in energy efficiency investments. Certain office equipment such as copiers are often leased, but this decision is independent of whether the equipment is Energy Star® certified.

Performance contracts: This method of financing shifts some or all of the risk to an outside vendor and can be applied to purchases and leases. In this structure, a service provider 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 and should consider staff time required to negotiate the contract and manage the project implementation and maintenance.

Information gathering guide

The CFO or controller should be able to provide information on the company's budgeting process and investment criteria.

- How does the host company evaluate internal facilities or fleet investments?
- Can the host company provide an analysis or presentation for a recent, successful investment?
- Does the host company evaluate investments on a pre- or post-tax basis? If post-tax, what tax rate does the company assume?
- What discount rate does the host company typically use? How was this discount rate determined?
- Are the following items depreciated? On what schedule?
  - Lighting equipment
  - Computers and office equipment
  - HVAC systems
- When are budgets determined for each department? Is there flexibility in this process or is it fixed?
- When does the host company choose leases over purchasing assets?
- What types of services does the host company outsource?

Notes

[1] For example, see http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Computer_bulk.xls.

[2] Moss, Steven, et al., "Distributed Energy Resource (DER) Implementation: Testing Effective Load Management at the Feeder Level." California Energy Commission, PIER. 2006, p. 73. Accessible at http://www.sfpower.org/Research/Report.doc.

[3] Internal Revenue Service, U.S. Dept. of Treasury, "Electing the Section 179 Deduction." Accessible at http://www.irs.gov/publications/p946/ch02.html.

[4] Internal Revenue Service, U.S. Dept. of Treasury, "Publication 946: Additional Material," Table B-1. Table of Class Lives and Recovery Periods. Accessible at http://www.irs.gov/publications/p946/ar02.html.

[5] 26 USC 168; Title 26, Subtitle A, Chapter 1, Subchapter B, Part VI, Section 168: Accelerated Cost Recovery System.

CHAPTER 15

Non-financial considerations

Goals

- Understand the written and unwritten "rules of the game" at the host company
- Develop non-financial arguments for energy efficiency investments relevant to the host company

Overview

Each company 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. Unwritten company policies and processes can usually be learned through careful observation during meetings as well as through candid conversations with trusted contacts.

There are a number of powerful arguments for making improvements to office space that have nothing to do with finance. It is frequently noted by people in the field that "no one asks for the payback period of carpet." Non-financial arguments must connect with the host company's goals and values and appeal to the emotions of the decision maker. Some of these arguments may include:

- Higher quality work environment (better lighting, air quality)
- Higher worker productivity and morale
- Reduced absenteeism
- Easier to recruit and retain skilled labor
- Meet regulatory requirements
- Follow industry best practices
- Public relations
- Demonstration of leadership on environmental stewardship

Even with an airtight business case, energy efficiency investments may not take place. In Chapter 5, several barriers to investments were discussed. One needs to address the organizational issues of scarce resources, language barriers, coordination challenges and accountability. In essence, who are the people responsible for the actual work and do they have the motivation and resources to accomplish it?

Information gathering guide

- What are the host company's general corporate goals?
- How is the host company run? Is the company an autocracy, bureaucracy or technocracy?
- What behaviors does the host company value?
- Obtain a copy of the organizational chart—understand who is responsible for what.
- For each type of investment:
  - Who needs to approve it?
  - Who can say no?
  - Who benefits?
  - Who is responsible for implementation?
  - What motivates this person?
- How does each one of these people like to receive information (email, formal meeting, etc.)?
- What is the process for getting new investments approved?
- Talk to other people in the office who were successful in getting things approved. "How did you do X?"
- Are there upcoming meetings where energy efficiency issues can be brought up and discussed?
- Are employees satisfied with current lighting and office temperature maintenance?
- What energy efficiency investments have industry peers made?
- Has anyone at the host company championed energy efficiency initiatives recently? Of those who have demonstrated interest in energy efficiency, who is in a leadership position in the host company?
- How might energy efficiency investments help meet other corporate goals?

APPENDIX A

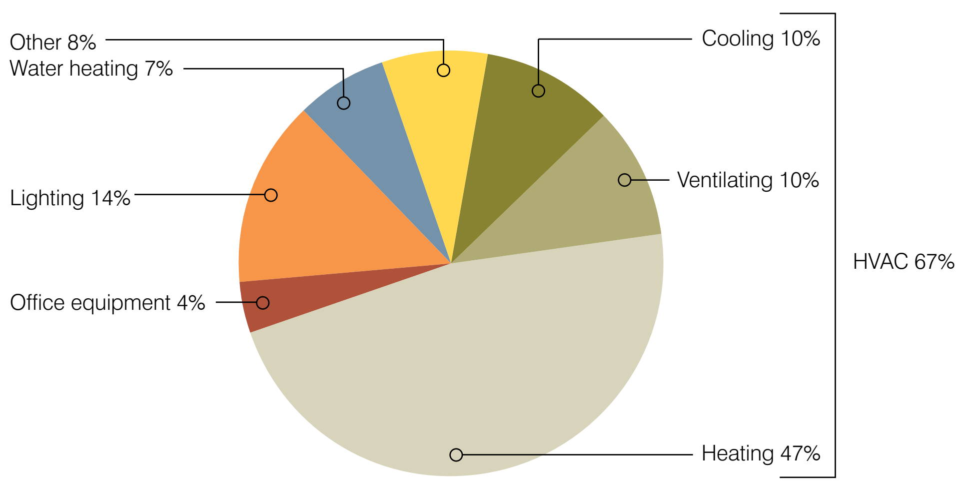
Energy consumption of U.S. commercial buildings by type

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 is sourced from: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Table E1A. Major Fuel Consumption (BTU) by End Use for All Buildings."[1] All accompanying text is sourced from: Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS): Description of CBECS Building Types."[2]

FIGURE A.1

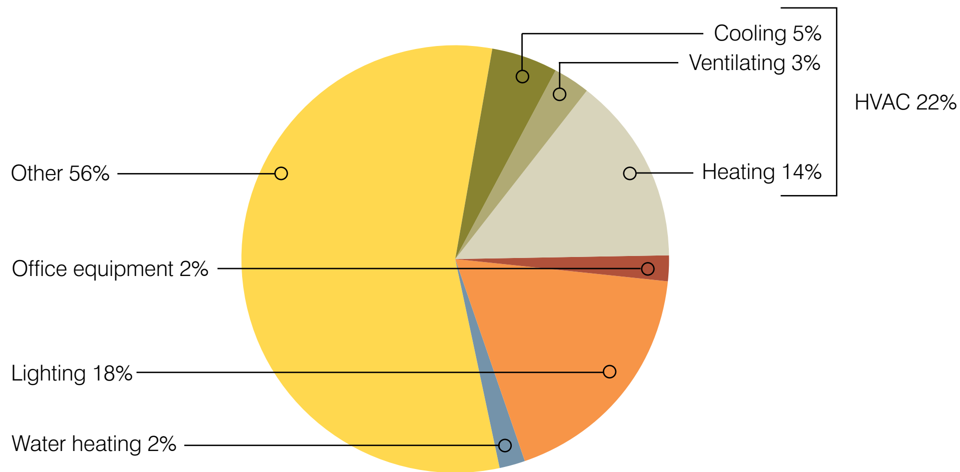
Energy use for education buildings



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

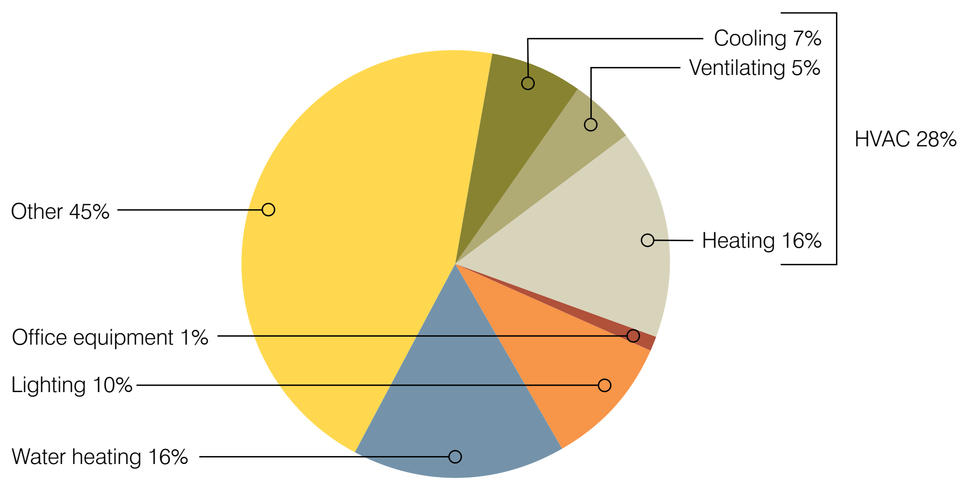
Energy use for food sales buildings



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

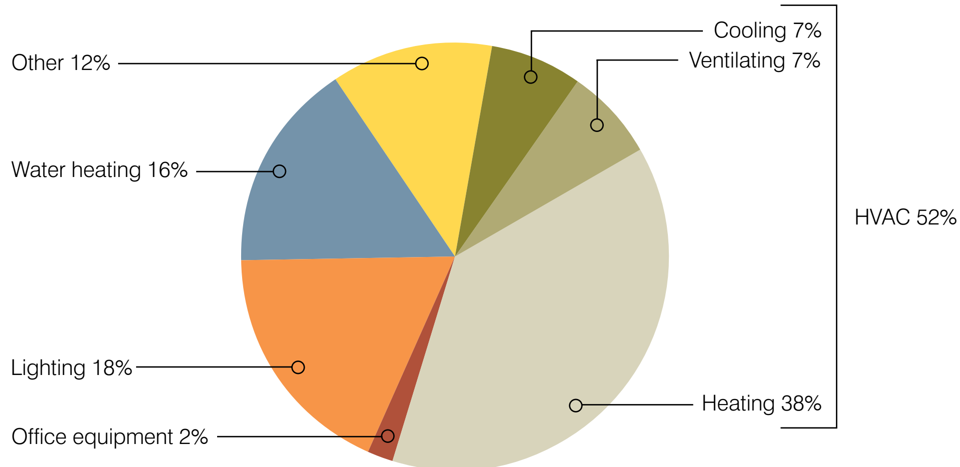
Energy use for food service buildings



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

FIGURE A.4

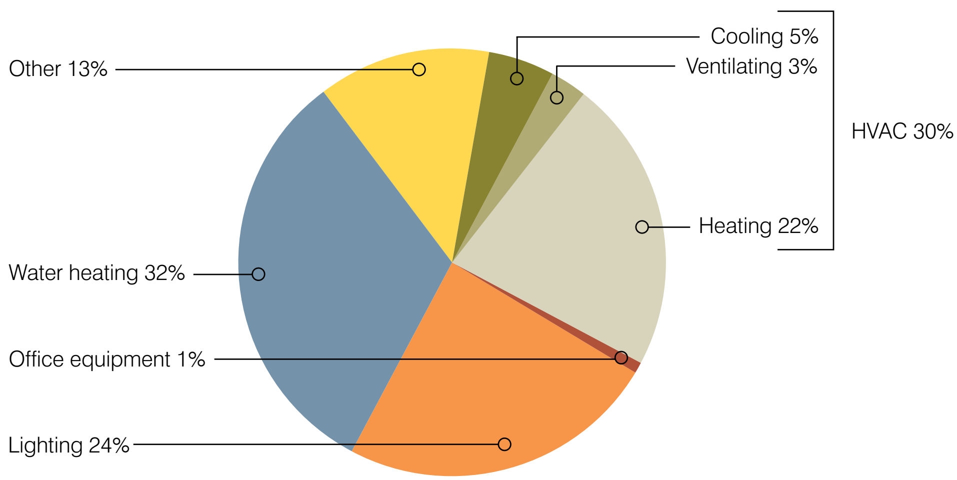
Energy use for healthcare buildings



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

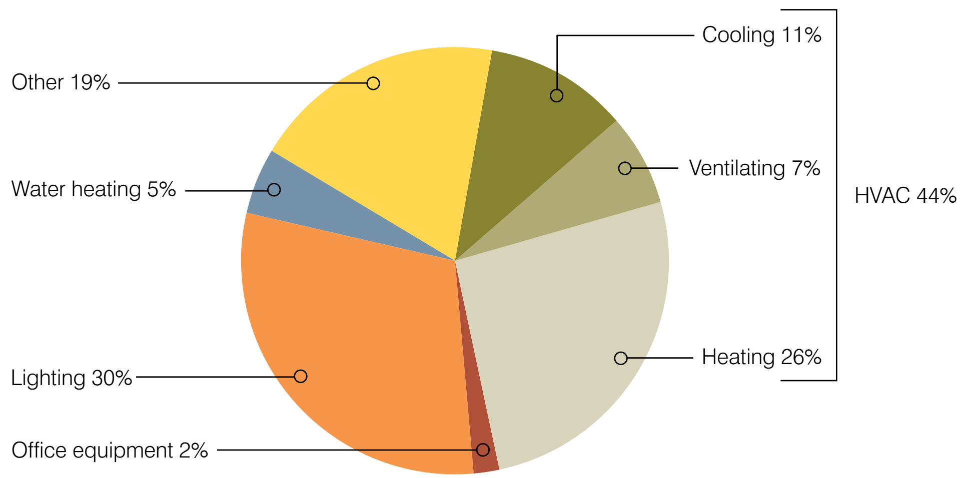
Energy use for lodging buildings



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

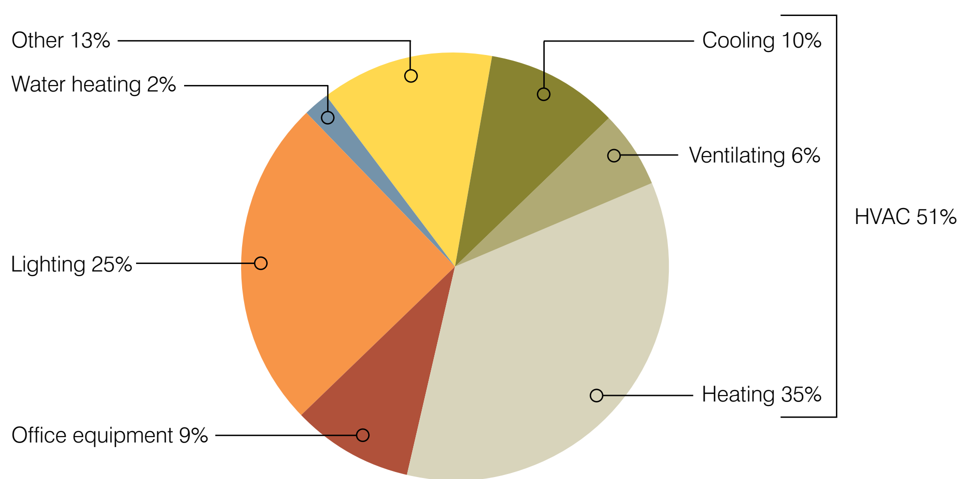
Energy use for retail buildings



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

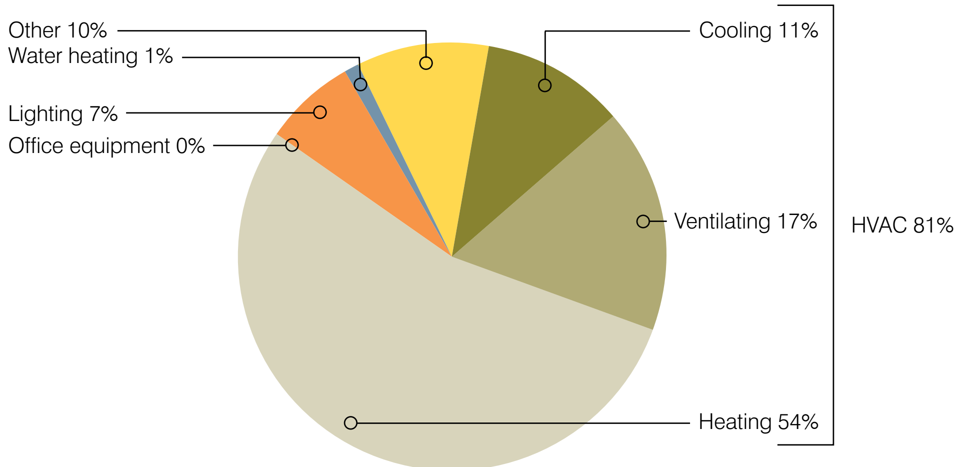
Energy use for office buildings



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

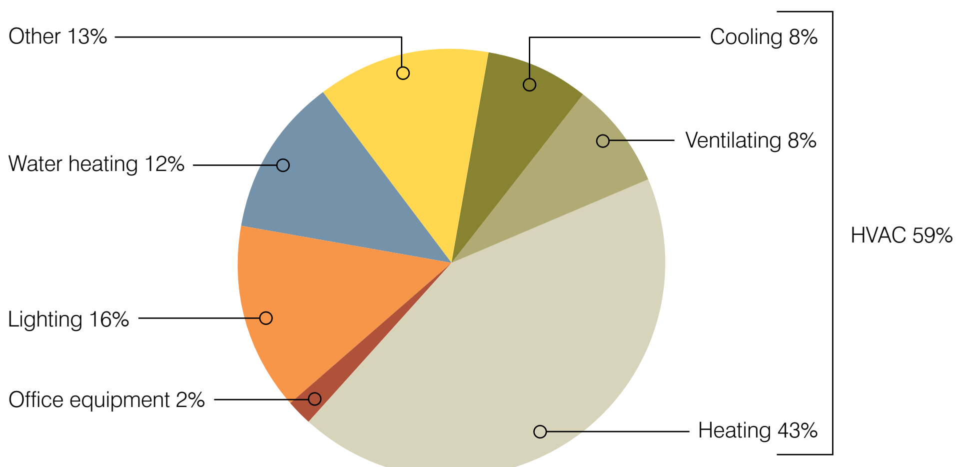
Energy use for public assembly buildings



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

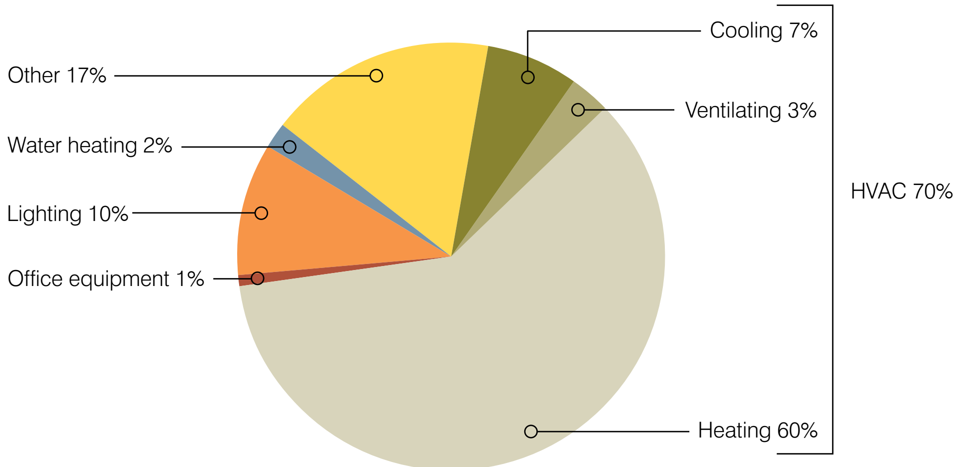
Energy use for public order and safety buildings



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

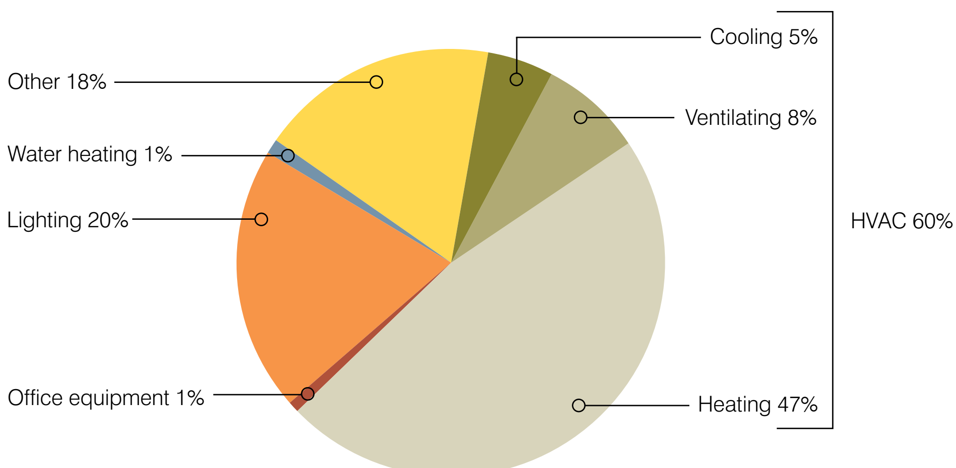
Energy use for religious worship buildings



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

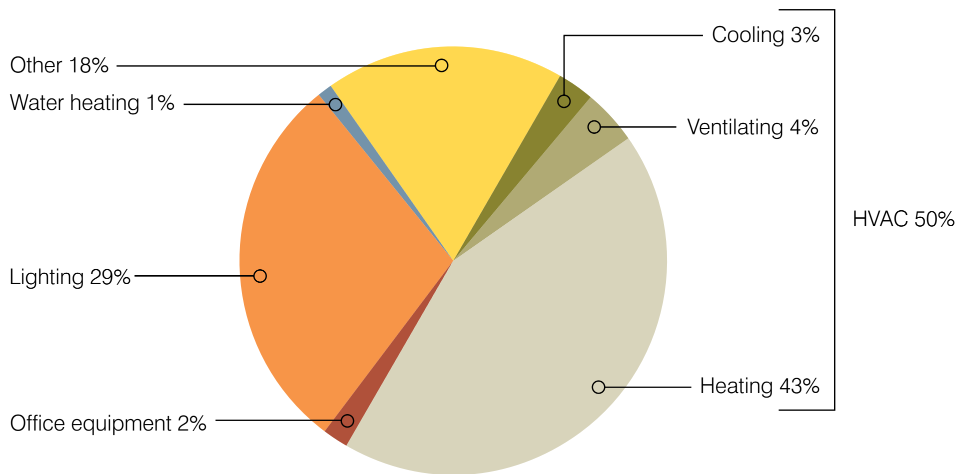
FIGURE A.11

Energy use for service buildings



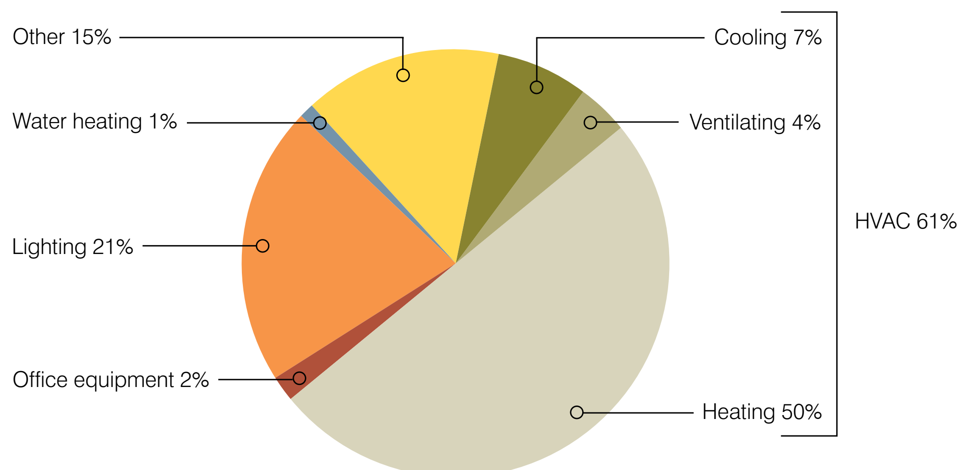
Buildings in which some type of service is provided, other than food service or retail sales of goods. **Includes:** vehicle service or vehicle repair shop, vehicle storage/maintenance (car barn), repair shop, dry cleaner or laundromat, post office or postal center, car wash, gas station, photo processing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

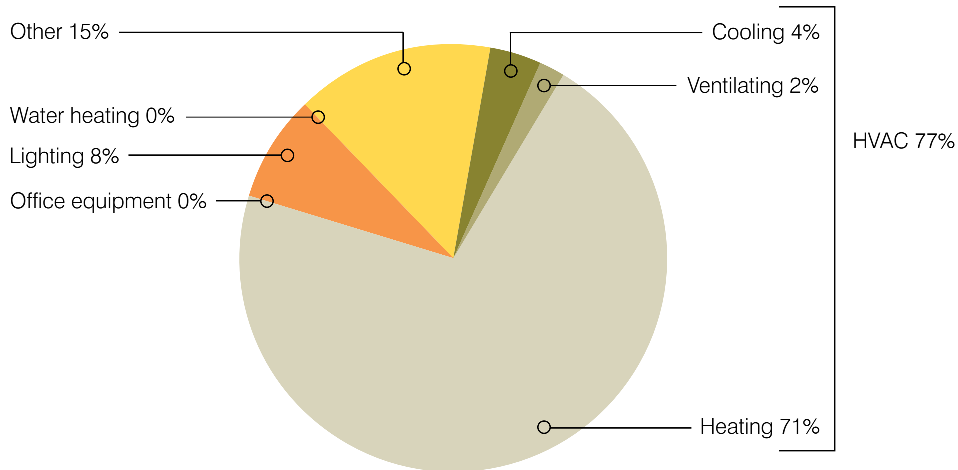
FIGURE A.13
Energy use for other buildings



Buildings that are industrial or agricultural with some retail space; buildings having several different commercial activities that, together, comprise 50 percent or more of the floorspace, but whose largest single activity is agricultural, industrial/manufacturing, or residential; and all other miscellaneous buildings that do not fit into any other category. **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.doe.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

Lighting background 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 (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 of an inch. Typically, T8s are more efficient than T12s.
  - **Compact fluorescent lamps (CFL)**: 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 diode (LED)**: LEDs are a solid-state light source that delivers a direct beam of light at a very low wattage. LEDs currently have efficiencies comparable to that of compact

fluorescent lamps: between 20–60 lumens per watt. Over the next twenty years, however, technology is projected to be able to achieve more than 150 lumens per watt. Although the efficiency of the individual LEDs currently may not be significantly higher than other, conventional sources, the efficiency of the entire lamp and **luminaire** combination is very high, as nearly all of the light gets directed out of the luminaire.

- **High-intensity discharge (HID)**: HID bulbs 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 illuminance, 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, train. Proper maintenance of equipment is a crucial component to keeping technology in the best shape it can be.

Additional information

For more information on lighting design optimization, see:

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

APPENDIX C

Energy use by miscellaneous equipment

Depending on the equipment present in the host company'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 C.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 company is using a significant number of these machines, it may be advantageous to replace equipment with more energy-efficient versions.

Notes

1 M. Sanchez et al., Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, "How Plugged in are Commercial Buildings?" February 2007, p.11. Accessible at http://enduse.lbl.gov/info/LBNL-62397.pdf.

APPENDIX D

HVAC background information

Unitary vs. centralized HVAC systems

Commercial buildings smaller than 20,000 square feet typically use factory-built, air-cooled "unitary" **HVAC** equipment. Buildings larger than 100,000 square feet and multibuilding 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 unitary and engineered systems, or among systems of either type, should consider the performance of the entire system, rather than just the chiller or the condensing unit.[1]

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 unitary systems are lower initial costs, independent zone control, lower failure risk and less floor space occupied by a mechanical room, ducts and pipes.[2]

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.[3] 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.

- **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 is an energy efficiency ratio (EER) of 8.9 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. 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.

Additional information

For more information on HVAC optimization, see:

- Nontechnical introduction to HVAC: NCDENR, "Energy Efficiency in Industrial HVAC Systems," 2003. Accessible at 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 American Council for an Energy Efficient Economy (ACEEE). "Online Guide to Energy-Efficient Equipment: High-Performing HVAC Systems," 2004. Accessible at http://old.aceee.org/ogeece/ch3_index.htm.

2 ERPI Office Complexes Guidebook, Innovative Electric Solutions. Chapter 6—Heating, Ventilating, and Air-Conditioning (HVAC). December 1997. TR-109450, p. 195.

3 Air-Conditioning and Refrigeration Institute. 2006 Standard for Performance Rating of Unitary Air-Conditioning Equipment and Air Source Heat Equipment.

APPENDIX E

Water heating background 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 preheaters 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 ed, pp. 601–603.)

Additional information

For U.S. and California appliance efficiency standards, see:

- California Energy Commission, "Appliance Efficiency Regulations," CEC-400-2006-002-REV2. Accessible at http://www.energy.ca.gov/2006publications/CEC-400-2006-002/CEC-400-2006-002-REV2.PDF.

For an introduction to facilities water management, see:

- James Piper, Maintenance Solutions, "Water Use: Slowing the Flow," 2003. Accessible at http://www.facilitiesnet.com/ms/article.asp?id=1969&keywords.

For a technical reference on hot water systems, see:

- Benjamin Stein and John Reynolds. 2000. *Mechanical and Electrical Equipment for Buildings,* Chapter 10: Water Supply, Sections 10.5, 10.6 and 10.7 containing Water Sources, Hot Water Systems and Equipment, and Fixtures and Water Conservation. Accessible at http://books.google.com/books?hl=en&lr=&id=ZldvdyPMhl8C&oi=fnd&pg=PR17&dq=stein+reynolds+Mechanical+and+Electrical+Equipment&ots=FVBfygZzL0&sig=aSuYqFDLNqW5vPottUD0NF3oREI#v=onepage&q&f=false.

Notes

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

APPENDIX F

Driving tips for increasing fleet efficiency

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.

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.

TABLE F.1

Potential for increased fuel economy through improved 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." Accessible at http://fueleconomy.gov/feg/drive.shtml.

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 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.

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 sources:

- California Energy Commission: http://www.energy.ca.gov/enhancedautomation
- Flex Your Power: http://www.fypower.org/bpg

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 ft^2, 391,339 ft^2 and 272,598 ft^2, respectively. Combined, they total 989,358 ft^2 of office space, resting atop 938,473 ft^2 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 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).

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%

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 ft^2 of office space, 28,000 ft^2 of covered parking and 19,000 ft^2 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.

Efficiency achievements

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).


Swinerton

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

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 helps 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

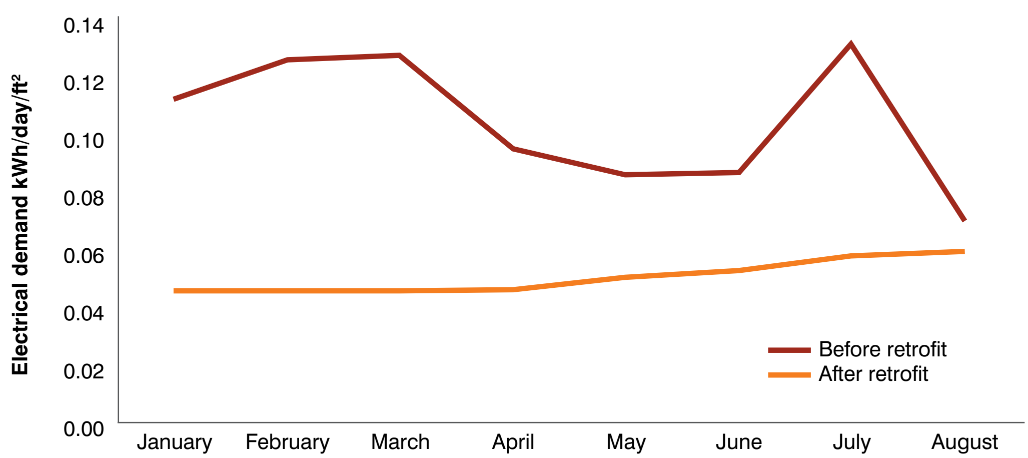
Swinerton's headquarters at 260 Townsend has access to a variety of public transportation options. It is located next to six bus stops, the Municipal Railway ("Muni") N-Judah Train and the Southbay commuter rail CalTrain. Alternative transportation is further encouraged by reserved access to parking 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 into 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, a 70%

FIGURE G.1

Before retrofit and after retrofit electrical demand for 260 Townsend



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 ft^2. 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.

Initial efficiency upgrade investments focused on retrofits to the lighting and HVAC (Heating, Ventilating 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).

Mathew Grimm

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

Glossary of terms

(CEC) denotes glossary definitions excerpted from the California Energy Commission Enhanced Automation Technical Options Guidebook.[1] (EPA) denotes glossary definitions excerpted from the U.S. EPA Energy Star® Building Upgrade Manual.[2]

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. (CEC)

Ambient lighting: Provides general base-level illumination of space.

Ballast: Electrical or magnetic devices that provide appropriate voltage when a fluorescent light is turned on and limit and stabilize the amount of current flowing to the lamp during operation. Fluorescent lights require ballasts to operate.

BAS: See Building automation system.

BMS: See Building management 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. (EPA)

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. (EPA)

Building management system (BMS): See Building automation system.

CFL: See Compact fluorescent lamp.

Chiller: Mechanical device that generates cold liquid, which is circulated through cooling coils to cool the air supplied to a building. (EPA)

Circuit level (energy monitoring): Electricity monitoring performed during an energy audit where electricity flow through each circuit is measured individually. Circuit level monitoring allows for a precise analysis of the specific electricity draw by different systems within a building.

Commissioning: A process by which equipment is tested to make sure it is performing according to design intent. Commissioning should be performed periodically on HVAC and lighting systems.

Compact fluorescent lamp (CFL): Fluorescent lamps suitable for use in fixtures designed for standard incandescent bulbs, with longer life and lower energy usage than comparable incandescent bulbs.

Cooling capacity: An HVAC performance measure rated as the amount of heat energy a cooling unit can remove from a space per hour, expressed in BTU per hour.

Demand response: The application of available load and price response mechanisms to balance energy demand and supply.

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

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

Dimmer (lighting): A device that varies the voltage running to a lamp in order to reduce or increase lighting intensity.

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.

EER: See Energy efficiency ratio.

Efficacy: The ratio of lamp lumen output to total lamp power input expressed in lumens per watt. (EPA)

EIS: See Energy information system.

Energy efficiency ratio (EER): Cooling capacity (BTU/hr) divided by the total input power (watts) requirement. (EPA)

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. (CEC)

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

Footcandle: Unit of illuminance equal to one lumen per square foot. (EPA)

HID: See High-intensity discharge.

High-intensity discharge (HID): A generic 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: Stands for Heating, Ventilation and Air-Conditioning.

IRR: See Internal rate of return.

Incandescent lamp: 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).

Information technology: 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.

IT: See Information technology.

Kilowatt (KW): 1,000 watts, a measure of power, similar to horsepower. Power plant capacity is measured in watts.

Kilowatt-hour (KWh): The amount of energy equivalent to the power of one kilowatt running for one hour. Electricity use for a building or a home is measured in KWh.

KW: See Kilowatt.

KWh: See Kilowatt-hour.

LED: See Light emitting diode.

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

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.

LPW: See Lumens per watt.

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. (EPA)

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

MWh: See Megawatt-hour.

NPV: See Net present value.

Net present value (NPV): A project's net contribution to wealth: present value minus initial investment.

Off-peak: Refers to 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.

Payback: The length of time required for the net revenues of an investment to return the cost of the investment.

Peak demand: See Peak load.

Peak load: Also known as peak demand. Refers to the highest electrical demand during a particular time period. If a utility uses time-of-day pricing, electric prices will be highest during periods of peak load.

Photosensor: A device that responds electrically to the presence of light. (EPA)

Plenum: An open space used to distribute cold air or collect hot air (as opposed to ducts). Data centers typically use underfloor plenums to supply air to server aisles.

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

PUE: See Power utilization effectiveness.

Reflector: A device installed in luminaires used to direct light from a source via specular or diffuse reflection. (EPA)

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.

Standby losses: 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).

Sub-meter: 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%.

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

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

T8: A linear fluorescent lamp with a diameter of 8/8th 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.

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.

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

Uninterruptible power supply: 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.

UPS: See Uninterruptible 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.

Notes

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

2 U.S. EPA, "Energy Star® Building Upgrade Manual." Accessible at http://www.energystar.gov/ia/business/BUM.pdf.

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