EDF Climate Corps Handbook

Strategic Energy Management for Organizations

EIGHTH EDITION

Environmental Defense Fund

Environmental Defense Fund (EDF) is a leading international nonprofit organization that creates transformational solutions to the most serious environmental problems. EDF links science, economics, law and innovative private-sector partnerships.

EDF Climate Corps embeds trained graduate students in organizations to help meet their energy goals by accelerating clean energy projects in their facilities. Over the course of a summer, fellows get clean energy projects on the fast track to accomplishment, improving both the organization's bottom line and environmental impact. Since 2008, EDF Climate Corps has worked with 400 leading organizations and identified over $1.5 billion in energy savings.

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

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Strategic Energy Management for Organizations

EIGHTH EDITION

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Cover photo: Solar-paneled roof of the Bullitt Center in Seattle, WA. Photo by Brad Kahn.

The complete report is available online at edfclimatecorps.org.

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CHAPTER 1

How to use this handbook

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

This handbook is a reference manual for identifying, analyzing and prioritizing energy management opportunities in commercial and industrial buildings. Each chapter provides an overview of the steps that an organization can take to reduce energy, increase energy efficiency and reduce greenhouse gas emissions. This handbook also focuses on strategies and other opportunities to reduce organizations' climate-related environmental impact through strategic energy management and clean energy.

The handbook contains chapters that focus on a typical organization's energy use and associated energy savings opportunities, which include **heating, ventilation and air conditioning (HVAC)**, lighting, water heating and office equipment. For many measures, the energy savings and expected rate of returns vary widely because of building and equipment variations. Chapters on data centers, industrial facilities and renewable energy are also included. Additional information on the electric grid and greenhouse gases are provided after the introduction to allow for a more comprehensive understanding of the relationship of electricity usage and emissions.

Chapters are devoted to concepts that will be useful to EDF Climate Corps fellows and include barriers to energy efficiency, how to interpret utility bills, basic energy efficiency financing and employee engagement considerations. The handbook contains extensive references and additional background information is included in the appendices. The vocabulary terms in **bold green** throughout the text are defined in the glossary.

The chapters contain examples of costs, typical energy savings and expected returns on investment for a number of the suggested management upgrades. Information on utility rebates and other incentives are referenced within the handbook but specific rebate information should always be sourced from the individual utilities for the most up-to-date and thorough information prior to implementation of any upgrade initiative. Rebate information is available from regional utilities and the Database of State Incentives for Renewable & Efficiency (DSIRE) at dsireusa.org. DSIRE is a federally-funded database of state, local, utility company and federal incentives and policies. However, DSIRE is often not up-to-date, so it is best to check with the local utility, the company's utility account manager or the utility website for current rebates and incentives. In conjunction with the handbook, Environmental Defense Fund has developed a companion Financial Analysis Tool, available to EDF Climate Corps fellows, to help analyze the financial attributes of specific energy efficiency investments in lighting, office equipment, HVAC and data centers. Consult the Climate Corps Financial Analysis Tool to generate estimates of energy savings and payback specific to the conditions of a particular building. The savings estimates can be used as the base of a business case for the organization.

Although the challenge of improving energy management in organizations may appear daunting at first, this handbook outlines countless approaches to energy management techniques. Many additions to this handbook have been made to accommodate the changes in environmental and sustainable energy opportunities. While the initial focus was energy efficiency, this handbook has since evolved to provide a holistic and innovative approach to applying sustainable solutions to organizations in an effort to save money, reduce energy use and mitigate climate change.

CHAPTER 2
Introduction

EDF Climate Corps Program objective

The EDF Climate Corps Program works with organizations to provide a progressive and holistic approach to energy management. The program places trained graduate students with companies, city governments and universities to help build the business case for energy management and accelerate sustainable solutions within their organization. These graduate students pursue a wide range of degrees, from MBAs and MPAs, to MEMs and MEngs. While initially centered on energy efficiency, the program has expanded to encompass other ways to accomplish greenhouse gas (GHG) reductions through strategic energy management, renewable energy, employee engagement and environmental policy. The program continues to evolve with organizational needs and it plans to lead the industry in holistic energy management strategy and implementation.

Energy management matters

Increasingly, companies, universities and government agencies see strategic energy management as a critical tactic for cutting costs, energy and GHG emissions. Through the implementation of innovative energy management techniques, mitigating climate change is possible.

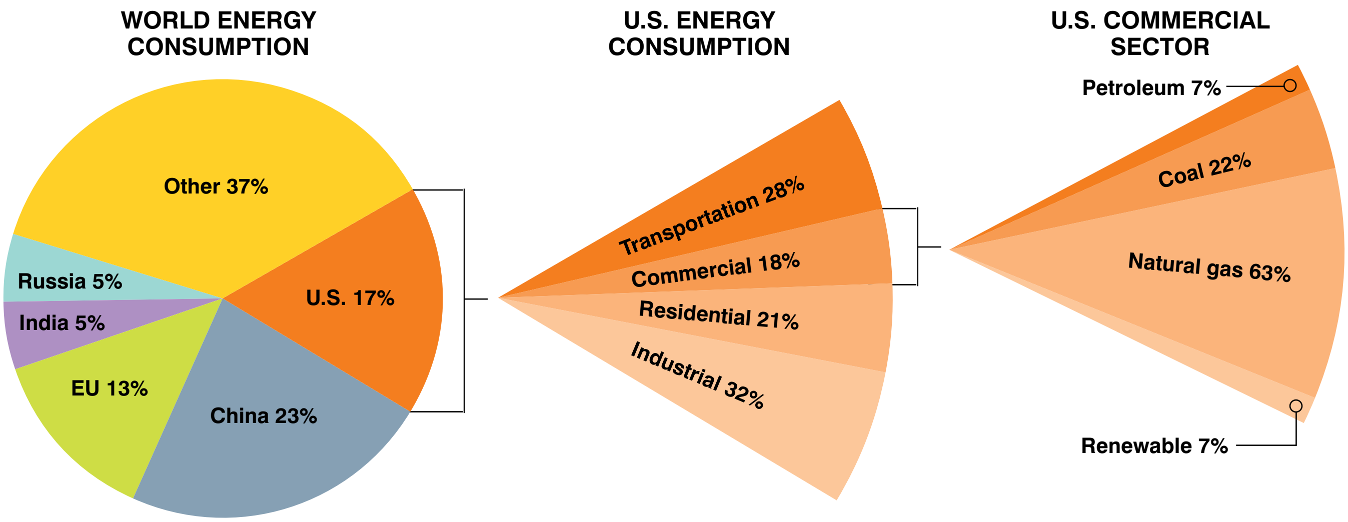
In the United States, the buildings sector accounted for about 40% of total energy consumption in 2015, more than either the transportation or the industrial sector.[1] Commercial buildings represent just under one-fifth of U.S. energy consumption, with office space, retail space and educational facilities representing about half of commercial sector energy consumption.[2] There is an abundance of opportunities available for organizations to reduce energy consumption and costs as outlined throughout this handbook.

Despite this, few organizations have fully invested in portfolio-wide strategic energy management in those buildings. The U.S. commercial sector spends $149 billion each year on energy bills for commercial buildings.[3] Even organizations that have made significant progress on energy conservation or energy efficiency often have not explored the full potential of energy management opportunities. A number of barriers prevent these organizations from identifying or approving smart energy management investments. Some barriers are financial; management improvements sometimes require a significant up-front investment followed by years of stable and predictable savings. Lack of available cash or financing can impede this investment, or organizations may impose an overly stringent hurdle (a one-year **payback**) that prevents many smart, low-risk investments from being approved. Renewable energy projects face substantial barriers against cheaper, more readily available fossil fuels. For additional information on combating barriers and instituting systematic improvements, see Chapter 6.

Since 2008, EDF Climate Corps fellows have helped organizations overcome these barriers and reap the energy and environmental benefits that accompany them. Identifying the

FIGURE 2.1

Energy consumption and U.S. commercial sector energy sources



Sources: BP, "Energy Economics: Country and Regional Insights" and Energy Information Administration, "Monthly Energy Consumption by Sector"

threat of greenhouse gases, this handbook goes on to explain the connection between our electricity use and GHG emissions and outlines various methods for implementing carbon reduction solutions.

Notes

[1] U.S. Energy Information Administration, "Monthly Energy Review," June 2016. http://www.eia.gov/totalenergy/data/monthly/pdf/sec2.pdf

[2] Ibid.

[3] U.S. Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS)," Table C2. Total Energy Expenditures by Major Fuel, 2012, released May 2016. https://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/c2.cfm

CHAPTER 3

Greenhouse gases

Goals

- Understand how to account for greenhouse gas emissions
- Determine best ways to decrease an organization's carbon footprint

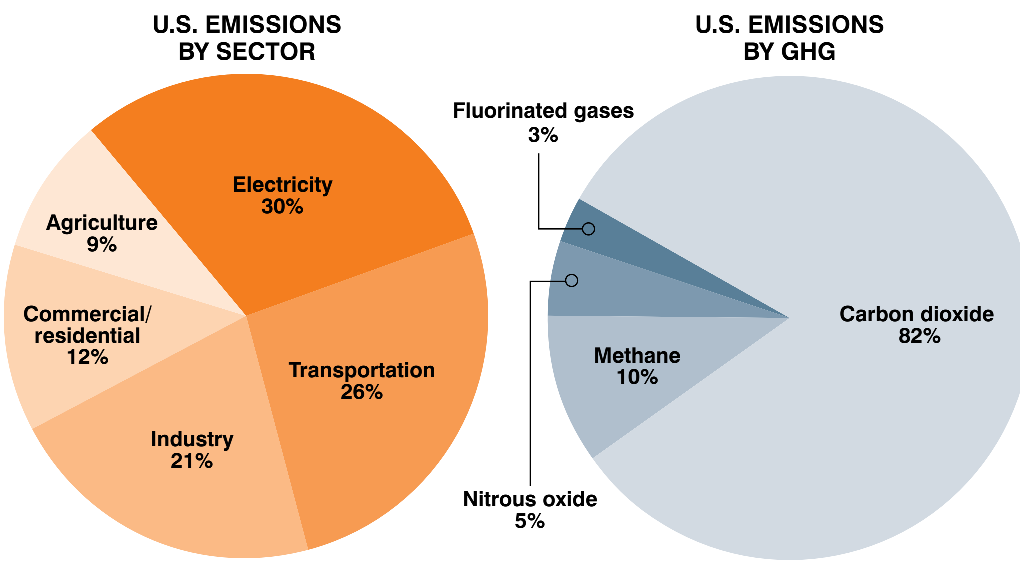
Overview

GHG emissions from human activity are directly leading to climate change by absorbing infrared radiation and trapping heat in the atmosphere. The consumption of energy generated by the burning of fossil fuels is one of the driving forces behind GHG emissions. Despite awareness that the growth in GHG emissions is having a devastating impact on the environment, energy consumption continues to increase year after year. It is an absolute necessity to decrease energy consumption and reduce GHG emissions in an effort to mitigate climate change.

The major GHGs resulting from human activities are carbon dioxide, methane, nitrous oxide and fluorinated gases. While they each contribute to climate change, carbon dioxide accounts for most of U.S. GHG emissions. According to the Environmental Protection Agency (EPA), carbon dioxide had the highest atmospheric concentration, accounting for 82% of U.S.

FIGURE 3.1

U.S. GHG emissions



Source: EPA, U.S. 2014 Greenhouse Gas Emissions

emissions in 2014, while methane came in second at 10%.[1] Figure 3.1 (page 4) provides a breakdown of U.S. emissions.

The U.S. contributes greatly to worldwide emissions and consequently is playing a significant role in accelerating climate change. In 2014, the U.S. was estimated to have emitted 6,870 million metric tons of **carbon dioxide equivalent (CO_2e)**, making the country one of the top global emitters, second only to China.[2,3]

Organizations can help to reduce global GHG emissions by addressing their own carbon emissions. The remainder of this chapter outlines how to measure and quantify GHG emissions and suggests methods to decrease them. An organization can not only reduce its environmental impact by decreasing its GHG emissions, but it can also benefit from reduced costs associated with energy use.

Quantifying GHG emissions

Defining emissions

The World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) developed the **Greenhouse Gas Protocol** in order to set a worldwide standard for calculating, managing and reporting emissions. This approach to measure and report the amount of CO_2e emitted into the atmosphere is referred to as carbon or GHG accounting. The principles to consider when calculating emissions are: completeness, transparency, accuracy, consistency and relevance. The GHG Protocol has also set boundaries to define how to account for GHG emissions. Organizations can use operational or organizational boundaries to help define the extent of their emissions accounting.

Organizational boundaries are determined using an equity share or control approach. Under the equity share approach, the reporting organization is only responsible for the emissions proportional to the amount of equity they have in the operation. Under the control approach, the organization accounts for 100% of the emissions from operations over which it has either financial or operational control.

Operational boundaries are based on the emissions generated as a direct or indirect result of the organization's operations. Due to the complexity and different levels of energy consumption that occur within an organization, there are scopes that define the varying degrees of associated emissions. According to the GHG Protocol, operational boundaries can be divided up into three scopes:

- *Scope 1:* Direct emissions owned or controlled sources. For example, emissions from company vehicles

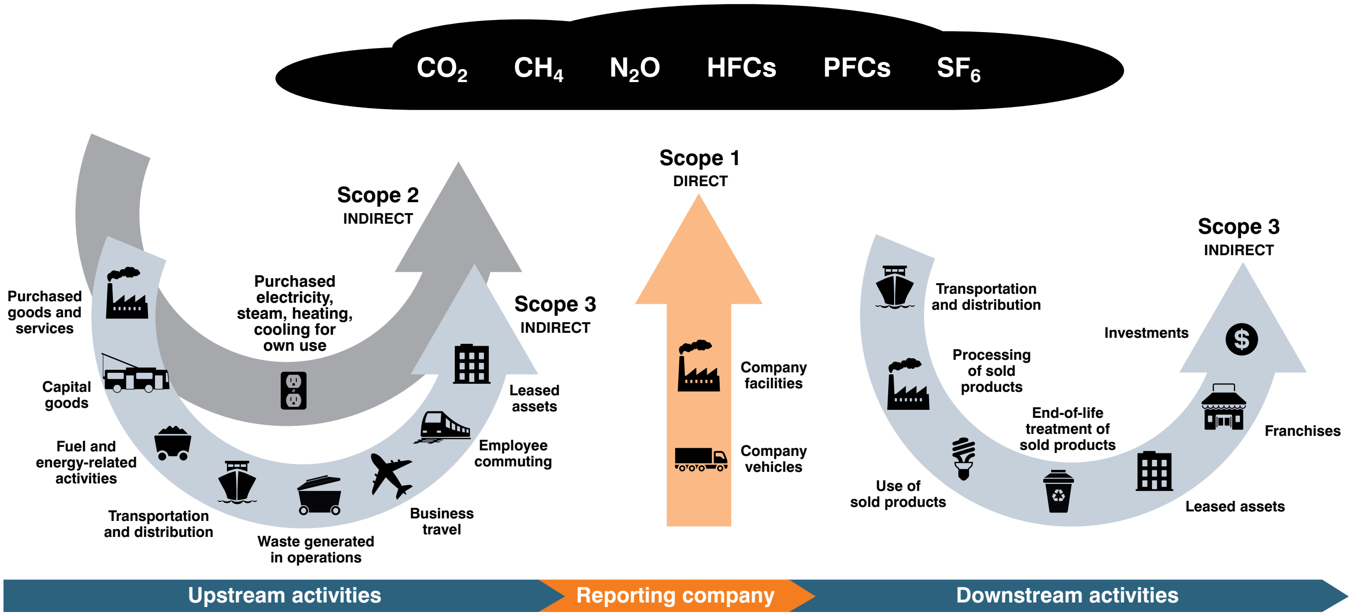
- *Scope 2:* Indirect emissions from generation of purchased energy. For example, emissions from purchased electricity, heat or steam

- *Scope 3:* Upstream and downstream emission activities. Emissions associated before and after the creation of a product, such as transportation or capital goods

The EDF Climate Corp fellowship program focuses primarily on implementing solutions to reduce Scope 2 emissions associated with electricity consumption. Scope 1 and 2 are relatively easy to identify and estimate, since data for these emissions are often accessible. Companies leading the industry in carbon accounting are now also accounting for Scope 3 emissions however, they are generally much more difficult to quantify. Figure 3.2 (page 6) provides a visual representation of these scopes with additional examples.

FIGURE 3.2

GHG protocol scopes and emissions



Source: GHG Protocol, Overview of GHG Protocol scopes and emissions across the value chain

Calculating emissions

There are three major factors that determine each gases' total effect on the environment: concentration, lifetime and strength. Higher concentrations and longer lifetimes result in greater atmospheric impact. The strength of a gas is based on its **global warming potential (GWP)**, and is indicative of how much heat it can trap in the atmosphere normalized into CO_2e to allow for direct comparison. Table 3.1 details the global warming potentials of the three most prevalent GHGs.

Once it has been determined which GHG emissions an organization is including in its GHG accounting, the emissions can be estimated using the following formula:

Quantity of source	x	Global warming potential	x	GHG emission factor	=	GHG emissions
energy used (e.g. kWh)		*of GHG for source (e.g. 1 for CO_2)*		*of GHG for source (e.g., eGRID factor for CO_2)*		*CO_2 equivalent*

The GHG emission factor for a source can be found based on the source of energy. When reporting on Scope 2 emissions from purchased electricity, the GHG Protocol states that all

TABLE 3.1

Global warming potential values

Industrial designation or common name	Chemical formula	GWP values for a 100-year time horizon: Second Assessment Report (SAR)	Fourth Assessment Report (AR4)	Fifth Assessment Report (AR5)
Carbon dioxide	CO_2	1	1	1
Methane	CH_4	21	25	28
Nitrous oxide	N_2O	310	298	265

Source: GHG Protocol, Global Warming Potential Values organizations shall report both their location-based and market-based emissions. These are two different methods of estimating the same number. Organizations use the U.S. EPA's eGRID factors to determine their location-based GHG emissions based on the location of their facility. The eGRID factors are essentially an average of the emission factors of the power suppliers in the region. Organizations should also estimate their market-based emissions using emissions factors of the actual power suppliers from which they have contractual instruments to purchase electricity. Each calculation method reflects different opportunities and risks associated with the organization's electricity supply and associated emissions, and can inform strategies to reduce emissions.

It is also important to use the eGRID total load emission factors when using the location-based method. The Climate Corps Financial Analysis Tool (CCFAT) uses eGRID non-baseload emission factors which are specifically designed to estimate savings from reduced electricity use and renewable energy implementation and are not intended for carbon accounting. The location-based emissions factors are provided by eGRID, accessible through EPA's website at https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

Emissions factors from sources outside of electricity, such as an organization's vehicle fleet emissions are dependent on fuel type. The U.S. EPA GHG emission factors sheet provides emissions factors for other sources of energy at http://www.epa.gov/sites/production/files/2015-12/documents/emission-factors_nov_2015.pdf

Reporting emissions

Reporting an organization's estimated emissions is the other major component to the GHG Protocol. Reporting emissions can facilitate a more positive public image by demonstrating an organization's commitment to a lower carbon future and can provide motivation for the organization to meet GHG reduction goals. As of 2013, 60% of Fortune 100 companies have set GHG reduction targets.[4] Reporting emissions could potentially become a requirement as climate issues continue to progress, so becoming accustomed to reporting will likely be in an organization's favor.

Decreasing GHG emissions

After quantifying an organization's current emissions through carbon accounting, the next step is to address how to reduce the organization's GHG footprint through Scope 2 emissions. There are many ways to decrease emissions and successful organizations often take a holistic approach to emissions reduction. These approaches are detailed below:

Goal implementation and emissions plan

Defining a quantitative goal and laying out a formal emissions reduction plan is an effective method to motivate an organization to decrease emissions. This goal may be established using the baseline and benchmarking approach as detailed in Chapter 9. It is important to baseline against similar organizations or historical emissions to ensure one's target is feasible and reasonable. Many organizations set emissions reduction goals for five to ten years in the future. Leading companies are setting science-based GHG emissions reduction goals that are in line with the level of decarbonization required to keep global temperature increase below 2º C.[5]

Energy efficiency implementation

An impactful way to decrease emissions is through energy efficiency, which decreases energy consumption and thus results in reduced emissions. Reducing energy consumption also results in energy cost savings, making it a win-win for organizations with GHG goals. Methods to identify and implement energy efficiency measures are outlined in detail throughout many of the succeeding chapters.

Carbon offsetting

Organizations can purchase carbon offsets to invest in emissions reduction projects that can offset their own GHG emissions. Offsets often finance existing projects in renewable energy, resource conservation or forestry. These projects facilitate GHG reductions by displacing fossil fuels or providing alternative ways to absorb carbon.

Renewable energy

Renewable energy procurement is another impactful way to decrease emissions. Renewable energy can mitigate emissions through on-site or off-site installation of renewable sources or by purchasing green power. Renewable energy options are explained in detail in Chapter 17. By procuring renewable energy, an organization consumes less electricity sourced from fossil fuels, thus lowering its Scope 2 emissions.

Additional information

For additional information and guidelines on GHG emissions, see:

- GHG Protocol: http://www.ghgprotocol.org
- The Climate Registry: http://www.theclimateregistry.org

Notes

[1] Environmental Protection Agency, "Greenhouse Gas Overview," https://www3.epa.gov/climatechange/ghgemissions/gases.html

[2] Environmental Protection Agency, Global Greenhouse Gas Emissions Data, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

[3] Environmental Protection Agency, "Sources of Greenhouse Gas Emissions," https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

[4] Ceres, "Power Forward 2.0: How American Companies are Setting Clean Energy Targets and Capturing Greater Business Value," http://tools.ceres.org/resources/reports/electric-power/reports/power-forward-2.0-how-american-companies-are-setting-clean-energy-targets-and-capturing-greater-business-value/view

[5] Science Based Targets, http://sciencebasedtargets.org/

CHAPTER 4

The electric grid

Goals

- Gain broad insight into the complexity of the electric grid
- Understand basic infrastructure, control, and market constructs

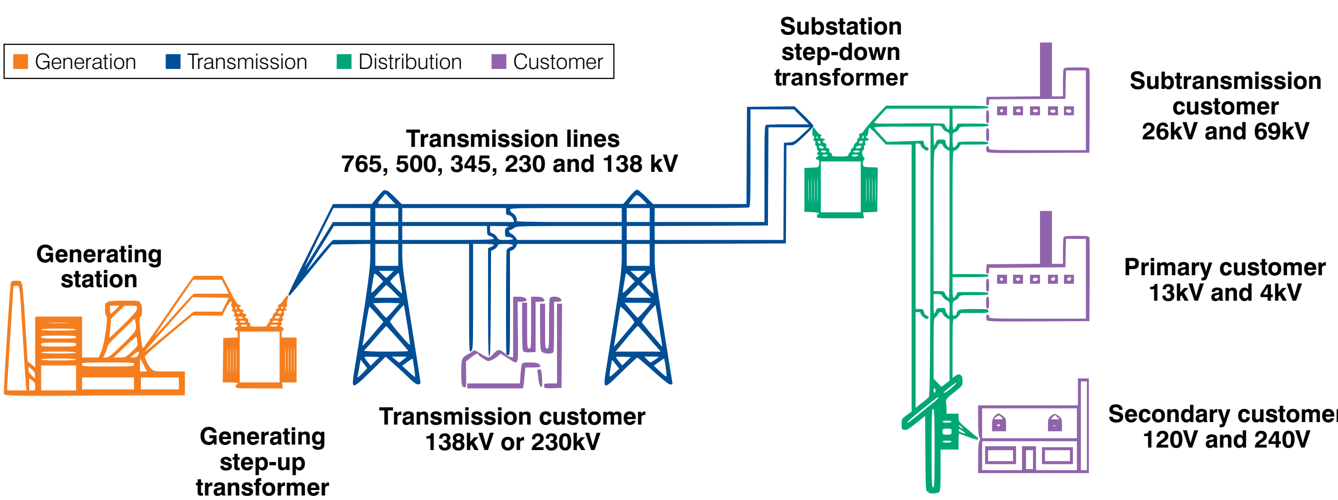
Overview

While initially small and localized when it was created in late 1800s, the U.S. electric grid has expanded to form one of the largest systems ever engineered. The grid is made up of hundreds of thousands of miles of electrical lines and stretches across the continental U.S. It operates through a combination of its physical infrastructure, control networks, economic markets and regulatory oversight. While it is an immensely complex entity, there are essential features to consider including:

- The supply and load are matched in real time. Electricity being consumed and pulled from the grid is simultaneously being generated. For example, in the same moment that a light bulb is being powered, electricity is being generated for that light bulb. Electricity storage is not prevalent on the grid, so electricity must be produced continuously.[1]
- There is no single entity that governs the electric grid. Management and oversight of the electricity grid is complex, with state, regional and federal entities sharing responsibilities and high levels of regional variation in governance structures.

FIGURE 4.1

Basic structure of the electric grid



Source: Union of Concerned Scientists, "How the Electricity Grid Works," 2015

The U.S. depends heavily on the electric grid, which generates an immense amount of electricity every year. According to the U.S. Energy Information Administration, utility scale facilities generate about 4 trillion kWh of power annually.[2] This is a monumental amount of energy, considering a single 10-watt LED light bulb used for eight hours a day consumes under 30 kWh annually. The electric grid plays a vital role in modern life and the complex nature of its composition is explored further throughout this chapter.

Physical infrastructure

Three basic components make up the physical infrastructure of the electric grid: generation, transmission and distribution. Figure 4.1 (page 9) provides a simplified explanation of how these three components relate.

Generation

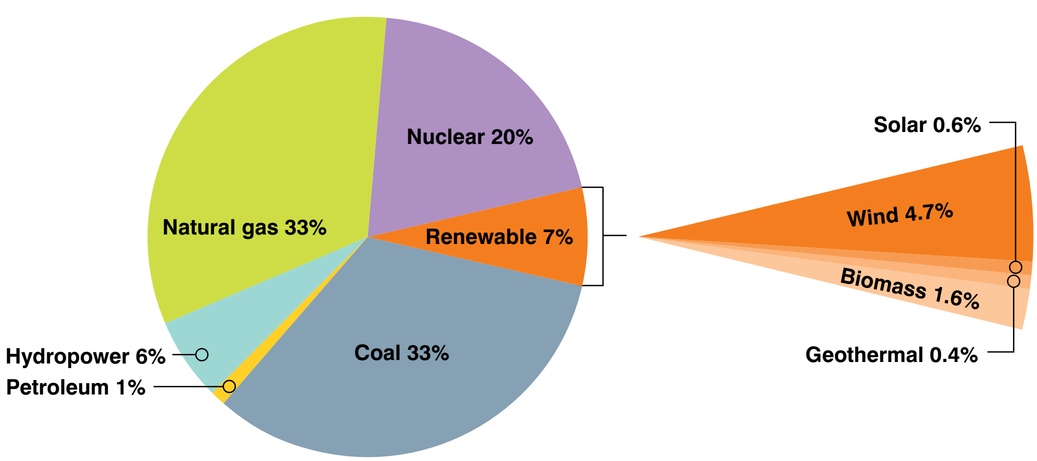
Power plants and individual generators generate the electricity supplied to the electric grid. The electrical energy is generated through a variety of different means. The majority of the electricity produced in the U.S. today is through the burning of fuels such as petroleum, coal and natural gas. The rest is generated from solar, wind, hydro and nuclear sources. Figure 4.2 depicts and compares U.S. electricity generation based on fuel.

The physical and operational differences in power plants create different grid applications and provisions. For example, plants with little flexibility, such as coal and nuclear, require longer start up and shut down intervals and thus cannot easily change their electricity output. On the other hand, natural gas-fueled plants are often used to meet peak demand due to their fast start up times. Renewable energy, such as solar and wind energy, are highly utilized because they have no associated fuel costs, but power from these source is intermittent due to daily variations in solar and wind resources.[3] Each day, grid operators plan according to forecasted energy needs, and additionally maintain a **reserve margin**, which is a source of backup electricity in the event of power failure or errors.

In the areas of the country where electricity is regulated, electricity generators are owned and operated by utilities. In de-regulated markets, independent power producers (IPPs), or non-utility generators (NUGs), generate electricity independently and sell the energy directly to wholesale power markets and directly to end users.

FIGURE 4.2

U.S. electricity generation by source



Source: Energy Information Administration, "FAQ: U.S. electricity generation by source," 2016

Transmission

Once high voltage energy has been generated, it is then transported through transmission lines over long distances. Transmission lines can be located above or below ground, but above ground lines are less reliable due to their exposure to the elements. A high transmission voltage is necessary, or the electricity will be lost through resistance in the form of heat. On average, 6% of electricity in the U.S. is lost in transit.[4] Line losses increase with distance and higher demand. Since power plants generally produce electricity at a much lower voltage, the electricity is converted from voltage as low as 110kV to an increased transmission voltage as high as 765kV through the use of transformers.[5]

Distribution

In the final stage of electricity delivery, the distribution systems carry electricity from transmission systems to the consumers. Through the use of transformers, the high transmission voltage is lowered. The voltage is initially decreased to medium voltage levels and carried to distribution transformers through primary distribution lines or subtransmission lines. Consumers with high power demand may be connected directly to this level. Otherwise, the voltage is then lowered again to utilization voltage ranging from 4 to 13kV for primary consumers.[6]

Interconnections

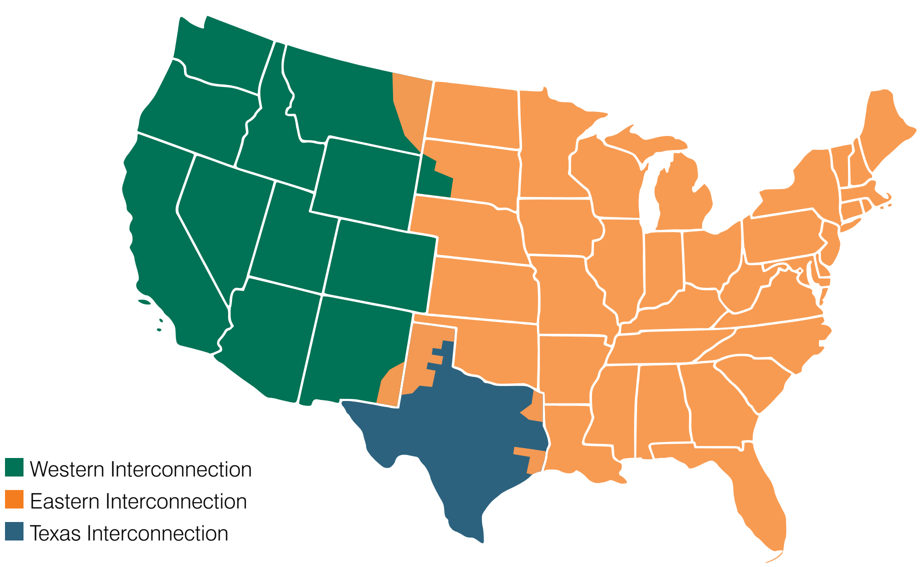
The electric grid is composed of three alternating current (AC) power grids, or interconnections. They serve as the main transmission networks across the continental U.S. and are broken up into the following three interconnections:

- Eastern Interconnection
- Western Interconnection
- Texas Interconnection (ERCOT)

As depicted in the map in Figure 4.3, the Western Interconnection encompasses everything to the west of the Rocky Mountains and the Eastern Interconnection encompasses everything to the east of the Rocky Mountains and some areas of northern Texas. Texas interconnection

FIGURE 4.3

Map of U.S. electric grid interconnections



Source: Energy Information Administration, U.S. Electric Power Regions, 2016 covers the majority of the state of Texas. These interconnections operate mostly independently from one another and power transfers between interconnections is limited. The network structure of the grids provides power system reliability by providing multiple routes for electricity to flow and allowing generators to source electricity to many **load centers**. Load centers distribute electricity supplied by utilities to homes and buildings. Interruptions in service from power plant or transmission failures are prevented through this route redundancy.[7]

Control network

Grid balancing authorities maintain load-interchange-generation balance, integrate resource plans ahead of time and support interconnection frequency in real time.[8] The Federal Energy Regulatory Commission (FERC) supports two major forms of balancing authorities: **Independent System Operators (ISO)** and **Regional Transmission Operators (RTO)**. Both operate a regional electricity grid, provide reliability planning and administer wholesale electricity markets. While the two authorities are very similar in many ways, RTOs are directly designated and governed through the FERC, whereas ISOs are formed at the recommendation of the FERC and operate under its federal regulation. The North American Electric Reliability Corporation (NERC) oversees eight regional entities, setting standards that improve the reliability of the bulk power system. Individual state level energy commissions regulate the rates and services that public utilities provide.

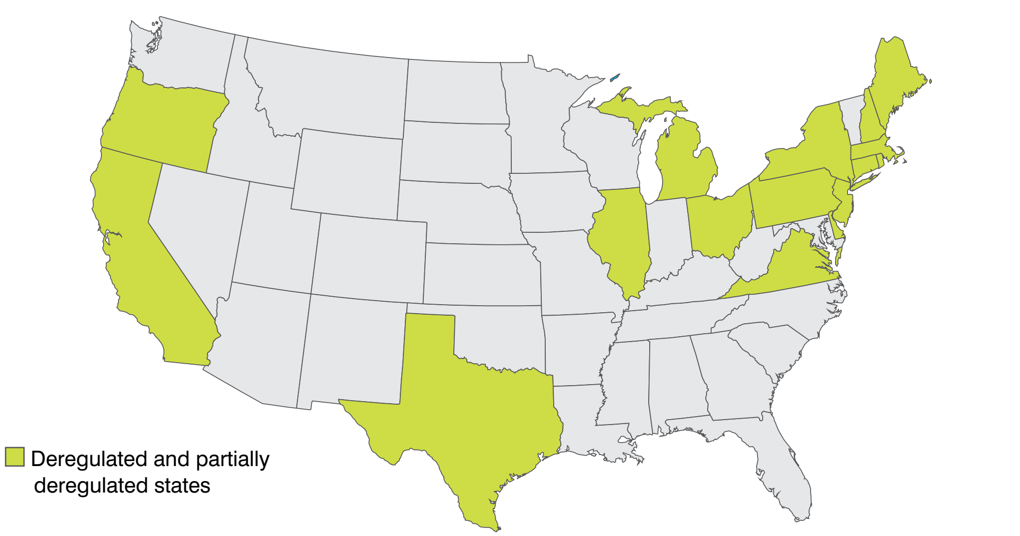
Electricity markets

Many aspects of electricity demand and pricing are explained throughout this handbook. In particular, utility bill electricity pricing can be found in Chapter 9 and demand response can be found in Chapter 18. As a result, this section will focus on physical electricity market basics.

Regulated markets are composed of vertically integrated utilities, meaning that they control the flow of electricity from start to finish. In many areas of the country, electricity markets have been fully or partially deregulated, meaning that distribution services have been decoupled from electricity generation and wholesale electricity markets have been established. See Figure 4.4

FIGURE 4.4

U.S. electricity deregulation map



Source: Electricchoice.com, "Map of Deregulated Energy States and Markets" (updated 2017) for a map of deregulated states. Wholesale electricity is bought and sold in bulk quantities through long-term, bilateral contracts or through wholesale transactions cleared by a market operator. Entities that provide electricity to customers but do not generate it (such as distribution utilities) and organizations with a large energy demand purchase electricity through the wholesale market. Wholesale prices fluctuate throughout the day, season and by location. Distribution utilities deliver electricity to customers, charging them for their commodity usage as well as for delivery costs. States with retail choice separate distribution charges from commodity charges and allow consumers to choose their preferred electricity retailer. Markets for power-related commodities (such as ancillary services) are not discussed in this chapter.

Conclusion

This chapter contains a broad overview and introduction to the U.S. electric grid and its basic components; however, the system is immensely complex and dependent upon location so additional research is recommended to understand how electricity is handled in your specific area.

Additional information

For additional information on how the electricity grid works, see:

- Switch Energy Project, "Electricity," 2011. http://www.switchenergyproject.com/education/CurriculaPDFs/SwitchCurricula-Secondary-Electricity/SwitchCurricula-Secondary-ElectricityFactsheet.pdf

For more information on how energy markets work, see:

- Federal Energy Regulatory Commission, "Energy Primer, A Handbook of Energy Market Basics," 2015. http://www.ferc.gov/market-oversight/guide/energy-primer.pdf

Notes

1 Harvard College, "A Primer on the Electric Grid," http://isites.harvard.edu/fs/docs/icb.topic1050197.files/US_Electric_Grid_Lesson_Slides_Kochavi_v3m.pdf

2 U.S. Energy Information Administration, "Electricity Net Generation," http://www.eia.gov/totalenergy/data/monthly/pdf/sec7_5.pdf

3 Union of Concerned Scientists, "How the Electricity Grid Works," February 18, 2015. http://www.ucsusa.org/clean-energy/how-electricity-grid-works#references

4 U.S. Energy Information Administration, "FAQ, Electricity lost in transmission and distribution," April 2016. http://www.eia.gov/tools/faqs/faq.cfm?id=105&t=3

5 Union of Concerned Scientists, "How the Electricity Grid Works," February 18, 2015. http://www.ucsusa.org/clean-energy/how-electricity-grid-works#references

6 Ibid

7 U.S. Energy Information Administration, "Today in Energy," July 2016. http://www.eia.gov/todayinenergy/detail.cfm?id=27152

8 Ibid.

CHAPTER 5

Steps to identify and prioritize potential energy conservation measures

Goals

- Understand how to identify energy conservation measures and prioritization

Overview

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

A large portion of this handbook focuses on energy efficiency opportunities in facilities and suggests measures that are suitable for retrofitting or replacing existing building technologies. The basic steps for identifying and prioritizing energy efficiency opportunities are the following:

Estimate baseline energy use intensity. High-level calculations of baseline **Energy Use Intensity (EUI)** can be performed by dividing annual purchased energy (electricity and fuel) by the square footage (or square meter) of the building or space. Performing this analysis involves obtaining the documentation of purchased energy from the previous fiscal year and the square footage of the space. Purchased energy can include electricity, natural gas, diesel fuel and/or district-purchased steam. To provide a rough estimate of possible gains to be accomplished through energy management measures, baseline estimates of EUI can be compared to benchmarked EUI figures. For more information on estimating baseline energy use and benchmarking, see Chapter 9.

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

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

Perform financial analysis of possible efficiency investments. For each potential project, forecast the initial or incremental investment cost, including installation, or the operational expense if this cost doesn't meet capital investment thresholds. On the benefits side of the equation, consider the expected annual savings. Reduction in energy usage will likely be the main financial driver for savings, but reductions in labor and replacement costs may also be relevant and significant. Additionally, tax incentives and utility rebates should be included in the calculation. Consideration should also be given as to whether the potential investment is relevant to one site or relevant across an organization's portfolio of sites. Multi-site projects are more complex, but offer significant savings for large companies. Refer to Chapter 8 for more details. The EDF CCFAT can be used to estimate the **net present value (NPV)** as well as the expected payback period for energy efficiency projects.

Prioritize options for investment. Investments should be ranked based on the NPV as well as on feasibility and the size of the initial investment. Small and easy NPV-positive investments should be implemented immediately. Larger investments will often create greater energy savings but need to be budgeted and managed with greater resources. Refer to Chapter 6 for further information on barriers and solutions to financing investments.

Evaluate financing options. Investments can be paid for in cash, financed with a loan, leased or financed through a performance contract (see Chapter 8). The best option for a given organization will depend on the organization's cash availability, budget cycle, incentive and rebate options, and purchasing policy. It is a good idea to work with the chief financial officer and managers to make recommendations based on all of these elements.

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. Monitoring and verification after project completion is immensely important to ensure project success and continued progress.

CHAPTER 6

The Virtuous Cycle of Strategic Energy Management

Goals

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

Overview

Organizations have the opportunity to save money while simultaneously reducing emissions through the implementation of an energy management framework. However, there are challenges to be faced:

- Organizations are not always structured to respond to efficiency opportunities
- Mandates and responsibilities are not always clearly established or communicated
- Resources may be insufficient, misallocated or difficult to access

The Virtuous Cycle of Strategic Energy Management provides a solution to these challenges and the opportunity to capitalize the benefits through a framework that drives exponential growth through positive feedback loops. The five components of the Virtuous Cycle as shown in Figure 6.1 (page 17) work in union to drive continuous improvement in energy management.

The components are highly interdependent and when ample resources are provided to each component, the cycle continuously prospers and accelerates. Improving just one component can also improve the overall effectiveness in other components; however, constraints or barriers in just one component can diminish the whole system's performance. The Virtuous Cycle of

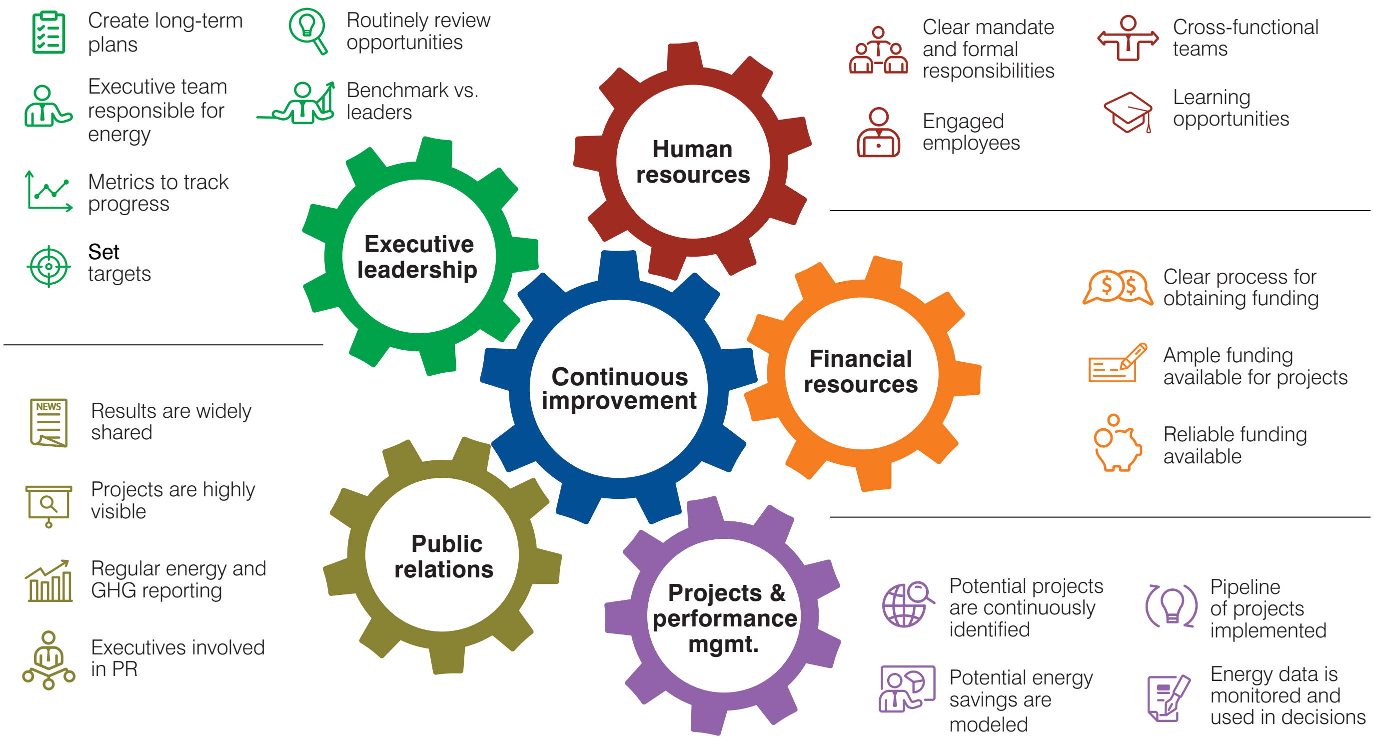
TABLE 6.1

Example of components, resources, barriers and solutions

Component	Key resource	Barrier	Solution
Engage executives	Executive attention	Diminishing attention	Goal setting
Invest in people	Staff expertise	Diminishing expertise	Dedicated energy manager
Access capital	Available budget	Diminishing budget	Dedicated funding
Manage projects and data	Project opportunities	Diminishing opportunities	Systematic project identification and tracking result
Share results	Visibility	Diminishing visibility	Periodic external reporting

FIGURE 6.1

EDF's Virtuous Cycle of Strategic Energy Management



Strategic Energy Management provides insight into the best solutions to minimize barriers and maximize system performance.

To better understand how the model works, each of the key components and possible barriers are examined below and best practices identified:

Engage executives

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

Key resources: Executives' attention and time.

Core strategy: Set aggressive, absolute goals linked to implementation plans.

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

Invest in people

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

Key resources: Employee expertise, motivation, attention and time.

Core strategy: Energy management accountability among staff through various, company-wide full time employees and cross-functioning teams.

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

A change initiative as complex as the implementation of an energy management program requires that responsible staff have clear deliverables and performance expectations related to program goals. These should be reviewed at regular intervals and provide staff with clear expectations. Incentives can boost staff motivation with direct and indirect responsibilities and rewards tied to program success. Staff may be recognized for adhering to suggested conservation actions, or contributing to resources and/or information that supports program goals. Additionally, an effective energy efficiency program should have goals that roll up directly to the organization's financial and other performance goals to ensure relevance and alignment.

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

Access capital

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

Key resources: Budget availability.

Core strategy: Establish sufficient funding source that is consistently available through a formalized and transparent method.

To ensure that energy-saving measures are funded on an ongoing basis, budgetary processes and financial requirements need to be structured in ways that allow for sufficient and reliable access to capital. Without effective tracking of efficiency investments, consideration of financial criteria that account for long-term value creation and dedicated funding sources for efficiency, organizations can fail to fund many highly cost-effective and profitable energy performance improvements. Common barriers to success include:

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

- Uncertainty around ROI (real and perceived)
- Split incentives

Financial considerations, including access to capital, are covered in greater detail in Chapter 8.

Manage projects and data

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

Key resources: Project opportunities, energy data and data management systems.

Core strategy: Identify, implement and track projects proactively. Ensure energy data is readily available to set priorities, select projects and verify results.

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

Share results

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

Key resource: Visibility.

Core strategy: Communicate results to key internal and external stakeholders who can drive further progress.

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

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

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

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

Additional considerations

There are additional barriers to consider when implementing the Virtuous Cycle for Strategic Energy Management. Organizational priorities and external factors are two important areas that are examined below.

Organizational priorities

In order to optimize efficiency efforts and initiatives, it is essential that leadership prioritize these efforts and make the commitment to energy efficiency known to, and accepted by, the rest of the organization. Without clear goals, effective management and benchmarking practices in place, organizations can lack the internal motivation and perspective to continuously improve their energy performance.

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

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

Organizations should align various needs and efforts. Different functional groups have different needs which individually may not justify or provide sufficient motivation for action. When these groups come together, however, the groups' needs can make a clear case for effective energy management. Consider some of these groups and their likely needs/benefits:

- Operations: Cost savings
- Procurement: Risk management (cost control)
- Corporate Social Responsibility or Sustainability
- Marketing: PR and brand enhancement, competitive pressures
- Investor relations: Reporting transparency (e.g. Corporate Sustainability Report and/or CDP reporting)

External factors

In addition to the internal conditions that can affect an organization's capability to continuously improve its energy performance, a variety of external factors can also influence performance. Without lease agreements that encourage ongoing capital investment in facilities, high prioritization of risk management related to changing energy prices and a sustained commitment to energy improvement despite fluctuating economic conditions, organizations can find themselves frustrated by landlord-tenant split incentives, unpredictable energy price fluctuations, and capital and staffing constraints that force priorities to shift erratically with time. Additional considerations include, but certainly aren't limited to:

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

Implementation

When implementing the Virtuous Cycle of Strategic Energy Management, the following steps should be taken:

1. Benchmark current energy management practices against current leading organizations and best practices
2. Prioritize Virtuous Cycle components as initial areas of concentration
3. Pinpoint specific barriers and constraints
4. Identify and implement strategies based on best practices

The EDF Smart Energy Diagnostic assessment can be utilized to help organizations benchmark energy management and focus on improvements. This can be accessed at edfclimatecorps.org/edf-smart-energy-diagnostic-survey

CHAPTER 7

Commercial building energy consumption

Goals

- Understand the general scope and variety of energy consumption in commercial buildings

Overview

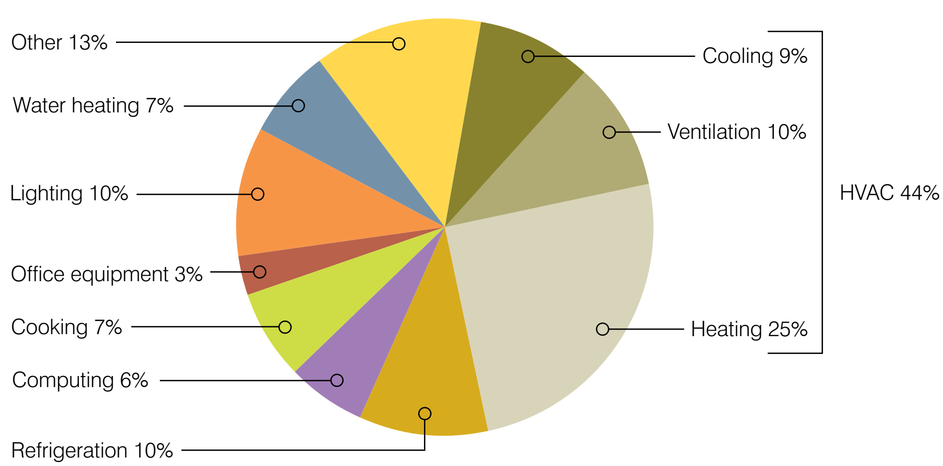
A first step in identifying opportunities that improve energy management is to understand how energy is used within a building. Different building types serve very different purposes, but there are common systems that most commercial buildings share (see Figure 7.1). According to the Energy Information Administration Data, most recently released in 2016, the systems that consume significant portions of energy in an average commercial building include HVAC (44%), lighting (10%), water heating (7%) and office equipment and computers (9%). Efficiency opportunities for each of these systems are explored in detail in subsequent chapters.

Energy use intensity by building type

Within the U.S. commercial sector, energy use is spread across a range of building types. Office buildings have the largest aggregated energy consumption, followed by retail and educational

FIGURE 7.1

Estimated energy consumption of U.S. commercial buildings

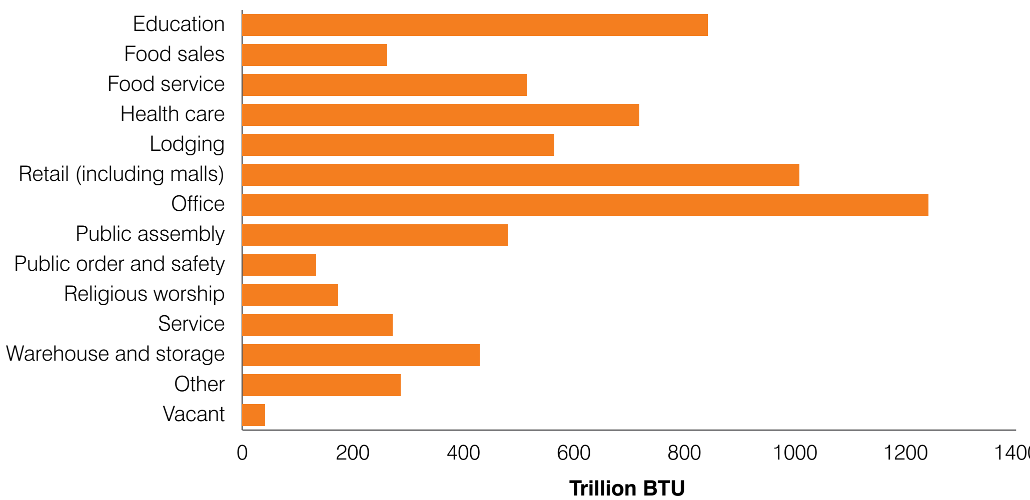


Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey, 2012," 2016 buildings (see Figure 7.2). If every office building in the country achieved a 30% decrease in energy use, the combined annual reduction in U.S. energy use would total over 340 trillion **BTUs**, enough energy to power over 638,000 homes for a year.[1,2]

An important measurement to understanding variations in energy consumption across building types is Energy Use Intensity (EUI). EUI is the amount of energy a building uses per square foot. Among commercial buildings, food sales, health care and food service buildings have the highest energy use intensity—each uses more than twice the energy per square foot of a typical office building (see Figure 7.3).

FIGURE 7.2

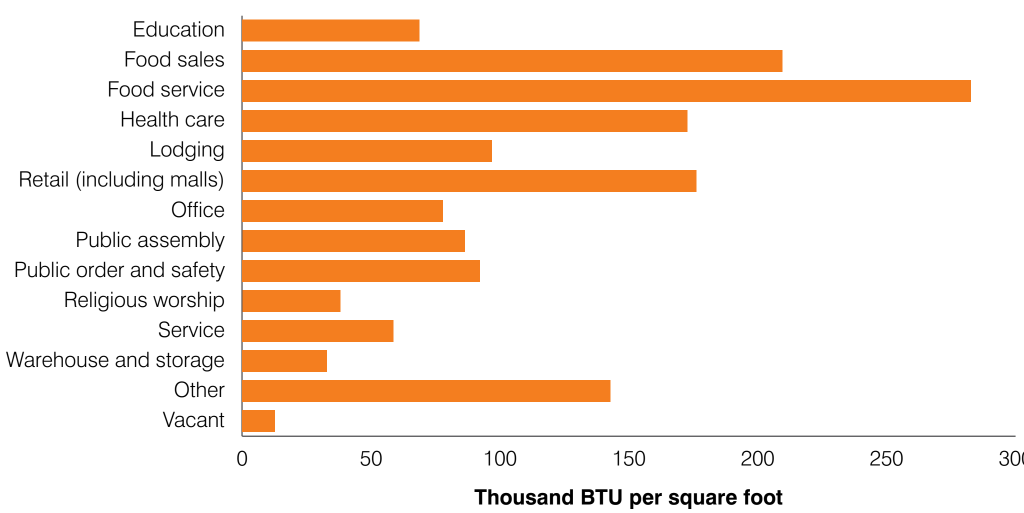
Estimated total fuel consumption by end use for all U.S. commercial buildings



Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey, 2012," 2016

FIGURE 7.3

Estimated energy intensities for U.S. commercial buildings



Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey, 2012," 2016

EUI 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 9.

For additional information on energy use patterns in a range of specific building types, consult Appendix A. The data for Appendix A and many of the figures in this handbook are taken from the 2016 Commercial Buildings Energy Consumption Survey (CBECS). The Energy Information Administration (EIA) normally conducts CBECS every four years. This energy consumption data will be updated upon the release of the next CBECS. Additional sources of data are available, including the U.S. Department of Energy's Buildings Energy Data Book, at https://catalog.data.gov/dataset/buildings-energy-data-book

Notes

[1] U.S. Department of Energy, "Buildings Energy Data Book-Commercial Sector," March 2012. https://catalog.data.gov/dataset/buildings-energy-data-book

[2] Derived using EPA's "Interactive Units Converter'' and "Greenhouse Gas Equivalencies Calculator," March 2010. http://www.epa.gov

CHAPTER 8

Energy efficiency financing

Goals

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

Overview

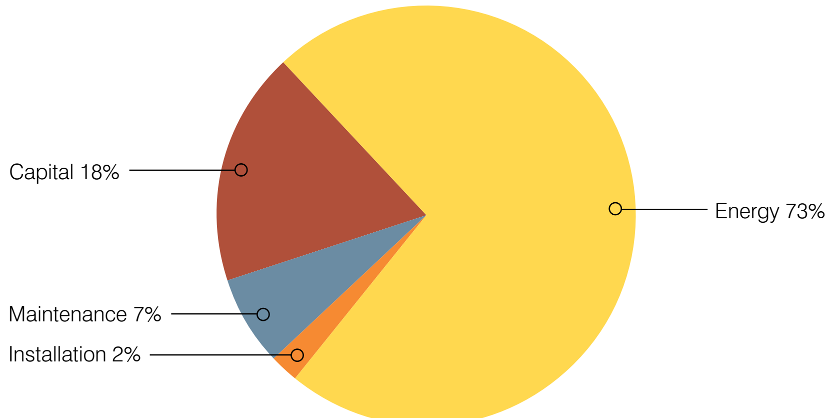
Energy-saving projects are different from most maintenance projects in that they often pay for themselves in cost savings over the life of the equipment. This chapter focuses specifically on financing energy efficiency projects; Chapter 17 addresses financing for renewables. Energy efficiency projects tend to fall into one of three major categories:

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

Evaluating a project based on the total costs of using equipment over its entire expected life is referred to as LCC, sometimes called total cost analysis (TCA). LCC considers the initial operating expense or capital investment, as well as the energy and maintenance expenses associated with the equipment, discounted into present value equivalent dollars. Knowing the LCC of a piece of equipment is important because the energy expenses over its lifetime can be several times the initial cost of the equipment. For example, the upfront capital costs for a compressed air system represent only 18% of the total life cycle costs of the equipment

FIGURE 8.1

Life cycle costs of compressed air system



Source: Carbon Trust, compressor costs over a ten-year life

while costs for electricity account for 73% of the LCC (Figure 8.1). Traditional low-bid contracting and purchasing strategies focus on minimizing the initial purchase cost only, which can often result in higher energy use and operating expenses.

When replacing failed equipment or specifying equipment for new construction, a marginally larger initial investment in more efficient equipment can result in a positive NPV compared to lower initial cost alternatives, including continuing with the existing status quo.

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

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

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

Financial analysis of energy opportunities

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

Net present value

NPV is the sum of forecasted cash flows discounted at the required rate of return, minus the initial investment, and is the primary measure of a project's attractiveness.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

C_t = Net cash flow during time period t

C_o = Total initial investment

r = Discount rate

t = number of periods

Using NPV properly positions energy savings opportunities as an investment, not as an expense, regardless of whether the project is paid for out of operating budgets or capital investment budgets. In general, projects with a positive NPV should be considered carefully for implementation. There are several variables that influence the estimation of NPV, including **discount rate**, tax rate and depreciation.

Discount rate

Generally, the discount rate that should be used in the financial analysis will be the organization's internal **hurdle rate**. The hurdle rate is an assigned discount rate for low risk investments. Discount rates reflect both the time value of money and the risk involved in a specific project. Energy efficiency investments may often have lower risk than other investments that organizations can choose to pursue. From a strictly financial perspective, efficiency investments should therefore be evaluated using correspondingly lower discount rates. Some organizations have different hurdle rates for low, medium and high risk projects, or at a minimum consider the risk level in evaluating the project in comparison to other investment opportunities. While energy efficiency experts have confidence in the low level of risk associated with efficiency investments, many corporate leaders perceive a higher risk for energy efficiency investments than investments that are more familiar to them. For example, an executive may be more comfortable investing in building remodels that are designed to drive higher traffic and sales than investing in less familiar energy efficiency opportunities.

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

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

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

Tax rate

Some companies will want to analyze investments on a pre-tax basis and some on a post-tax basis. Whereas a post-tax analysis is more accurate, it also creates opportunities for errors if the company's tax policies are not followed precisely. If the financial manager of the company prefers a post-tax analysis, it is important to learn from finance managers how purchases for lighting and other improvements are depreciated. In particular, some purchases may qualify for a Section 179 deduction, which allows firms to deduct the full expense in the year of purchase.[2]

Depreciation

Organizations will vary in terms of which assets they choose to depreciate. The IRS guidelines, assumes five years for computers, copiers and printers, seven years for office fixtures (furniture) and equipment, and 39 years for HVAC systems.[3] In some cases, special or temporary tax treatment for some capital projects allows full **depreciation** to be taken in the same year that the investment is made—effectively treating the capital expenditure as an expense. Another example of specialized depreciation is the **Modified Accelerated Cost Recovery System (MACRS)**. Through this system, tax deductions for depreciation allow capitalized property costs to be recovered at an accelerated rate. Many renewable energy projects, as discussed in Chapter 17, are eligible for this accelerated recovery period, as well as bonus depreciation. Equipment installed before 2018 may qualify for 50% bonus depreciation, equipment installed during 2018 qualify for 40% and those installed during 2019 qualify for 30%.[4] Bonus depreciation is additional depreciation awarded beyond what is ordinarily available and is collected in the first year the depreciable item is in service. Depreciation varies significantly by the type of organization and the project specifications. Discuss the organization's specific approach to depreciation and special tax treatment with the corporate tax specialist, and keep in mind that some organizations will be tax exempt. If taxes are not included in the financial analysis, including or excluding depreciation will have no effect on the analysis, as there will be no **tax shield**.

Other financial metrics for assessing energy projects

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

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

Return on investment (ROI), the most commonly used investment metric, is a simplistic measurement that does not consider the time value of money, but does provide flexibility in what is used to determine costs and return. This flexibility depends on the underlying assumptions around those costs and returns, and ROI calculations often don't include the LCC considerations (see page 29). Given this, and the fact that ROI does not consider the time value of money, NPV or IRR are much more sophisticated and suitable measures for energy efficiency investments.

Life cycle costing—items to include

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

- Initial investment (including installation costs)
- Energy expenses avoided through the efficiency upgrade during equipment life
- Estimated maintenance expenses avoided or incurred during equipment life, including:
  - Replacement costs
  - Labor costs
  - Downtime costs

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

- Risk reduction associated with reduced exposure to volatile energy prices
- Improved lighting quality or indoor environmental quality, leading to:
  - Potential reductions in absenteeism
  - Improved safety
  - Increased productivity
- Environmental benefits, i.e. GHG emissions reductions
- Contributions to corporate social responsibility strategy and related brand enhancement and employee engagement benefits

Prioritizing efficiency investments

From a financial perspective, the most attractive investments will be those that generate the greatest cash flow in excess of the cost of capital—those with the largest NPV. Recognizing that the size of the upfront investment does have an impact on the decision, this information can be presented with a matrix that has NPV and initial investment on each axis, as represented in Figure 8.2 (page 30).

Investments with relatively low initial costs and high NPV or energy savings potential, such as "Adjust/tune HVAC controls" in Figure 8.2, should be pursued first.

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

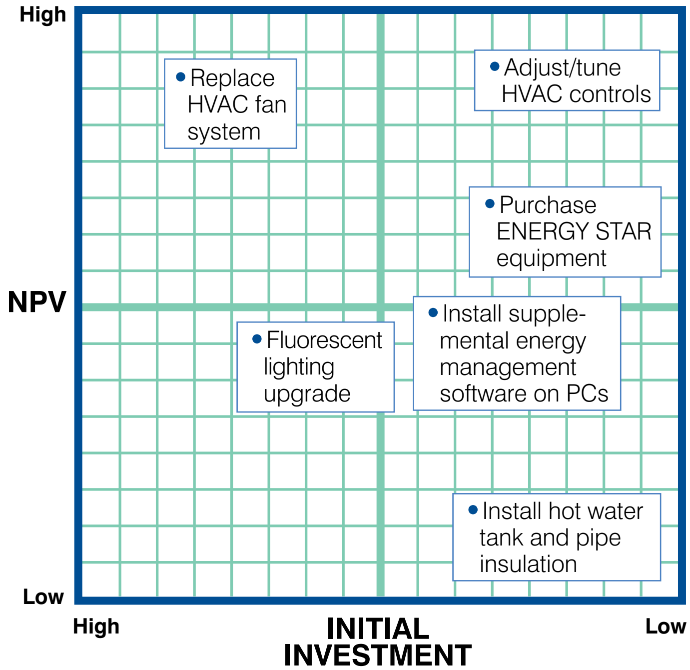
- Payback period
- NPV
- Upfront capital required
- Cost of environmental benefit (i.e. cost per metric ton of avoided CO_2e)

Navigating capital budget and expense budgets

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

FIGURE 8.2

Example prioritization matrix for potential energy efficiency investments



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

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

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

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

Similarly, the owner of the operating expense budget that would benefit from energy projects may not have a capital budget to fund those projects. Thus, organizational silos and standard budgeting and approval processes may hinder a project that the financial analysis indicates should be funded. Some common best practices that are used to overcome these issues are:

- Engage relevant financial decision makers responsible for the various aspects of financial management. This means discussing the challenges outlined above and potential approaches for overcoming those barriers with financial analysts, the CFO and capital budget directors. Identify the language, metrics and assumptions they use in financial analysis, as well as their concerns and perception of opportunities in regards to energy efficiency projects. Ensure that your financial analysis reflects an understanding of their typical approach.
- Understand the organization's financial and non-financial drivers and include information about the financial and non-financial benefits of your recommended upgrades in the project analysis.
- Present the recommendations to all financial stakeholders simultaneously and facilitate a conversation regarding the benefits and impacts of the recommendations on specific budgets, as well as the overall benefits to the organization.
- Recommend the creation of a dedicated energy efficiency capital budget, with specific expectations for returns. This budget can fund high priority capital projects. It can also close efficiency project funding gaps for departments that have budgets for basic equipment replacement, but not incremental amounts to enable the purchases of higher efficiency equipment.

Financing investments

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

Cash: Paying with cash is ideal if the investment is relatively small and the organization has a strong balance sheet. The organization can depreciate the investment and no adjustments need to be made to the base NPV analysis. Some organizations may maintain dedicated budgets for energy efficiency improvements. A **green revolving fund (GRF)** is created when savings from implemented energy management projects are cycled back to finance future energy projects, resulting in a sustainable financing program.[5] GRFs have gained momentum in the university segment and are increasingly being adapted to state governments and companies.

Debt: If the upfront cost of the investment is greater than the available cash, debt financing may be required. Debt financing means borrowing money without relinquishing ownership. Interest rates and strict conditions often accompany this form of financing. Examples of debt financing options include loans, bonds and overdraft. It may be useful to identify whether there are any below market rates available for specific energy efficiency investments. These might include financing through community development funds, special government funds or charitable funds.

Lease: Although uncommon for most energy efficiency investments, certain kinds of office equipment are often leased. Unfortunately, the leasing decision is typically independent of whether the equipment is ENERGY STAR certified. There are also some capital lease options for larger investments, which are typically related to the performance contractor model explained in the next section. Lease agreements are typically shorter than 12 years, but can last as long as 15–20 years. In a lease-purchase, the title to the equipment is held by the governmental entity; however, in the case of a true lease, the lessor holds the title until maturity. Another important distinction is between tax-exempt and commercial leases. In commercial leases, the commercial entity holds the title and the interest paid is taxed. For a tax-exempt lease, the title is held by a tax-exempt entity and interest is exempt from federal income tax. Additional information on lease financing from the Department of Energy is also available at http://www.energy.gov/eere/slsc/leasing-arrangements

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

Other: An innovative variation on debt financing is **Property-Assessed Clean Energy (PACE)** financing. PACE is a means of financing energy efficiency upgrades in which municipal governments offer a bond to investors and then loan the money to consumers and businesses to fund energy efficiency, renewable energy and water conservation investments. The loans are repaid over the assigned term (typically 15 or 20 years) through an annual assessment on their property tax bill. The loan takes the form of a transferable lien on the property, tying the financing to the property and allowing change of ownership. Given that the municipal bonds require a complex approval process and are only available in certain jurisdictions, opportunities to use PACE financing (or institution specific bond financing) are limited. They also require state legislation and local support from a taxing jurisdiction. While PACE programs are young and still face some challenges, they are becoming increasingly popular because they allow projects to be funded with no upfront costs to the owner. Further information on PACE financing can be found under the “Additional information” section at the end of this chapter.

Additionally, there are other emerging financing options such as **on-bill repayment (OBR)**, Efficiency Services Agreements and Managed Energy Service Agreements. Through on-bill repayment, the capital cost of a clean energy upgrade is paid by a third party, not the utility, and the customer repays this investment through their utility bill. In the case of service agreements, a third party assumes payment of the improved energy bill and the customer continues to pay the same utility rate. For more information on these emerging financing options, as well as performance contracting and PACE financing, see the "Additional information" section below and EDF's *Show Me the Money*.[6]

These and additional financing options for Renewable Energy Projects are detailed in Chapter 17.

Additional information

For more information on financing options, see:

- Department of Energy, "Better Buildings Financing Navigator," https://betterbuildingssolutioncenter.energy.gov/financing-navigator

For more information on PACE, see:

- Department of Energy, "Property-Assessed Clean Energy Programs," http://www.energy.gov/eere/slsc/property-assessed-clean-energy-programs
- PACE Nation, http://pacenation.us/what-is-pace/
- American Council for Energy Efficiency Economy, "PACE," http://www.aceee.org/sector/state-policy/toolkit/pace

For more information on On-bill repayment, see:

- Department of Buildings, "Bill Financing and Repayment Programs," http://www.energy.gov/eere/slsc/bill-financing-and-repayment-programs

For more information on Efficiency Service Agreements, see:

- EDF, "Need Help Funding a Retrofit? Use an Efficiency Service Agreement," http://blogs.edf.org/energyexchange/2015/05/19/need-help-funding-a-retrofit-use-an-efficiency-services-agreement/

For more information on financial incentives, see:

- Database of State Incentives for Renewables and Efficiency (DSIRE), http://www.dsireusa.org

Notes

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

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

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

4 DSIRE, "MACRS," http://programs.dsireusa.org/system/program/detail/676

5 Sustainable Endowments Institute & the Association for the Advancement of Sustainability in Higher Education, "Green Revolving Funds: .An Introductory Guide to Implementation & Management," January 2013. http://greenbillion.org/wp-content/uploads/2013/01/GRF_Implementation_Guide.pdf

6 Environmental Defense Fund, "Show Me the Money. Energy Efficiency Financing Barriers and Opportunities," July 2011. http://www.edf.org/sites/default/files/11860_EnergyEfficiencyFinancingBarriersandOpportunities_July%202011.pdf

CHAPTER 9

Benchmarking energy usage and interpreting utility bills

Goals

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

Overview

Tenants pay for electricity through one of three ways (assuming not owner operated):

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

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

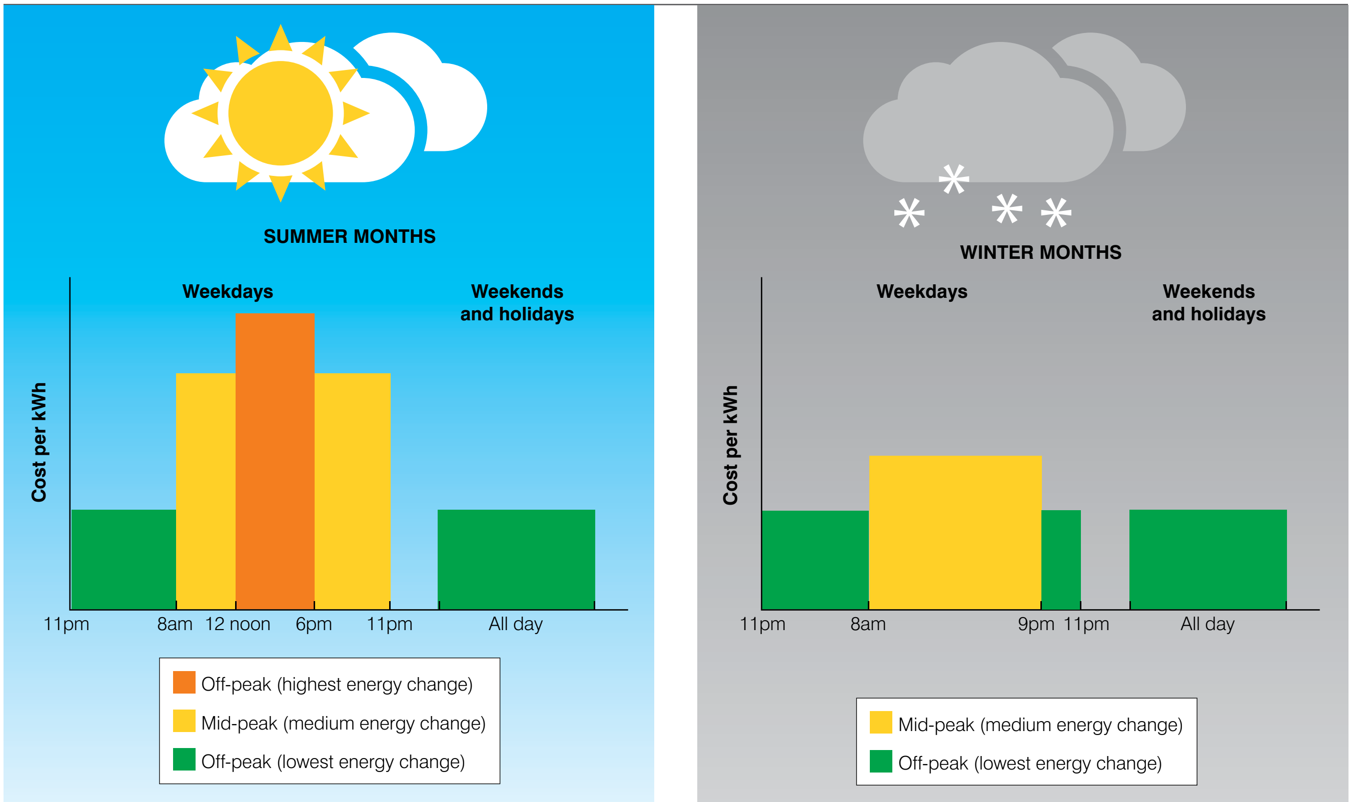
Energy and demand

This is the most common pricing scheme. The dollar amount that organizations pay at the end of each billing period is based on an energy charge and a **demand charge**. For electricity, the energy charge is based on the total amount of energy used and is measured in **kilowatt-hours** (**kWh**, a unit of work). The demand charge is based on the maximum load in **kilowatts** (**kW**, a unit of power) drawn by the organization's equipment, normally recorded over a 15-minute time interval each month. The demand charge is significant because it sets the amount of generation and transmission system capacity the utility needs to build to meet customer demand. Increased demand charge can require construction of new power plants, which is expensive and may lead to higher electricity rates for customers. For more information on demand and demand response programs, see Chapter 18.

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

FIGURE 9.1

Time of use pricing



Source: Southern California Edison

Time of use (TOU)

The **time of use (TOU)** pricing scheme is also based on energy use and demand; however, there are different rates for peak and **off-peak** demand and during different seasons. Under this scheme, electricity used during periods of highest (peak) demand will be more expensive than electricity used during periods of lower relative (off-peak) demand. In the summer months (generally June through September), there are three rate periods: off -peak, mid-peak and peak. There are only two rate periods during the winter months (generally October through May): mid-peak and off-peak. Figure 9.1 illustrates an example of TOU for a commercial building.

This pricing model encourages customers to lower energy usage during peak periods and thus save money. TOU rates, peak and seasonal timeframes vary by utility company and location, so the best way to determine TOU rates for a particular organization is to evaluate its energy bills.

Real-time pricing

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

Critical peak pricing (CPP)

Customers are notified by their electricity provider that electricity prices will peak dramatically in the near future. As a result, customers limit electricity use during these periods of inflated prices and high demand to avoid steep costs.

Critical peak rebate (CPR)

Customers receive financial compensation for reducing their energy use. Utilities pay for each kWh of reduction relative to the customers' normal peak time use. This is another method in which reductions in energy usage are encouraged through financial means.

Benchmarking energy usage

Benchmarking is the process of evaluating and comparing performance to past performance or to that of similar buildings. In the case of energy management, energy use intensity is the best measure of performance. The energy use intensity of a facility can be expressed by two values: electricity intensity and fuel intensity. To calculate these values for an office building or floor, simply divide total electricity or fuel usage of the space for one year by total square footage of office space.

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

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

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

To determine how a building performs compared to similar buildings, compare its energy use intensity values to known benchmarks for the building type and geographic area. If a given building has energy use intensity values that are higher than the benchmarks, there could be significant potential for cost-effective energy management improvements. Average intensities based on building floor space are outlined in Table 9.1. Alternative benchmarks may be found in the organization's historical records, other departments in the organization, similar outside organizations, public databases or academic papers. Determining an energy usage benchmark provides a platform for the energy management plan.

One of the most popular options for facility benchmarking is the EPA Portfolio Manager, an online tool that has been used to benchmark 250,000 commercial buildings since 2012. Portfolio

TABLE 9.1

U.S. average energy use intensities for commercial buildings

Building floor space (square feet)	Electricity intensity (kWh/square foot)	Natural gas intensity (therms/square foot)
1,001 to 5,000	17.4	66.4
5,001 to 10,000	13.3	50.2
10,001 to 25,000	11.7	33.6
25,001 to 50,000	12.8	34.0
50,001 to 100,000	14.4	33.2
100,001 to 200,000	15.3	30.1
200,001 to 500,000	16.9	36.4
Over 500,000	18.4	38.6

Source: Energy Information Administration, "Commercial Buildings Energy Consumption Survey: Table C21. Electricity consumption" and "Conditional Energy Use Intensity by Building Size and table C31. Natural Gas Consumption and Conditional Energy Use Intensity by Building Size," 2016

Manager compares input information about building characteristics and energy consumption with Commercial Buildings Energy Consumption Survey (CBECS) data. A rating of 1–100 is assessed, corresponding to a percentile rank for that building compared to similar buildings nationwide (e.g., a rating of 90 indicates that a building has better energy performance than 90% of similar buildings).

Additional information

For information on billing structure and DR programs, consult the regional utility company.

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

- Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS), 2012," released May 2016. http://www.eia.gov/consumption/commercial/reports/2012/energyusage/

For more information on EPA Portfolio Manager, see:

- EPA, "Portfolio Manager Overview," http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager

For more information on Benchmarking Energy Usage, see:

- Department of Energy, "Building Energy Use Benchmarking," http://www.energy.gov/eere/slsc/building-energy-use-benchmarking

For more information on Time of Use, see:

- EDF, "All Electricity is Not Priced Equally: Time-Variant Pricing 101," http://blogs.edf.org/energyexchange/2015/01/27/all-electricity-is-not-priced-equally-time-variant-pricing-101/?_ga=1.30986748.2137613792.1465849163

CHAPTER 10

Energy management and information systems

Goal

- To determine whether an organization could benefit from an **Energy Management Information Systems (EMIS)** installation or upgrade

Overview

EMIS manage building energy use through the combined use of hardware and software products. EMIS allow for centralized monitoring and control of energy use across building systems. The upgrades to controls for lighting, office equipment, HVAC and water heating all constitute "stand-alone" control systems (such as **photo sensor-based** dimming controls for lighting); in contrast, an EMIS 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 are called monitoring points, and serve as data inputs for the EMIS. In turn, the EMIS uses that information to adjust control points like dimmers, chillers and **boilers**. Since many sensors are proprietary, they are often not compatible with new EMIS, so it is important to replace sensors when a new EMIS is installed to ensure reading accuracy.

In recent years, EMIS technologies have become more affordable and more widely used. According to the Lawrence Berkeley National Laboratory, EMIS technologies enable 10–20% site energy savings in best practice implementations.[1]

EMIS technologies can be classified into two sections: Whole-building Level EMIS and System Level EMIS. This classification system is illustrated in Table 10.1.

TABLE 10.1

EMIS technologies

Whole-building level EMIS	System level EMIS
Benchmarking and monthly utility bill analysis	Building Automation System
Energy Information System	Fault Detection and Diagnostics
Advanced Energy Information System	Automated System Optimization

Source: Lawrence Berkeley National Laboratory, A Primer on Organizational Use of EMIS

Whole-building level

Benchmarking and monthly utility bill analysis

This method uses monthly whole-building data and is primarily historical or peer-to-peer building energy performance tracking. Software is often utilized as an analysis tool to track monthly energy use and generates additional data such as ENERGY STAR ranking, carbon footprint, cost trend data and a cost summary. This technology provides insight into energy performance for the whole building; software examples include EnergyCAP, EPA Portfolio Manager and EnergyPrint. Complete information on benchmarking and utility analysis can be found in Chapter 9.

Energy information system (EIS)

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

Advanced EIS

Advanced EIS provide further analytic data beyond basic EIS features. Advanced EIS provide a higher degree of automated analytics, in unison with baseline models that are used to normalize for time of week, weather and other significant energy drivers. These models can then be applied to perform automated energy anomaly deductions, project savings verification and sum energy savings overtime. EIS vendors include EnerNOC, EFT Energy Manager and EnergyICT EISever.

System level

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

Facilities managers and energy efficiency engineers may also refer to **building management systems (BMS)** or **building automation systems (BAS)**. BAS maintain humidity, ventilation, indoor temperature and lighting. They also provide storage, reporting, visualization and trend logging in more modern systems. Key performance metrics can also tracked by this system in relation to energy management and routine operations. BAS vendors include Siemens APOGEE, Johnson Controls Metasts and Novar Opus EMS.

Fault Detection and Diagnostics (FDD)

Fault Detection and Diagnostics (FDD) tools automatically identify HVAC system or equipment performance problems and often provide probable root causes and recommendations for correction. FDD tools often incorporate BAS data, as well as submeter and whole-building data. Common methods used by FDD tools include rule-based systems, like-equipment comparisons and models that use historical data to characterize typical performance. FDD vendors include Johnson Control Panoptix, Schindler Electric Building Analytics and Cimetrics Analytika Pro.

Automated System Optimization (ASO)

Automated System Optimization (ASO) tools adjust BAS control settings to optimize HVAC system energy usage and retain occupant comfort. ASO tools are characterized by their two-way communication with BAS; they not only read BAS data, but also send adjusted setpoints back to the BAS. An ASO tool's primary goal is not to achieve the highest efficiency of individual equipment; it is to achieve minimum energy cost, use or demand of the entire system. ASO vendors include BuildingIQ and Optimum OptiCX.

Additional Energy Management System options

New EMIS installation/retrofit upgrade

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

According to the California Energy Commission (CEC), any building with a peak demand over 200 kW should consider employing an EMIS.[2] Additionally, if an existing EMIS is over 12 years old, full system replacement should be considered.[3] If an organization currently employs an EMIS that has been installed within the last 12 years, it may still be advantageous to undertake a retrofit upgrade to a more sophisticated system. However, an EMIS retrofit could be as simple as installing and connecting additional sensor and control points to the existing system and reprogramming the software to incorporate the added equipment.

Selecting the correct system for a given building requires considering the needs and capabilities of the organization's operations staff. Clearly, an organization should not invest in a system with features it is unlikely to fully utilize; the best EMIS should maximize energy savings potential per dollar invested. An EMIS specialist can advise on the feasibility of retrofit upgrades, as well as present a range of installation or upgrade options accompanied by estimates of energy savings potential and installation cost. These estimates, along with knowledge of organization needs, can provide the basis for analysis of whether an EMIS installation or upgrade will be cost effective, and if so, what level of system is best for the organization.

Additional information

For additional information on Energy Management and Information Systems see:

- Department of Energy and Lawrence Berkeley National Laboratory, "A Primer on Organizational Use of Energy Management and Information Systems," https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/A_Primer_on_Organizational_Use_of_EMIS_V1.1.pdf

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

- California Energy Commission, "Enhanced Automation: Technical Options Guidebook," Section 5, Energy Management Systems, http://energy.ca.gov/reports/2002-05-15_400-02-005F.PDF
- California Energy Commission, "Enhanced Automation: Business Case Guidebook," http://energy.ca.gov/reports/2002-06-20_400-02-005F.PDF

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

- California Energy Commission, "Enhanced Automation: Technical Options Guidebook," Section 6, Energy Information Systems, http://energy.ca.gov/reports/2002-05-15_400-02-005F.PDF

Notes

[1] Lawrence Berkley National Laboratory, "A Primer on Organizational Use of Energy Management and Information Systems (EMIS)," November 2015, https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/A_Primer_on_Organizational_Use_of_EMIS_V1.1.pdf

[2] California Energy Commission, "Technical Options Guidebook," http://www.energy.ca.gov/reports/2002-05-15_400-02-005F.PDF

[3] California Energy Commission, "Business Case Guidebook," http://www.energy.ca.gov/reports/2002-06-20_400-02-005F.PDF

CHAPTER 11

HVAC (heating, ventilation and air conditioning)

Goals

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

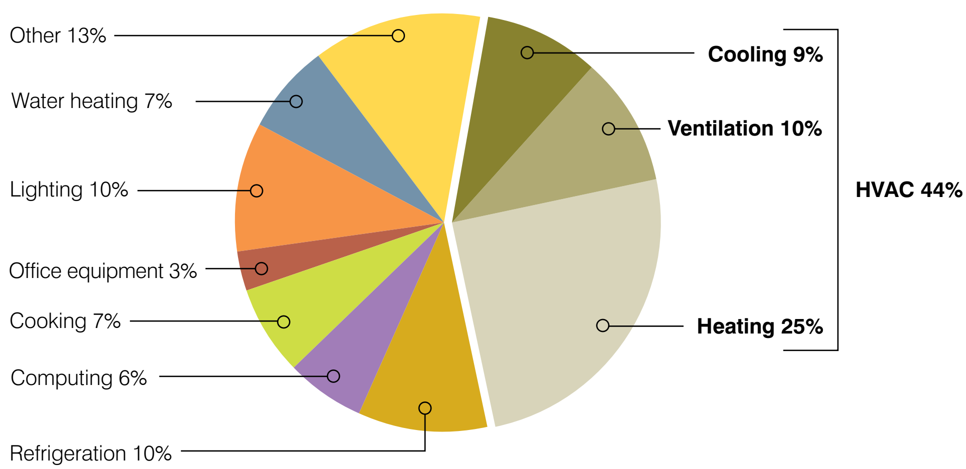
Overview

Building 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, about 44% on average in commercial buildings in the U.S. (25% heating, 10% ventilation, 9% 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 effect of office

FIGURE 11.1

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



Source: U.S. Energy Information Administration, "Commercial Buildings Energy Consumption Survey, 2012," 2016 equipment, lighting, water heaters and people within the building. Additionally, HVAC systems often operate at high levels during periods of regional **peak load** (for example, hot summer days) when electricity prices are highest, which can significantly increase an organization's power costs.

HVAC designs vary widely across building types. Standard HVAC systems are considered "active" technologies, which require energy input to drive mechanical equipment. Components of a typical system include chillers, boilers, air ducts, fans and heat exchangers. Passive heating and cooling technologies include natural ventilation, evaporative cooling systems and radiant heating and cooling systems. Since they use on-site energy instead of mechanical systems, passive technologies are typically more energy efficient than active technologies. However, they are rarely implemented into existing buildings; instead, they are most effective when incorporated directly into the design and construction stages of new buildings.

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

Like lighting quality, HVAC performance is vital 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. Note, costs and energy savings for HVAC efficiency measures vary widely depending on building characteristics.

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 (e.g. occupancy, temperature settings)

3. Calibrate and tune system controls

4. Consider upgrading HVAC equipment

Tactics for reducing energy use

▶ 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

See Appendix F for a financial case study on HVAC retrofitting.

Efficiency tune-ups

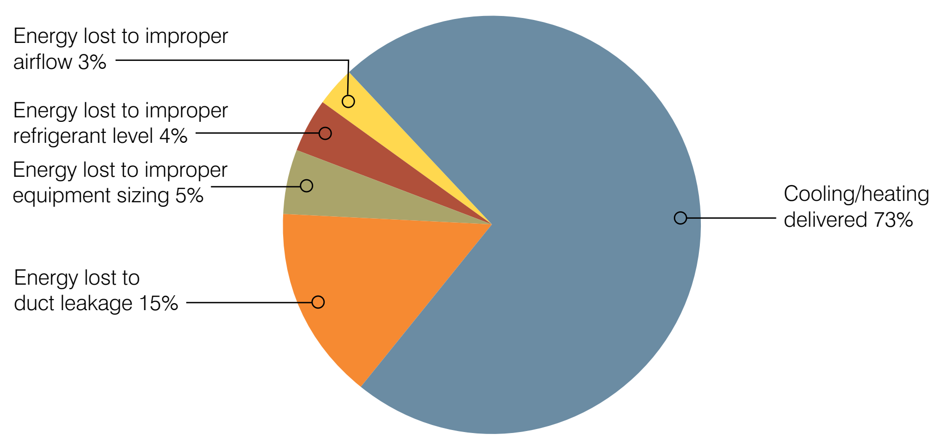
Complete envelope upgrades. An energy efficiency engineer can evaluate whether upgrades to the **building envelope** can reduce heating/cooling load. Envelope upgrades include:

- 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 $5–7 per square foot with labor. Window films have a typical lifetime of ten to fifteen years.[3]

Tune/install thermostat controls. An HVAC engineer should compare a building's heating/cooling patterns with its occupancy schedule to determine whether controls can be adjusted to reflect occupancy. Additional savings can be accomplished through the installation of combined automated control systems for HVAC and lighting (see Chapter 10). HVAC and lighting can then be continuously monitored and adjusted based on occupancy and the environment. An HVAC engineer should evaluate the feasibility of preheating or pre-cooling

FIGURE 11.2

Estimated energy usage of typical air conditioner or heat pump



Source: ENERGY STAR, "Quality Installation: Heating & Cooling," 2009 the building at night using off-peak electricity. A complete breakdown of the different areas of HVAC energy consumption can be found in Figure 11.2 (page 44).

Equipment replacement/purchasing

Full replacement of up-to-date HVAC systems is unlikely to be cost-effective if undertaken solely to increase energy efficiency. However, many modern buildings are operating with outdated and inefficient HVAC systems. Upgrading an older system to a higher efficiency system should be considered, particularly if the building in question has experienced HVAC performance problems. The principle objectives of HVAC upgrades are to improve year-round occupant comfort and convenience and achieve higher energy efficiency with lower operational costs. Often HVAC upgrades can be made by replacing certain components of the existing HVAC system or purchasing and installing equipment that can be integrated into the system.

Install outside air economizers. Air-side economizers use a damper to control intake of outside air. When outside air is cooler than return air, the damper adjusts to maximize air intake; when outside air is warmer, the damper reduces outside air intake to the minimum required by building codes.[4] Air-sized economizers can also be used to pre-cool buildings at night.

Correctly size and retrofit HVAC fan systems. Fan systems (which distribute heated or chilled air throughout a building) are often more economical to replace than the heating and chilling equipment. Building maintenance staff can often identify opportunities to replace oversized fans but it will normally be necessary to contract with an HVAC engineer to conduct a more detailed analysis and make recommendations for optimizing the system.[5]

Constant volume fan systems circulate a set volume of air and regulate temperature through heating or cooling air. They 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%.[6]

A VAV system can be retrofitted to control fan speed using a **variable-frequency drive (VFD)**, also called variable speed drive or adjustable speed drive. VFDs vary fan speed according to need, resulting in energy savings during reduced fan speeds. A recent EPA study found that installing a VFD in an existing VAV system achieved a mean savings of 52% in fan system energy requirements.[7] See Appendix F for a financial case study on replacing and updating HVAC equipment.

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

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

When feasible, replace outdated or highly inefficient HVAC systems or components. “Reheat systems,” which cool and circulate a set amount of air and then reheat the cooled air as necessary to achieve desired temperatures, and “multi-zone systems,” which mix cooled and heated air to produce desired air temperatures, are extremely inefficient. An HVAC engineer can consult on the feasibility of converting these types of systems to more efficient ones. Mechanical components such as boilers, motors, fans and heat pumps should be individually evaluated for efficiency and need for replacement. More information on efficiency evaluations and standards is located in the Additional Information section below.

Additional information comparing packaged AC units and centralized HVAC units can be found in Appendix B.

Additional information

For more information on maintenance and commissioning, see:

- U.S. EPA, "ENERGY STAR Building Upgrade Manual—Recommissioning," October 2007. https://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_CH5_RetroComm.pdf
- Ellicott and Rothstein, National Conference on Building Commissioning, "Procuring Commissioning Services—Who, When, and How," May 2005. http://www.bcxa.org/ncbc/2005/proceedings/11_Ellicott_NCBC2005.pdf

For more information on building envelope upgrades, see:

- U.S. EPA, "ENERGY STAR Building Upgrade Manual—Reducing Supplemental Loads." August 2007. https://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_CH7_SupLoads.pdf

For more information on heating and cooling systems, see:

- U.S. EPA, "ENERGY STAR Building Upgrade Manual—Heating and Cooling," January 2008. https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/comprehensive-approach/energy-star
- UC Davis, "Best Practices in Small Commercial HVAC Programs," https://eec.ucdavis.edu/files/03-25-2013-Best-Practices-in-Small-Commercial-HVAC-Programs-1.pdf

For more information on HVAC components (boilers, motors, pumps and fans), see:

- U.S. Department of Energy, "Boilers and Furnaces," https://energy.gov/energysaver/furnaces-and-boilers
- U.S. Department of Energy, "Premium Efficiency Motor Selection and Application Guide," https://energy.gov/sites/prod/files/2014/04/f15/amo_motors_handbook_web.pdf
- U.S. Department of Energy, Appliance and Equipment Standards, "Pumps," https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=41&action=viewlive
- AMCA, "Fan Efficiency Standards for Commercial and Industrial Buildings," http://www.amca.org/UserFiles/file/FEG%20PDF%20for%20AHR%20Expo%202014%20(2).pdf

Notes

[1] Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS)" Table E1. Major Fuel Consumption (BTU) by End Use, 2012, May 2016. http://www.eia.gov/consumption/commercial/data/2012/c&e/pdf/e1.pdf

[2] U.S. EPA, "ENERGY STAR Building Upgrade Manual: Retrocommissioning: Supplemental Loads," October 2007. https://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_CH5_RetroComm.pdf

[3] Tint Industry—Commercial, January 2011. http://tintindustry.com/commercial-window-tinting.html

[4] U.S. EPA "ENERGY STAR Building Upgrade Manual—Air Distribution Systems," April 2008. https://www.energystar.gov/buildings/tools-and-resources/energy-star-building-upgrade-manual-chapter-8-air-distribution-systems

[5] U.S. EPA "ENERGY STAR Building Upgrade Manual—Air Distribution Systems: Right Size Fans," April 2008. https://www.energystar.gov/buildings/tools-and-resources/energy-star-building-upgrade-manual-chapter-8-air-distribution-systems

[6] U.S. EPA "ENERGY STAR Building Upgrade Manual—Air Distribution Systems: Variable Air Volume System," April 2008. https://www.energystar.gov/buildings/tools-and-resources/energy-star-building-upgrade-manual-chapter-8-air-distribution-systems

[7] U.S. EPA "ENERGY STAR Building Upgrade Manual—Air Distribution Systems: Variable -Speed Drives," April 2008. https://www.energystar.gov/buildings/tools-and-resources/energy-star-building-upgrade-manual-chapter-8-air-distribution-systems

CHAPTER 12

Lighting in commercial buildings

Goals

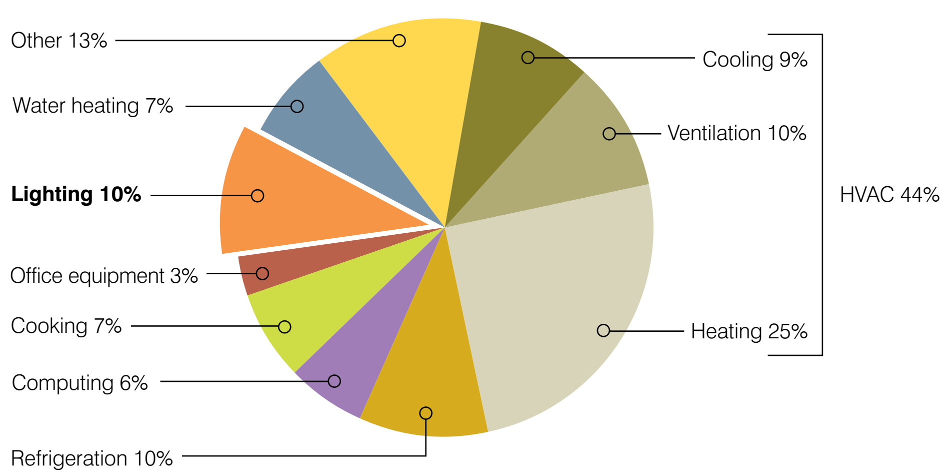
- Uncover lighting energy savings opportunities by identifying locations that are overlit, unoccupied locations that are lit and areas where lighting sources can be replaced with lower wattage alternatives
- Develop estimates of energy usage and calculate the estimated savings potential of installing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

Overview

On average, lighting consumes 10% of the energy used by commercial buildings in the U.S.[1] While commercial buildings have reduced lighting energy consumption in recent years, there are still many opportunities to further reduce consumption. Poor control schemes, lighting of unoccupied space, lack of daylight harvesting and over-illumination all contribute to higher than necessary energy demand. In addition to energy inefficiencies for general illumination, all lighting sources (incandescent, fluorescent metal halide, etc.) produce latent heat, which can be a major contributor to a building's cooling load. Therefore, improvements in lighting system efficiency not only decrease energy costs associated with lighting, but can also reduce energy costs associated with HVAC and building cooling systems.

FIGURE 12.1

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



Source: U.S. Energy Information Administration, "Commercial Buildings Energy Consumption Survey, 2012" 2016

The efficiency of a lighting system can be increased through:

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

Tactics for reducing energy use

Policy and process changes

Train/educate staff to turn off lights. Processes and policies that prevent lights from being left on when spaces are vacant are simple, no-cost efficiency upgrades that organizations can easily institute. Determine which users of the space are responsible for turning lights on and off at different times of the day/week and ensure those tasks have been adequately communicated. Increased communication and coordination among office managers, office staff and cleaning crews can result in decreased energy consumption. Installing a master switch that can simultaneously turn off all lights on a floor will make it easier to ensure that all lights are off at the end of the occupancy period.

Incorporate task lighting. **Task lighting** targets a specific area in a room in order to provide illumination where it is most needed, such as paper documents or work spaces. Because it is located closer to where light is most needed, it tends to be more efficient than the most energy efficient ceiling ambient lights. In addition, individual workers have more control over task lighting and can adjust it as needed for the task being completed. Incorporating adjustable task lighting in addition to low ambient light can:

- Improve lighting quality, comfort and control for workers
- Reduce unnecessary or ineffective lighting
- Reduce lighting costs

Practice regular lighting maintenance. It is important to ensure that a regular maintenance and cleaning schedule is in place for existing light fixtures, **reflectors**, **diffusers** and **lenses**.

Lighting control efficiency measures

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

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

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

A lighting specialist can provide guidance on the appropriate time clocks and occupancy sensors for a given space, but generally 24-hour time clocks can be used where occupancy patterns are similar throughout the week and weekend, whereas seven-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.

Installing occupancy sensors can save significant amounts of energy in spaces that are often unoccupied or occupied unpredictably, such as stairwells, restrooms and conference rooms. They are especially effective during the night and early morning when buildings have significant unoccupied space that does not require lighting. To avoid performance problems, occupancy sensors must 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. According to a Rutgers University study of New Jersey municipal buildings with occupancy sensors, average payback periods (before any state or local rebates are considered) ranged from one to just over two years.[3]

TABLE 12.1

Estimated energy savings achieved via occupancy sensors

Type of room	Energy savings (%)
Breakroom	29%
Classroom	40–46%
Conference room	45%
Corridor	30–80%
Office, private	13–50%
Office, open	10%
Restroom	30–90%
Storage area	45–80%
Warehouse	35–54%

Source: U.S. Department of Energy, "Wireless Occupancy Sensors for Lighting Controls," March 2016

Install photo sensors, dimmable **ballasts** and dimming controls in indoor zones that have natural daylight. Full-power artificial lighting is often unnecessary in areas that receive good natural daylight. Photo sensors are electronic control units that automatically adjust the output level of electronic lights based on the amount of ambient daylight detected. A continuous dimmer controlled by a photo sensor reduces artificial lighting by depending on daylight to maintain an optimum light level. Energy and cost savings will vary widely depending on natural light availability.

Both manual and automatic electric lighting **dimming controls** not only reduce energy, but also provide flexibility in providing a middle ground between on and off. Fluorescent lamps can be dimmed when fitted with dimming ballasts. Low-voltage **tungsten halogen** bulbs are dimmed with low-voltage dimming controls. **Light emitting diodes (LEDs)** require a dimming power supply in combination with LED dimming controls. Dimmable ballasts operated in conjunction with photo sensors or other control devices achieve a gradual, controlled change in lamp output.

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

Lighting source efficiency upgrades

Upgrading to more efficient lighting sources often yields the most significant efficiency gains in building lighting. Outdated lighting includes incandescent and **T12** linear fluorescents. Replacing them with modern, more efficient sources like **T8** or **T5** linear fluorescents, **compact fluorescent lamps (CFLs)**, LEDs and **high intensity discharge (HID)** lamps will reduce lighting energy costs. For background information on lighting types, consult Appendix C.

Replace T12 and first generation 32-watt linear fluorescent lamps with newer generation T8 linear fluorescents lamps and high efficiency ballasts or LED linear tubes. T8 linear fluorescents (narrower in diameter and more efficient than T12 linear fluorescents) are the standard lighting source used in most commercial buildings constructed after 1995. Much less efficient T12 lamps may still be in use in older buildings and should be upgraded to T8s.

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

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

The original generation T8 lamps consumed 32 watts; today many manufactures have T8 lamps that only require 27 or 28 watts to produce the same output. These bulbs are interchangeable in most fixtures, so making a practice to only buy 27-watt lamps is an easy way to save 15% with no added costs. Note that 32-watt lamps are still common and are still manufactured. Future purchases of 32-watt lamps can be prevented by identifying 32-watt lamps in current inventory and changing the part numbers for any upcoming purchase orders.

LED versions of T5, T8 and T12 lamps have recently been released to replace the fluorescent versions of these lamps. LEDs do not contain mercury, making them safer for the environment and have both dimmable and directional capabilities. T8 LED bulbs are about 30% more efficient than T8 linear fluorescent lights and the LED alternative has an average life of 50,000 hours, compared to an average life of 30,000 hours. While the cost of T8 LEDs are three to five times greater than their fluorescent alternatives, the tax incentives, rebates and energy savings make them an overall smart investment.[4]

Remove unnecessary light fixtures. Incentives may be available for de-lamping or permanently removing unnecessary light fixtures. Most utilities with an incentive program will offer a specific dollar amount for each fluorescent lamp that is permanently removed.[5] Because newer 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 retrofit. However, be aware of building code requirements for lighting minimums when designing a de-lamping plan.

Replace incandescent lamps with comparable CFLs or LEDs. CFL and LED lamps are not only more energy efficient than incandescent lamps, their lifespans are significantly longer than that of an incandescent. This means that replacement of incandescents with CFLs or LEDs will not only result in energy savings but reduced maintenance and cooling costs as well. A typical incandescent bulb loses 95% of its energy in waste heat and has an expected lifespan of 1,000 hours. CFLs, which are designed to be compatible with traditional incandescent fixtures, are 60–75% more efficient than comparable incandescent lamps and have an expected lifespan of up to 10,000 hours. LEDs have an impressive expected life of between 25,000 and 50,000 hours and use 25–30% of the energy of comparable incandescents.[6] As they also continue to drop in price, it is clear to see why LEDs are becoming a much more attractive option for retrofits.

In particular, LEDs have become standard for replacement of exit signs, because although exit signs draw a relatively low wattage, they are never turned off. The long life of an LED provides the added benefit of increased safety and reduced maintenance.

FIGURE 12.2

Comparison of bulb types

ENERGY USE AND ENERGY COST PER YEAR

LEAST EFFICIENT → MOST EFFICIENT

	YOU USED TO BUY	YOUR CHOICES NOW		
	Standard incandescents	New halogen incandescents	CFLs	LEDs
LESS BRIGHT 450 lumens	40W $5.34/yr	29W $3.87/yr	10W $1.34/yr	5W $0.67/yr
800 lumens	60W $8.02/yr	43W $5.74/yr	13W $1.74/yr	10W $1.34/yr
1100 lumens	75W $10.02/yr	53W $7.08/yr	16W $2.14/yr	15W $2.00/yr
MORE BRIGHT 1600 lumens	100W $13.36/yr	72W $9.62/yr	20W $2.67/yr	19W $2.65/yr
	Typical life = 1 yr	Typical life = 1–2 yrs	Typical life = 10 yrs	Typical life = 15–25+ yrs

RATED LIFE IS BASED ON 3 HOURS OF USE PER DAY

Source: NRDC, "Light Bulb Buying Guide"

CFLs and LEDs come in a variety of shapes and sizes and can serve many different lighting needs, so they are both viable replacements in almost all lighting applications. LEDs emit light in a specific direction, so the use of LEDs reduces the need for reflectors and diffusers. Recent and continuing advances in technology allow LEDs to be dimmed and to provide color control as well.

The typical payback for replacement of incandescent bulbs with comparable CFLs is under six months. Typical payback for replacement of incandescent bulbs with comparable LEDs is seen anywhere from six months to four years, depending on the specific application. Payback for the replacement of incandescent exit signs with LED exit signs is typically less than one year.[7] See Figure 12.2 for an illustration of bulb purchase and operating costs.

To generate more specific payback estimates for light bulb savings, consult the EPA ENERGY STAR calculator at https://www.energystar.gov/ia/partners/promotions/change_light/downloads/bulb.html

Upgrade outdoor lighting by installing bi-level controls or replacing incandescent fixtures with pulse-start HID lamps or LED fixtures. HID lamps and LEDs provide energy savings greater than 50% over incandescent sources and are well suited to outdoor applications.

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

In a typical dimming request, there is one step between two settings—bright to dim—which is why the dimming system is called "two level" or "bi-level." Tri-level dimming systems, which can operate at three fixed levels, are also an option.

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

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

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

HID and LED prices vary broadly depending on application, but are generally significantly more expensive to purchase than comparable incandescent lamps. Most utilities with an incentive program offer reasonable rebates for the replacement of incandescent or HID fixtures with LED fixtures. Despite the high incremental cost of HID and LED fixtures, the wattage reductions achieved are significant enough to keep payback under two years, before any state or local rebates are considered.[8]

Additional information

For a general lighting guide, see:

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

For more information on occupancy sensors, see:

- Ernest Orlando Lawrence Berkley National Laboratory, "A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings," https://eetd.lbl.gov/publications/meta-analysis-energy-savings-lighting-controls-commercial-buildings
- U.S. Department of Energy, "Lighting Controls," https://energy.gov/energysaver/lighting-controls
- Wisconsin Public Service, "Lighting Tips," http://www.wisconsinpublicservice.com/home/

For more information on dimmable ballasts, see:

- Lawrence Berkley National Lab, "Retrofit Fluorescent Dimming With Integrated Lighting Control Economic and Market Considerations," http://www.energy.ca.gov/2005publications/CEC-500-2005-141/CEC-500-2005-141-A05.PDF
- Lighting Controls Association, "The Next Generation of Electronic Lighting Systems: Smaller, Smarter and Greater Energy Savings," http://lightingcontrolsassociation.org/

For more information on photo sensors, see:

- U.S. EPA, "ENERGY STAR-Learn About CFLs," https://www.energystar.gov/products/lighting_fans/light_bulbs/learn_about_cfls#how_work
- U.S. DOE Federal Energy Management Program, "Energy Cost Calculator for Compact Fluorescent Lamps," https://energy.gov/eere/femp/maps/energy-cost-calculator-compact-fluorescent-lamps

For more information on HID lamps, see:

- Lighting and Daylighting: High-Intensity Discharge Lighting, https://energy.gov/eere/energybasics/articles/high-intensity-discharge-lighting-basics

- Lighting Research Center, "Lighting Answers: Mid-wattage Metal Halide Lamps," http://www.lrc.rpi.edu/programs/nlpip/lightinganswers/mwmhl/differenceprobepulse.asp

For more information on LEDs, see:

- U.S. Department of Energy, "LED Basics," https://energy.gov/eere/ssl/led-basics
- U.S. Department of Energy, "Using LEDs," https://energy.gov/energysaver/led-lighting
- ENERGY STAR, "Learn about LEDs," https://www.energystar.gov/products/lighting_fans/light_bulbs/learn_about_led_bulbs

Notes

1 Energy information Administration, "Commercial Buildings Energy Consumption Survey (CBECS)," Table E1. Major Fuel Consumption (Btu) By End Use for All Buildings, 2012, May 2016. http://www.eia.gov/consumption/commercial/data/2012/c&e/pdf/e1.pdf

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

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

4 Premier Lighting, "Should you Replace your T8 Fluorescent Lights with T8 LED Tubes?" July 2015. http://www.premierltg.com/should-you-replace-your-t8-fluorescent-lamps-with-t8-led-tubes-2/

5 PG&E, "Business Rebates & Incentives Information," http://www.pge.com/en/mybusiness/save/rebates/index.page

6 Department of Energy, "Energy Saver," https://energy.gov/energysaver/lighting-choices-save-you-money

7 Estimate generated using EDF Climate Corps Financial analysis tool

8 Estimate generated using EDF Climate Corps Financial analysis tool

CHAPTER 13
Water heating

Goals

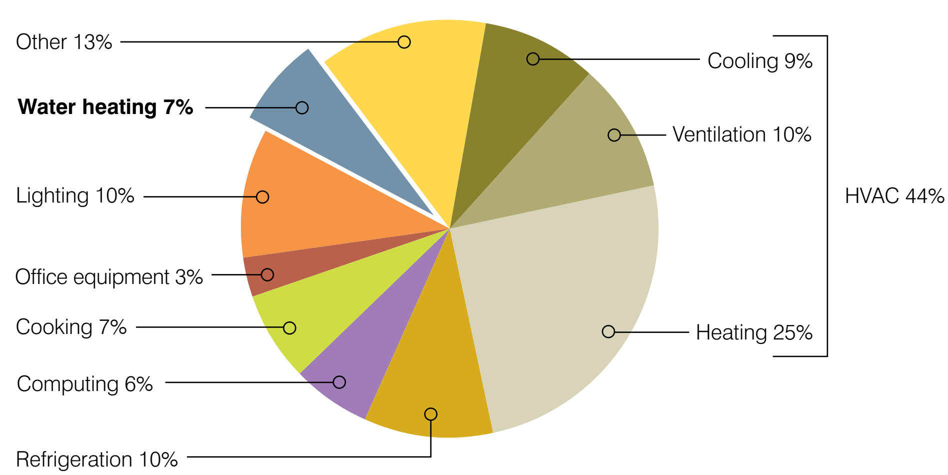
- Determine whether the organization has potential to benefit from reduced energy costs through increases in water heating efficiency
- Determine whether the water heating system is aligned correctly with hot water applications and demand
- Develop estimates of energy usage from water heating and calculate estimated savings potential of efficient use upgrades and heating equipment upgrades
- Understand solar water heaters and determine whether they are a viable heating alternative

Overview

Water heating accounts for 7% of the energy consumed by an average commercial building.[1] Many organizations may be wasting money by heating water unnecessarily. Common water wasting practices include heating water at a temperature that is too hot for daily applications and owning an oversized water heater. 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 13.1

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



Source: U.S. Energy Information Administration, “Commercial Buildings Energy Consumption Survey, 2012” 2016

The energy costs of heating water tend to be low relative to the costs of HVAC and lighting. 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 when organizations use heated water, they often pay for it in three separate ways: water use, energy and sewage disposal. Therefore, measures taken to reduce heated water use will often result in more than just energy savings.

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.

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. By one estimate, every 10°F reduction in hot water temperature can save 3-5% of water heating costs.[2] An energy efficiency consultant can determine the appropriate temperature setting for a specific application. Table 13.1 gives an estimate of temperatures required for a range of applications.

Install pipe and water tank insulation. Pipe and tank insulation reduces standby heat loss from hot water, reducing energy required to maintain the correct water temperature. Energy saved with pipe and tank insulation varies widely depending on application, but can be estimated for a specific building by an energy efficiency engineer. 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. 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 volume of hot water consumed, resulting in reduced energy used in heating water. 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[4] and super-efficient showerheads have flows of 0.5–1.5 GPM.[5]

TABLE 13.1

Hot water temperatures required for given activities

	TEMPERATURE	
Use	**°F**	**°C**
Handwashing	105	40
Showers and tubs	110	43
Commercial and industrial laundry	160–180	71–82
Residential type dishwashing and laundry	140	60
Commercial spray type dishwashing-wash	150 minimum	65 minimum
Commercial spray type dishwashing-final rinse	165–195	73–90

Sources: The Engineering ToolBox, Hot-Water Temperatures, and NSF Recommended Field Evaluation Procedures for Commercial Warewashing Machines, Hot Water Sanitizing Specifications

Additional information on maximum flow rate restrictions can be found on EPA's website at https://www3.epa.gov/watersense/docs/matrix508.pdf

In addition to energy savings from avoided water heating, installation of both low-flow fixtures and automatic sensor controls will result in savings from reduced water use. According to Greener Buildings, a resource center for environmentally responsible building, "In a typical 100,000-square-foot building, low-flow fixtures coupled with sensors and automatic controls can save a minimum of one million gallons of water per year, based on 650 building occupants each using an average of 20 gallons a day."[6]

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

▶ Equipment upgrades

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

Correctly size water heater for organization needs. The organization may be operating with a larger-than-necessary water heater. An energy efficiency consultant can evaluate the heater size required to meet hot water demand. The hot water needs of a typical office building are two gallons per person per hour (maximum), and five gallons per person per day (on average).[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] It is important to note that water heater efficiency is expressed in a different unit than commercial efficiency: energy factor (EF), which ranges from 0.00 to 1.00 (higher values indicate higher efficiency). EF is a combined measurement of thermal efficiency and standby loss.

Typical oil and gas-fired heaters have thermal efficiencies of ~80%, but can reach up to 95%. Gas-condensing water heaters are more efficient than traditional gas-fired heaters because they can increase thermal efficiency by up to 20%. Electric water heaters typically have a thermal efficiency of 98%.

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. Tankless heaters are typically more expensive than comparable storage type heaters. Consult with an energy efficiency engineer for an estimate of efficiency gains, costs and payback period and look for rebates based on location. For example, PG&E will rebate $1.00/therm saved for customized water heating efficiency projects.[9]

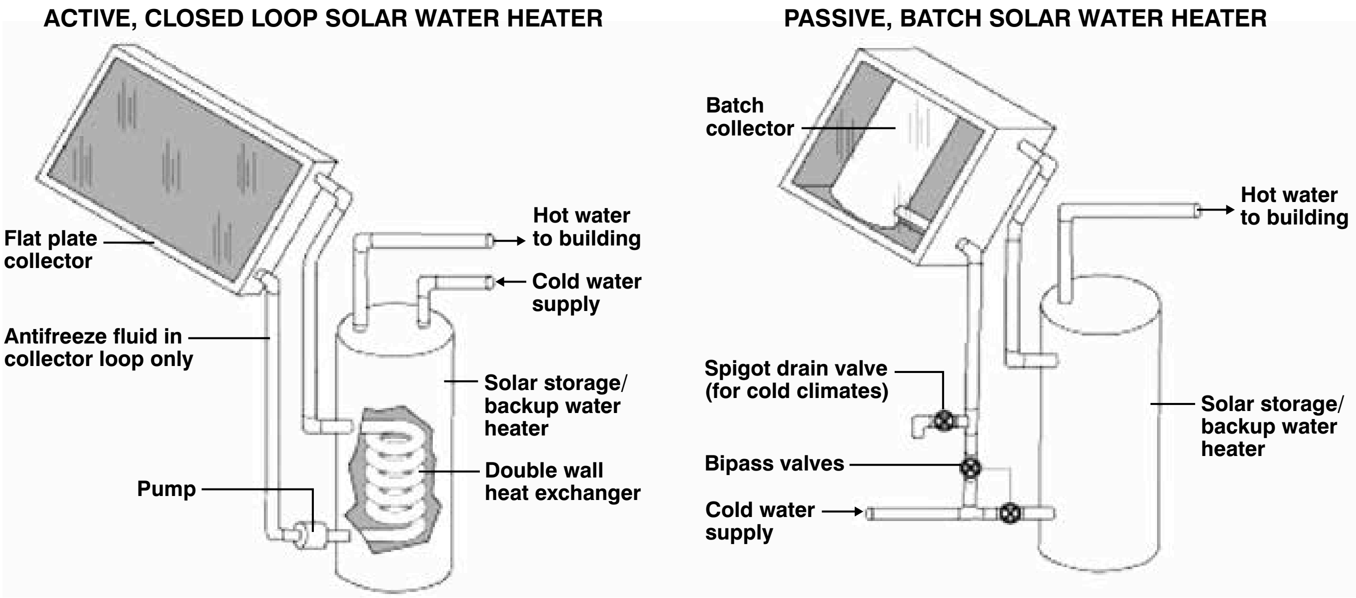
▶ Solar water heating

One cost-effective alternative is to implement a solar water heating system. This method harnesses solar energy to generate thermal energy and heat water. Since the sun serves as the heat source, this system is applicable virtually everywhere. Solar water heating offers financial savings by cutting water heating costs 50–80% on average. They are durable as well, lasting up to 25 years with little maintanence.[10] Solar heating systems are comprised of solar collectors and storage tanks and are designed in two forms: active and passive.

Active solar heating: Systems circulate pumps and controls. This additional equipment enhances the heater's efficiency when converting solar energy to heat and electric power.

FIGURE 13.2

Active and passive solar water heating systems



Source: Department of Energy, Solar Water Heaters

In direct circulation systems, water is circulated through the system and directly heated by the sun. Indirect circulation systems include a heat exchanger where a nonfreezing fluid circulates through the system and transfers the heat to the water via the exchanger. These systems are more suitable for colder climates, where the temperatures drop below freezing.

Passive solar heating: These systems do not contain any mechanical equipment. Integral collector-storage passive systems and thermosyphon systems are available. In integral systems, the tank and collector are combined to form a batch heating system. In thermosyphon systems, water circulates based on natural convection.

Consult with an energy efficiency engineer for an estimate of installation costs and payback period. Solar water heaters may be eligible for a 30% federal tax credit. Rebates are available, but dependent on location. For example, PG&E will rebate up to $800,000 for solar water heating projects in businesses.[11]

Additional information

For more information on solar water heaters, see:

- ENERGY STAR, "Solar Water Heaters," https://www.energy.gov/energysaver/solar-water-heaters
- Department of Energy, "Solar Water Heaters," https://www.energystar.gov/products/water_heaters/water_heater_solar

For more information on Solar Heating financing and savings, see:

- Department of Energy, "Estimating the cost and energy efficiency of a solar water heater," https://www.energy.gov/energysaver/estimating-cost-and-energy-efficiency-solar-water-heater
- ENERGY STAR, "Save Money and More with ENERGY STAR Qualified Solar Water Heaters," https://www.energystar.gov/products/water_heaters/water_heater_solar/benefits_savings

Notes

[1] Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS)," Table E1. Major Fuel Consumption (BTU) by End Use, 2012, May 2016. http://www.eia.gov/consumption/commercial/data/2012/c&e/pdf/e1.pdf

[2] Department of Energy, "15 Ways to Save on Your Water Heating Bill," October 2009. http://energy.gov/energysaver/articles/15-ways-save-your-water-heating-bill

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

[4] Department of Energy, "Best Management Practice #7: Faucets and Shower Heads," http://energy.gov/eere/femp/best-management-practice-7-faucets-and-showerheads

[5] AM Conservation Group, Inc., "High Efficiency Shower Heads," October 2014. http://www.amconservationgroup.com/categories/water-conservation-products/showerheads/

[6] Greener Buildings, "Water Use Backgrounder," May 2004.

[7] The Engineering ToolBox, "Water Consumption per Occupant," February 2016. http://www.engineeringtoolbox.com/hot-water-consumption-person-d_91.html

[8] Department of Energy EERE News, "Residential Water Heaters Key Product Criteria," http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters

[9] PG&E, "Business Rebates and Incentives Information," http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/

[10] PG&E, "Solar Water Heating," https://www.pge.com/en_US/residential/solar-and-vehicles/options/solar/water-heating/water-heating.page

[11] Ibid.

CHAPTER 14

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

Goals

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

Overview

In a typical commercial building in the U.S., 9% of energy is used for office equipment, including computers, monitors, printers, copiers and vending machines. In an office building, however, office equipment accounts for a larger portion of energy consumption—16% on average.[1] Waste heat from office equipment 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.

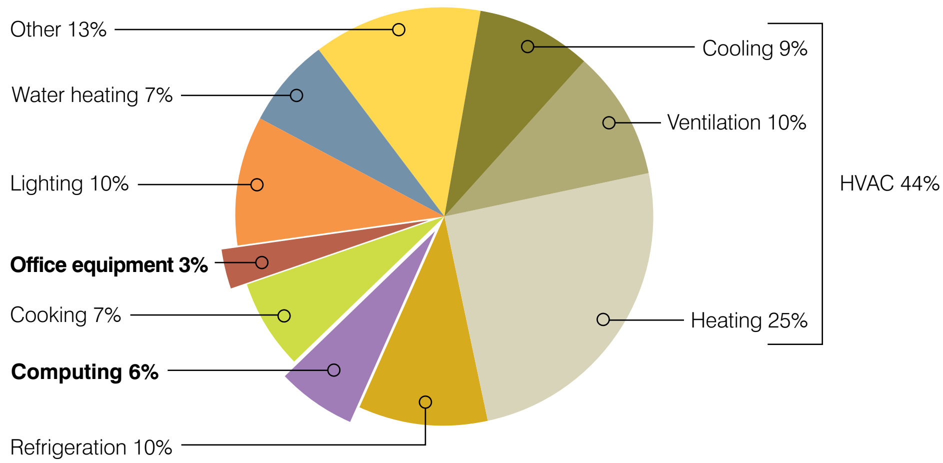
This chapter presents a combination of strategies for reducing the power draw of typical office equipment. These strategies include applying power management settings, consolidating and reducing the quantity of equipment and purchasing more efficient equipment. A number of relatively simple solutions can be implemented to reduce power consumption of existing equipment; however, in many offices, even the simplest efficiency measures have not been taken. For example, in a survey of large offices by Lawrence Berkeley National Laboratory, 59% of desktop PCs were consistently left on at night. Of those computers, only 6% had power management settings activated to reduce their energy draw.[2]

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

Since office equipment is typically replaced more often than building systems like lighting and HVAC, further reductions in energy draw can often be made through the purchase of more efficient equipment. EPA's ENERGY STAR program sets standards for efficiency in office equipment, providing a convenient way for purchasing groups to identify more efficient equipment. Most importantly, ENERGY STAR rated equipment often carries little to no price premium.

FIGURE 14.1

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



Source: U.S. Energy Information Administration, "Commercial Buildings Energy Consumption Survey, 2012," 2016

TABLE 14.1

Energy saving potential and strategies for typical office equipment

Equipment	Estimated energy savings potential (kWh/yr)	Emissions reduction (pounds of CO_2)	Estimated energy savings potential percentage	Energy saving strategies
Desktop PC	124	190	43%	• Enable power-saving settings • Install power management software • ENERGY STAR-certified equipment purchase
Laptop PC	37	57	42%	• Enable power-saving settings • Install power management software • ENERGY STAR-certified equipment purchase
Computer monitor	31	47	36%	• Enable power-saving settings • Install power management software • ENERGY STAR-certified equipment purchase
Monochrome laser printer (standard format)	47	72	26%	• ENERGY STAR-certified equipment purchase • Use of duplex mode
Copier (standard format)	47	72	26%	• ENERGY STAR-certified equipment purchase • Use of duplex mode
Multifunction device	248	381	0.59%	• ENERGY STAR-certified equipment purchase • Use of duplex mode

Source: Derived from detailed information found on grey tabs of the ENERGY STAR Savings Calculator—"Office"
Note: Numbers reflect savings for a single piece of equipment

Tactics for reducing energy use

Efficient use of office technologies

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

Install supplemental computer power management software. Centralized power management software sets the power settings of all networked PCs and monitors, overriding individual user power settings. If operations require that computers not be turned off at night, centralized power management software allows IT administrators to put PCs in a low power state and then power them up as needed (to install software, update virus definitions, etc.).

Some examples of this software include: ANSA PC Power Management, Power Save Enterprise by Faronics, Surveyor by Verdiem, Nightwatch Enterprise by E1 and Power Manager by Verismic. For a full listing of software providers, consult the ENERGY STAR power management products website at https://www.energystar.gov/products/low_carbon_it_campaign/implementation_resources_enterprises/commercial_software

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

Install energy saving devices on vending machines or ask vendors to provide more efficient vending machines. Installation of a VendingMiser® or similar device should be considered for each cooling-equipped vending machine. These devices manage the flow of power into the machine, and use an occupancy senor to control lighting. VendingMiser states that its devices reduce the energy consumption of vending machines by about 50% while maintaining proper temperature and necessary illumination.[3]

For more information on energy efficient vending machines, see https://www.energystar.gov/products/other/vending_machines

Equipment replacement/purchasing

Purchase ENERGY STAR certified PCs and servers equipped with 80 PLUS® certified power supplies (AC to DC converters). The 80 PLUS performance standard requires that power supplies be at least 80% efficient at 20%, 50% and 100% of rated load, with increasing badge levels of efficiency: Bronze, Silver, Gold, Platinum and Titanium. PCs with 80 PLUS certified power supplies are estimated to be 33% more efficient than PCs without them.[4] The ENERGY STAR Version 6.0 specification for desktop computers requires that PC power supplies meet 80 PLUS baseline performance standards. ENERGY STAR's Version 2.0 specification for enterprise and computer servers went into effect December 2013 and requires a minimum of 80 PLUS Silver and Gold criteria levels. The complete versions can be accessed through the following links:

- Computer Specification Version 6.0 at https://www.energystar.gov/products/spec/computer_specification_version_6_0_pd
- Enterprise Server Specification 2.0 at https://www.energystar.gov/products/spec/enterprise_servers_specification_version_2_0_pd
- A full listing of 80 PLUS certified power supplies can be accessed at https://plugloadsolutions.com/80PlusPowerSupplies.aspx

Replace desktop PCs with laptops. Laptops use significantly less energy and provide employees the benefit of taking their laptop home or when traveling.

Replace all remaining cathode ray tube (CRT) monitors with flat-panel LCD monitors. The new LCD monitors are economical, use much less electricity, take up less space and don't have issues with flickering that can cause eye strain.

Purchase ENERGY STAR certified PCs, printers, copiers and monitors. These products automatically switch to low-power standby modes after a period of inactivity. Overall, ENERGY STAR certified office equipment uses 30–75% less electricity than standard equipment.[5]

Purchase high-speed, duplex-capable laser printers. While these printers draw energy at a higher rate, their faster printing time results in less energy use per page. 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, average energy draw per print job was reduced by 40% on the 24 ppm printer.[6]

High-speed printers are generally priced higher than low-speed printers, but because they can handle larger loads, fewer printers are needed. Thus, the net cost of high-speed printers tends to be lower on a cost/ppm basis. Utilities typically do not provide rebates for efficient printers.

Duplex printing reduces the cost of paper and paper disposal by up to 50%. A reduction in paper use will also lower the organization's upstream GHG footprint. For more information, see http://c.environmentalpaper.org/home

Reduce personal printers in favor of centralized networked printers. Larger, newer printers tend to be less expensive to maintain, as well as more efficient per page.

Savings calculators for ENERGY STAR office equipment can be found at http://www.energystar.gov/sites/default/files/asset/document/Office%20Equipment%20Calculator.xlsx

For more information on efficient office equipment, see the New Building Institute's Plug Load Best Practices Guide at http://newbuildings.org/resource/plug-load-best-practices-guide/

Additional information

For more information on different office equipment energy efficiency, see:

- ENERGY STAR, "Office Equipment," https://www.energystar.gov/products/office_equipment
- Department of Energy, "Energy Efficient Computers, Home Office Equipment and Electronics," https://www.energy.gov/energysaver/energy-efficient-computers-home-office-equipment-and-electronics

Notes

1 Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS)," Table E1. Major Fuel Consumption (BTU) by End Use, 2012, May 2016. http://www.eia.gov/consumption/commercial/data/2012/c&e/pdf/e1.pdf

2 Lawrence Berkeley National Laboratory, "Space Heaters, Computers, Cell Phone Chargers: How Plugged In Are Commercial Buildings?" August 2006. http://eetd.lbl.gov/publications/space-heaters-computers-cell-phone-chargers-how-plugged-are-commercial-buildings

3 VendingMiser® website, http://thevendingmiser.com/

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

5 U.S. EPA and U.S. DOE. ENERGY STAR, "Office Equipment," https://www.energystar.gov/index.cfm?c=ofc_equip.pr_office_equipment

6 Portland Office of Sustainable Development, "Green Office Guide," November 2001.

CHAPTER 15

Data centers and IT equipment

Goals

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

Overview

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

Data centers are critical to business

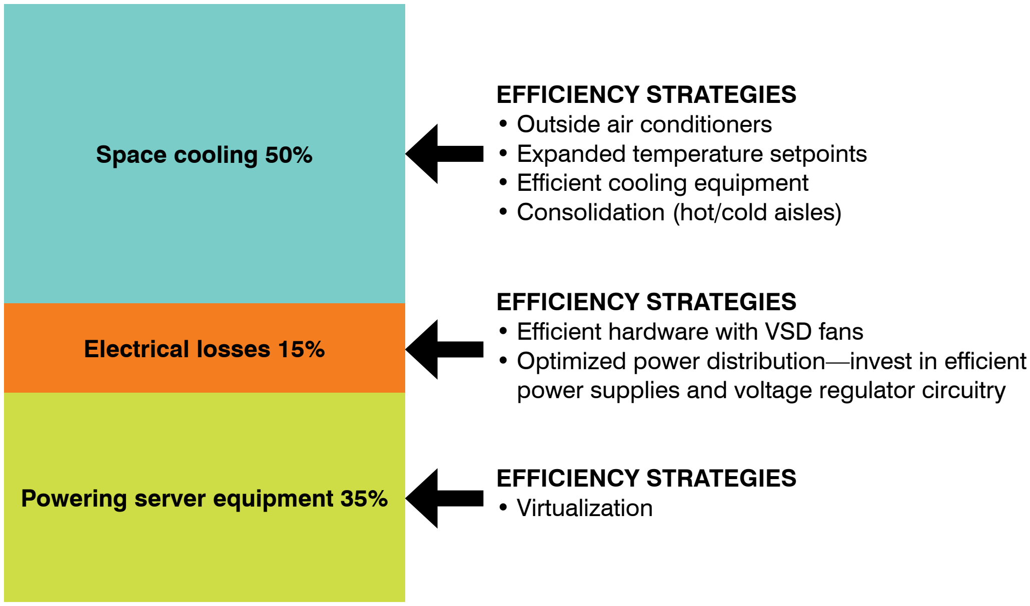
Businesses of all types have become increasingly dependent on **information technology (IT)**. Most businesses rely on IT to manage core business functions such as account management, web presence and sales, as well as finances, human resources and email systems.

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

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

FIGURE 15.1

Estimated energy consumption of an average data center



Source: Rocky Mountain Institute, "Making Big Cuts in Data Center Energy Use," May 2012

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

A strong business case exists for making data centers more efficient. In a typical data center, about 35% of the power consumed is used for computing operations. The other 65% is simply lost along the way as heat in the servers, conversion losses in power supplies, powering fans and lights and in cooling systems required to remove this waste heat.[1]

Efficiency opportunities exist at each step of the system. Because increased energy use drives increases in both operating costs (electricity) and capital costs (for back-up generators, battery banks and cooling systems), efficiency measures in data centers generally cut costs dramatically and pay back relatively quickly.

Efficiency measures provide economic value in three main ways:

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

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

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

Energy efficiency improvements of 20–40% are typical in data centers, with savings over 50% possible in some cases.[2] The savings and cost numbers in this chapter are *rough estimates*; costs and savings from efficiency measures vary among data centers. Data centers are complex facilities, and efficiency potential depends on a wide range of factors. Large energy and cost-saving opportunities exist and are well documented, but unfortunately there are many organizational and risk management issues that have prevented most organizations from achieving those savings. Data center decisions are subject to influence from many stake-holders, including 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.

Organizational dynamics and considerations that can contribute to or impede the successful deployment of data center efficiency include:

- *Cost and environmental impact of IT electrical.* This use must first be measured before it can be managed.
- *IT's focus on maximum uptime at any cost results in wasted capital investment and excess energy spends.* It is a best practice to implement robust and resilient software that allows flexible and efficient physical environments.
- *Disconnect between who pays the costs of efficiency efforts and who receives financial benefits.* IT or a similar department often pays the cost, while the facilities department benefits. Finance needs a way to transfer funds between budgets to allow utility savings to fund increased IT equipment and facility equipment investment.
- *Treatment of physical IT hardware like capital assets* (depreciation over time) rather than rapidly changing technology that for optimum financial return should be replaced every 18 months to two years can delay investments in more efficient technologies.
- *Procurement and contract management and incentive programs that focus only on lowest up-front purchase price.* These programs can be detrimental to energy efficiency projects, because they do not take into account the full LCC of equipment decisions.

Tactics for reducing energy use

▶ Prerequisite: Monitoring and benchmarking

Although monitoring and benchmarking do not directly create energy savings, these low-cost measures play an important role in informing efficiency programs and tracking their impact.

Calculate and monitor PUE. The **power utilization effectiveness (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 only half of the energy and the rest is consumed by infrastructure systems to keep the data center environment cool and manage power quality. PUE can be calculated in different ways depending on where and how measurements are taken. Therefore, an organization should establish guidelines on how PUE is calculated to ensure consistency. The PUE can change over time and throughout the year depending on server loads and outside temperatures, so it should be monitored regularly to track data center performance. Note that PUE is not a measure of data center overall efficiency or productivity since it does not measure the output produced by the IT equipment; it only compares the ratio of electricity use. For example, a data center with newer IT equipment may have more production (processing or storage) and lower total energy use (thus more efficient), but a higher PUE than another data center that has older IT equipment but a lower PUE. EPA provides a useful Data Center benchmarking tool at https://www.energystar.gov/index.cfm?c=prod_development.server_efficiency

Track server utilization. Average servers operate at less than 10% of their potential capacity, due to unpredictable loading patterns. Installing software that monitors server use helps to identify efficiency opportunities in underutilized servers, as well as in servers that are no longer being used at all.

Install sensors to monitor temperature and humidity. Servers have specific temperature ranges (see "Cooling system optimization," page 68). Improved monitoring can identify isolated "hot spots" within the data center where the air is significantly hotter than the average room temperature. This data can be used to focus cooling efficiency programs and allow more servers to be added to the data center without overheating. Note that only the air temperature at the INLET to the IT equipment matters—no action is needed to address "hot spots" that occur in the exhaust air from servers.

Use kW/ton metric to assess cooling system performance. The ratio of power consumed by a cooling system (kilowatts) to heat removed (tons, equivalent to 12,000 Btu/hr) is a measure of the cooling efficiency. Optimized cooling systems may operate at 0.9 kW/ton or less. Cooling systems with 0.8 kW/ton efficiency is considered good practice, however, highly efficient data centers aim to benchmark their efficiency at a rate of 0.6 kW/ton.[3] In many data centers, values are above 2.0 kW/ton, indicating a large potential for efficiency improvements.

▶ Energy efficient software

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

Design or purchase new software that minimizes energy use. Software efficiency is a complex issue because efficiency measures are specific to individual programs and tasks. In addition, minimizing energy use is rarely a priority for software developers. As a result, software often puts high demands on server hardware. Incentivizing 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.

▶ Improved server utilization

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

Unplug and remove servers that are not being used at all. Surprisingly, a significant fraction of servers (in some cases, 20% or more) in many data centers are no longer being used. If an office employee quits, others would quickly notice if the unused desktop computer kept turning on every day. Servers are less obvious; they can run their operating systems and background applications invisibly for months or years before they are removed. To identify unused servers, run programs to monitor network activity over time. This effort will identify potential "zombie servers," which then must be individually investigated to determine whether they can safely be unplugged and removed.

Virtualize multiple servers onto a single machine. Virtualization uses software to simulate multiple "virtual" or "software" servers that allow multiple operating system copies and applications to run simultaneously on a single physical server. Because virtualization consolidates several underutilized servers onto a single server, it can have a huge impact in saving physical space and reducing energy use and excess heat generation. It can be tricky to implement software virtualization because operating systems and applications must be compatible and reliably managed to avoid interruptions to operations. However, the potential benefits are so great that an increasing number of organizations are implementing virtualization initiatives. Virtualization potential is often quantified as 3:1 or 5:1, reflecting the number of servers that can be consolidated onto a single machine. In many cases, however, virtualization levels exceeding 15:1 are possible. There are a few key best practices for considering server visualization:

- Understand the benefits and drawbacks of a virtualized environment
- Take the role of each virtual system into account
- Consider what components are required for a perfect scale-up
- Back up virtual machines and systems
- Do not neglect security[4]

More information on server virtualization is available under the Additional Information section at the end of the chapter.

Consider advanced resource allocation through application 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. Using a method known as 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.

Efficient server hardware design

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

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

Mandate efficient power supplies. In recent years, efforts to raise power supply efficiencies have gained momentum. Server power supplies transform Alternating Current (AC) electricity to the low voltage Direct Current (DC) demanded by electronic components. Historically, many power supplies have operated at as low as 60% efficiency, meaning that only 60% of the input power (AC) is converted to DC power. Many off-the-shelf servers today have power supplies certified by the 80 PLUS program, which demands at least 80% average efficiency. In fact, power supplies with efficiencies over 90% are available (the 80 PLUS program provides 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 and intermittent. 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.

Cooling system optimization

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

Block excess holes in raised flooring. Many data centers use an open **plenum** beneath a raised floor to distribute air to the server racks. Fans are used to pressurize the air in the plenum. Perforated tiles are positioned where cold air is needed (at the air intake side of server racks), which allows cold air to be pushed up into the room. However, in many data centers, floor tiles are removed to run wires or conduct maintenance and are never replaced. This allows cold air to escape and reduces the efficiency of the cooling system. An easy fix for this is to replace floor tiles and cut out small holes for cables.

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. Data centers typically restrict allowable temperatures to narrow ranges in order to reduce risk of server failure. Many data centers adopt the "recommended range" from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) of between 65°F 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 its upper limit temperature.[5] This falls within the ASHRAE allowable range of 59°F–90°F (A1) or 41°F–113°F (A4). Allowing warmer data center temperatures can reduce cooling energy use. The largest potential benefit of allowing broader environmental conditions is that it increases the opportunity to use air economization or "free cooling," where outside air is used to cool the data center partially or fully, replacing the need for mechanical cooling, enabling that equipment to be turned off. ASHRAE also recommends a humidity range of 42°F DP—60% or 59°F DP, allowing a range of 20–80% or 63°F DP.

Enclose "hot" or "cold" aisles and block holes in racks with blanking panels. To maximize efficiency of an air-cooled data center, cold supply air should be physically isolated from hot return air. The simplest way to achieve this is to encapsulate an aisle of server racks by adding end doors, roof panels over the racks and "blanking panels," which fit into the racks and block air from flowing through empty slots. When implemented, air flows from the cold aisle through the servers to the hot aisle and exhaust air stream without "short-circuiting" (cold air bypassing servers and merging with hot exhaust air) or "recirculation" (hot air flowing back to the server inlets, leading to overheating problems).

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

Other loads: Power supply and lighting systems

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

Reduce lighting energy use with automated controls and more efficient fixtures. Lights are a small piece of data center energy use, but they can easily be improved. In many data centers, lights are glaringly bright so that workers can see into the dark racks to configure servers. Furthermore, lights are often on 24/7, as maintenance work may be necessary at any time. Occupancy sensors allow lights to turn off when the data center is empty, potentially saving 50% or more of the lighting energy used. Lights can also be divided into separate banks, so that the entire space does not have to be lit when people are working in one area. Finally, the quality of light may be improved by using light-colored interior surfaces and server racks and by using indirect lighting fixtures.

Additional information

For more information on data center energy use, see:

- ENERGY STAR, "12 ways to save Energy in Data Centers," https://www.energystar.gov/products/low_carbon_it_campaign/12_ways_save_energy_data_center
- Jonathan Koomey, "Growth in Data Center Electricity Use 2005 to 2010," Oakland, CA: Analytics Press, 2011. http://www.co.twosides.info/download/Koomey_Johnathon_G-_Growth_In_Data_Center_Electricity_Use_2005_to_2010_2011.pdf

For more information on server utilization, see:

- Microsoft, "Selecting the Right Virtualization Technology," https://technet.microsoft.com/en-us/library/bb897468.aspx
- ENERGY STAR, Server Virtualization, February 2012. https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_virtualization%20

For more information on best practices in data center efficiency, see:

- PG&E, "Data Center Best Practices Guide," October 2012. https://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/DataCenters_BestPractices.pdftPractices.pdf
- Department of Energy, "Best Practices Guide for Energy-Efficient Data Center Design," March 2011. https://energy.gov/sites/prod/files/2013/10/f3/eedatacenterbestpractices.pdf
- Center of Expertise for Energy Efficiency in Data Centers, https://datacenters.lbl.gov/

For more information on data center efficiency assessment, see:

- NRDC, "Data Center Efficiency Assessment," August 2014. https://www.nrdc.org/sites/default/files/data-center-efficiency-assessment-IP.pdf

Notes

[1] Rocky Mountain Institute, "Making big cuts in Data Center Energy Use," May 2012. http://blog.rmi.org/blog_making_big_cuts_in_data_center_energy_use

[2] Best Practices for Data Center Energy Efficiency Workshop, Datacenter Dynamics, Dale Sartor, P.E. Lawrence Berkeley National Laboratory, May 25, 2012. https://datacenters.lbl.gov/sites/all/files/dc-ee-dcd-07-4-2013.pdf

[3] Practices U.S. Department of Energy Federal Management Program, "Best Practices Guide for Energy-Efficiency Data Center Design," March 2011. https://energy.gov/sites/prod/files/2013/10/f3/eedatacenterbestpractices.pdf

[4] Techtopia, "5 Best Practices for Server Virtualization," https://www.techopedia.com/2/28238/trends/virtualization/server-virtualization-5-best-practices

[5] Oracle SPARC Servers, SPARC T5-2 Server, "Oracle Data Sheet," http://www.oracle.com/us/products/servers-storage/servers/sparc/oracle-sparc/t5-2/sparc-t5-2-ds-1922871.pdf

CHAPTER 16

Industrial facilities

Goals

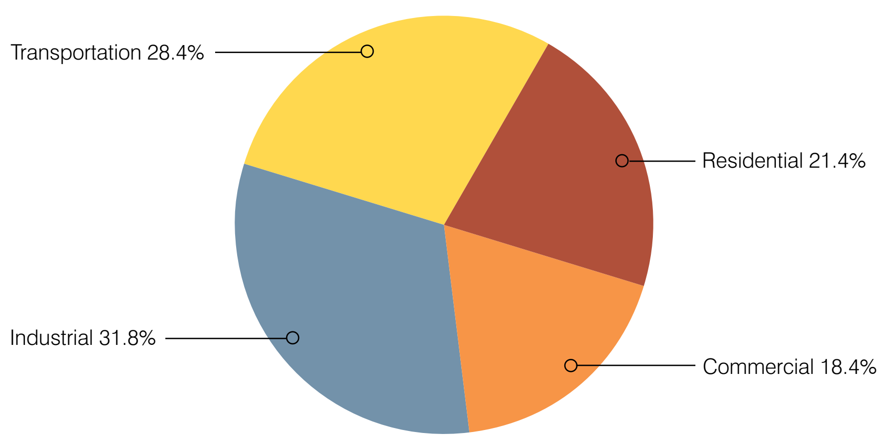
- Achieve an understanding of the characteristics of industrial and non-commercial facilities and how they are similar and different from commercial facilities
- Develop an overview of the types of equipment and systems common to industrial facilities and associated energy efficiency opportunities
-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

Overview

Industrial facilities include a wide range of sites ranging from oil refineries, steel and cement mills, airplane, auto and semiconductor factories, to wineries, food processors, wastewater treatment plants, coal, gas and nuclear power plants, and many more. In general, "industrial" is used as a catch-all term for facilities that are neither residential nor commercial. An industrial facility is typically a manufacturing facility, where something is made or transformed, but the term can also be used to refer to distribution centers and pipeline pump stations.

FIGURE 16.1

Percentage of 2015 U.S. energy sales by sector



Source: U.S. Energy Information Administration, "Monthly Energy Review, Table 2.1," 2015

It is difficult to make generalities about such a diverse and large group, so when reviewing this chapter keep in mind that exceptions to this information may be common. The unique characteristics of each industrial facility should always be well understood and taken into consideration.

According to the U.S. Department of Energy and the Energy Information Agency, industrial sites as a group use more energy in the United States each year than the residential and commercial sectors combined and more than all forms of transportation (see Figure 16.1, page 70). Due to high energy use, industrial facilities have a large impact on national carbon emissions, as well as on most other waste streams.

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

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

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

The U.S. Department of Energy conducted a number of sector-specific studies, available at https://energy.gov/eere/amo/advanced-manufacturing-office

Industrial energy using systems

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

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

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

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

Self-generation and Combined Heat and Power (CHP) are sometimes found at industrial sites due to their constant operation (most run 24/7 year-round), large energy use and tendency to need simultaneous heating and cooling. These systems are complex but offer large opportunities for cost and carbon reductions and thus are a focus of major education and research efforts by the U.S. Department of Energy and EPA. More information can be found at https://energy.gov/eere/amo/combined-heat-and-power-basics

Top energy efficiency measures in industrial facilities that require low cost and yield observable energy savings are:

- Peak energy demand identification
- Weekend energy use adjustment
- Weeknight set-backs
- Reducing start-up spikes
- Compressed air system efficiency

For more information see http://www.sustainableplant.com/2013/03/the-top-five-energy-efficiency-measures-for-industrial-businesses/

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

Production is the priority

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

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

- *Lack of attention.* All time is focused on maximizing and maintaining production.
- *Lack of resources and funding.* Financial budgets are prioritized for projects that will be able to increase production.

- *Lack of time.* When equipment fails, all effort is focused on getting the plant back into production as fast as possible. There is often not enough time to research or order more energy-efficient alternative equipment.
- *Fear of negative impact to production.* A common (but often false) belief is that it is not possible to optimize both production and energy efficiency in a way that saving energy does not negatively impact production. The concern alone—without data or justification—may be enough to prevent energy efficiency efforts.
- *Fear of change.* Optimizing operations for energy often requires changes of equipment and operating practices; this raises concerns that those changes could negatively impact production. This often includes the assumed reasoning that any impact to production would be a larger financial cost than whatever savings could result from energy efficiency.

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

Best practices for industrial energy efficiency

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

Start by evaluating current conditions and practices. Have any energy projects been completed in the past? If so, how did they happen? Who drove them and why? What challenges were encountered? What was learned and can the lessons be applied?

Lighting and HVAC system upgrades can be attractive first steps. These systems do not directly impact production, so proposed changes to them are less likely to be met with concerns about production impact. In addition, upgrades are generally straightforward to analyze and plan. There are likely to be utility or government incentives and rebates available, making them financially attractive as well.

Create buy-in with critical personnel. Identify key staff, such as production supervisors or maintenance managers, who are in roles that could veto or delay implementation of energy efficiency projects. Listen to their concerns and include them in the solution development process. Make sure that they not only feel ownership of the proposed energy efficiency project, but that they also receive credit when the project is completed.

Identify, quantify and highlight non-energy benefits of energy efficiency projects. Energy waste is often a symptom of industrial process and equipment inefficiencies, so increased energy efficiency often results in other benefits, including reduced maintenance, lower down-time, increased production or quality and lower labor costs. Make sure to clearly list these benefits in any energy project proposal.

Develop an energy management strategy and documented plan. Develop a process for collecting and monitoring energy use data. Establish goals for improving energy performance and track actual performance compared to goals and historical trends. Identify major drivers of energy use and opportunities for improvement. See ENERGY STAR for an industrial energy management program assessment tool at https://www.energystar.gov/buildings/facility-owners-and-managers/industrial-plants/build-energy-management-program

Commit and implement Superior Energy Performance and/or ISO 50001. Released in 2001, ISO 50001 is a voluntary energy management system standard that provides a framework for organizations to set and pursue goals in energy management. According to the ISO, the framework requires organizations to:

- Develop a policy for more efficient use of energy
- Fix targets and objectives to meet the policy
- Use data to better understand and make decisions about energy use
- Measure results
- Review how the policy works
- Continually improve energy management

Adoption of ISO 50001 allows a standardization of energy management. Additional ISO systems, such as ISO 50003, have been released in 2014 for energy audits and further energy management standard frameworks.

Identify and implement outside energy assessments (audits). These provide a fresh perspective and ideas for energy efficiency opportunities.

Identify corporate and external resources. Utilities, equipment vendors and energy efficiency consultants can assist in identifying and implementing improvement projects at a facility when on-site staff does not have the time or knowledge to do so.

Document and quantify successes. Once a project is finished, take time to complete a post-project analysis by documenting all financial savings and non-financial benefits (increased lighting levels, better light color or consistency, better employee comfort, etc.). Management is more likely to embrace future energy project financial return forecasts if there is clear visibility to the results of prior projects.

Additional information

For more manufacturing energy reduction resources, see:

- U.S. Department of Energy, "Energy Analysis by Sector," https://energy.gov/eere/amo/advanced-manufacturing-office
- U.S. Department of Energy, "Advanced Manufacturing Office projects, analysis, protocols and strategies to reduce industrial energy and carbon emissions in specific industries and technologies," https://energy.gov/eere/amo/industries-technologies
- U.S. Department of Energy, "Initiatives, technology research, and implementation for manufacturing," https://energy.gov/public-services/manufacturing
- U.S. Department of Energy, "Manufacturing Energy and Carbon Footprints," https://energy.gov/eere/amo/manufacturing-energy-and-carbon-footprints-2010-mecs

For more information on certification programs and ISO see:

- U.S. Department of Energy, “Superior Energy Performance certification program for verifying energy performance improvements and management practices,” https://www.energy.gov/eere/amo/superior-energy-performance
- ENERGY STAR for Industry, https://www.energystar.gov/index.cfm?c=industry.bus_industry
- ENERGY STAR Energy Management Program Assessment, https://www.energystar.gov/index.cfm?c=guidelines.assess_energy_management
- Department of Energy, “ISO 50001 Energy Management Standard,” https://energy.gov/eere/amo/iso-50001-energy-management-standard

For more information on specific industrial energy consuming systems see:

- Department of Energy, “Advanced Manufacturing Office,” https://energy.gov/eere/amo/advanced-manufacturing-office

For more information on Combined Heat and Power (CHP), see:

- Department of Energy and EPA, “Combined Heat and Power (CHP) as a clean energy solution,” https://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf

CHAPTER 17
Renewable energy

Goal

- Understand why the organization is considering **renewable energy**
- Achieve a basic understanding of renewable energy implementation options
- Evaluate the potential financial and environmental impacts of sourcing renewable energy
- Determine financing options available for renewable energy procurement

Overview

As prices for renewable energy continue to drop, commercial renewable energy purchasing is becoming more and more popular. In 2015 alone, U.S. companies agreed to buy 3,440 megawatts of solar and wind power, roughly the carbon equivalent of taking 1.4 million cars off the road.[1] Renewable energy can play a key role in helping a company achieve its GHG emissions reduction goals and advance its energy management strategy.

Clean or renewable energy is energy that is collected from resources that are naturally regenerated over a short period of time, such as solar, geothermal, biomass, wind and tides. Electricity generated from renewable resources can also be called green power. Most renewable energy sources have little or no GHG emissions associated with generation.

Renewable electricity capacity is also growing. In 2015, renewable generation made up 61% of capacity additions to the U.S. electric grid.[2] Electricity users can play a key role in reducing GHG emissions by increasing demand for renewable energy, which in turn decreases the demand for fossil fuels. Increasing the proportion of renewables in a company's energy supply can be a financially smart business decision as well.

This chapter will help breakdown commercial/industrial renewable energy by focusing on three key areas:

- Defining success
- Understanding implementation options
- Characterizing the costs and financing opportunities

Defining success

Setting goals: What does the organization hope to achieve with renewable energy?

It is important to understand why an organization is considering renewable energy, as this will impact the best renewable energy option to meet their needs. There are many reasons why renewable energy may be an attractive strategy for an organization:

- *GHG goals.* Well over half of the Fortune 100 companies have set GHG reduction targets.[3] Transitioning an organization's electricity supply from fossil-based fuels to renewable energy will reduce Scope 2 emissions from purchased electricity, furthering progress towards these goals.

- *Tax incentives.* Organizations can take advantage of tax incentives at the state and federal level, which are designed to encourage increased adoption of renewable energy technologies. For example, in 2015 the U.S. Congress extended the solar Investment Tax Credit (ITC), a 30% federal tax credit for solar installations of any scale. Additional state level incentives can be found on the Database of State Incentives for Renewables & Efficiency (DESIRE).

- *Cost savings and risk mitigation.* Many organizations view using renewable energy as a practical way to save money on electricity costs. By entering into a contract which provides electricity at a known, long-term price, an organization can hedge against rising electricity prices. Some organizations may also be able to take advantage of **net metering**, a billing mechanism that allows solar system owners to sell excess electricity back into the grid and receive a credit on their electricity bill. Net metering policies can vary widely depending on state legislation and can be available for projects both on-site and off-site.

- *Resilience and reliability.* Renewable energy can help create a more reliable and resilient energy supply to an organization by diversifying supply sources in both type and location. Because it is also a local and distributed source of energy, renewable energy can also be said to boost grid resilience.

- *Brand and stakeholder relations.* Some organizations may consider renewable energy procurement to help promote its brand as environmentally conscious. It can also help an organization demonstrate a public commitment to a low carbon future.

Before choosing the renewable energy implementation option, all organizations should evaluate their current electricity demand. As energy conservation measures such as LED lighting retrofits and HVAC improvements can reduce overall electricity consumption, it is important to first complete these projects to ensure that renewables projects are sized appropriately. Since renewable energy such as solar has a relatively stable capacity, implementing energy efficiency projects before a renewable resource investment can avoid the future cost of changing capacity.

Renewable energy sources

Solar Photovoltaic

More U.S. organizations are choosing to install solar than ever before, due to its availability and rapidly falling cost. **Solar Photovoltaic (solar PV)** systems convert sunlight into electricity. Solar PV can be installed on a variety of buildings and property types, and on-site systems can range in size from a few kilowatts up to several megawatts. The average installation cost for large commercial applications has dropped to below $3 per watt and is continuing to trend downwards.[4] There are very few operations and maintenance costs for solar systems and they have a lifespan of up to 30 years.

Considerations: Solar systems generate the most electricity when the sun is at its strongest, so it often does not coincide with peak electricity demand in the early morning and late afternoon. Implementations that combine solar with battery storage technology can be a solution, especially as battery storage is starting to become more economically feasible.

Wind turbines

Wind turbines convert kinetic energy present in wind motion to mechanical energy for electric power generation. Like solar, the costs of wind power have been decreasing over time and many organizations are contracting for long-term wind power. In 2015, over 50% of the MW capacity from wind **Power Purchase Agreements (PPAs)** came from companies, universities and city governments.[5] Wind is a free and inexhaustible fuel, enabling long-term fixed price purchase contracts. On-site wind installations can vary from demonstration-scale rooftop turbines to commercial 50kW installations, and even installs of a single 1MW turbine. Large-scale wind farms are now typically more than 100MW of capacity and higher.

Considerations: Similar to solar, wind speeds are often highest at times that do not match peak demand. In addition, the most productive wind farms are often located far from densely populated areas, requiring substantial transmission infrastructure to carry the power to population centers.

Biomass

Biomass is plant material that is burned directly for heating or to produce electricity. Biomass can be a good candidate for combined heat and power (CHP) at facilities with large thermal loads and is most suited to locations that have large biomass resources nearby.

Considerations: There is some controversy over whether biomass from sources such as wood pulp should be considered a renewable fuel source due to the CO_2 it produces when it is burned and its reliance on the future growth of trees to make the fuel carbon neutral.

Fuel cells

Fuel cells convert the chemical energy of hydrogen or another fuel into electricity by way of an electrochemical process rather than a combustion process. Organizations can use fuel cells as a replacement for traditional lead-acid batteries in specialty vehicles (e.g. forklifts), for emergency backup power and to help provide grid-independent power generation for critical load facilities (locations where even short grid failure would result in security vulnerability or financial loss). Fuel cell technology is also being used in CHP applications.

Considerations: Fuel cells emit no traditional air pollutants and are efficient forms of energy generation; however, they can only be considered a renewable energy resource if they operate on a renewable energy fuel.

Other renewable energy

Hydroelectric and geothermal power contributes 25% and 2% respectively of total renewable energy in the U.S.[6] Hydroelectric power uses the force of water to generate electricity and emits no GHG emissions. Geothermal energy uses reservoirs of hot water that are located miles under the Earth's surface for electricity generation, heating and cooling. Most modern closed-loop geothermal plants emit no GHG emissions.

Considerations: Today, only run-of-river or other non-impoundment methods of hydropower are considered appropriate as new renewable resources. These implementations require specific locations and are not likely to be broadly applicable. Geothermal power is highly constrained by available resources, as well as the risks and high costs of its development, and therefore is not a great candidate for most organizations.

Implementation options

Commercial access to renewable energy has significantly increased over the past decade due to cost reductions, electricity market deregulation and new financing mechanisms. Often the best approach to greening 100% of an organization's electricity supply is to combine a number of these implementation options, along with energy efficiency projects, into a portfolio approach for GHG reduction.

Buying renewable energy credits

A **Renewable Energy Credit (REC)** is a tracked and verified certificate that represents the environmental benefits of the carbon reduction created by adding one megawatt-hour of renewable electricity to the grid. With RECs, organizations can de-couple the environmental benefit of renewable energy from the physical delivery of electrons. Organizations that purchase RECs often want to support green power and claim environmental benefits but are unable to purchase renewable energy from their local electricity provider or are unable to implement renewable energy systems close to their facilities. A downside to purchasing RECs is that the organization misses out on the price benefits of renewable energy.

There are two markets for buying and selling RECs: compliance and voluntary. In a compliance market, buyers purchase RECs in order to comply with a **Renewable Portfolio Standard (RPS)** or emissions caps. Twenty-nine states have an RPS, many of which allow RECs from neighboring states to be used for some portion of a regulatory compliance obligation. RECs, which are eligible for use as compliance tools, are priced according to the supply and demand created by the regulations; some can cost hundreds of dollars per MWh, while others may be $3 or less. In voluntary markets, customers voluntarily purchase RECs. Corporate purchasers of renewable energy typically buy RECs from voluntary markets or from the least expensive compliance markets. REC revenue streams often help generators offset the installation and maintenance costs of renewable energy projects.

Purchasing green power

Another option for organizations is to purchase green power, electricity that is supplied in whole or in part from renewable energy sources. Green power is conveniently paid through the utility bill, however it is almost always more expensive than the standard electricity rate. In deregulated states that allow electricity competition, customers can purchase green power products from competitive electricity suppliers. In regulated states, some customers can purchase green power from utilities under green pricing programs. States in the U.S. that allow electricity competition are illustrated in Chapter 4. Organizations that purchase green power are promoting renewable energy and may get to claim the environmental benefits of the electricity generated. However each green power purchasing program is different, so research should be done on the green power product to ensure it accomplishes the organization's renewable energy goals.

On-site generation

Many large corporations like Apple, IKEA and Walmart have been investing heavily in on-site renewable energy (mostly solar PV), over the last few years. Installing on-site renewable energy systems is a great option for organizations who want to claim environmental benefits and directly power their facilities by renewable energy. To generate renewable energy on-site, the location must have the space needed for the equipment, as well as adequate access to the energy source (e.g. wind or solar). Long-term financial contracts such as leases and PPAs can help make on-site renewable generation financially feasible for facilities located in areas with good solar resources (see more about PPAs in the financing section of this chapter).

Depending on the contract, the organization may be able to sell or retain and retire RECs related to the renewable energy generated. If the organization sells their RECs for revenue, then they are not able to claim the environmental benefits of the electricity generated from the RECs sold. As mentioned previously, excess generation from an on-site system can (in some states) be sold back to the grid in a process called net metering.

Off-site generation

Considering property limitations such as space, rooftop strength and availability of sun or wind, off-site renewable energy systems may be optimal for some organizations. Off-site PPAs are projects located geographically near the facility but not on it, and can help organizations meet environmental goals while enhancing transmission and distribution networks of surrounding communities. Organizations can also locate off-site projects geographically far from the facility, structured by **Virtual Power Purchase Agreements** which allow for the long-term purchase of RECs without the actual delivery of energy (see more about virtual PPAs in the financing options section of this chapter).

Characterizing the costs and financing opportunities

What are the financial benefits of renewable energy?

Hedging against electricity price volatility. Fuel costs contribute to a large percentage of total costs for gas and coal fired electricity generation, therefore the volatility of gas and coal prices have significant impacts on electricity prices. Because renewable energy has a stable cost, no fuel requirement and lower price risks, the costs over time are more predictable. Many organizations choose to invest in renewable energy for this long-term electricity price stability.

Hedging against future risk of carbon pricing or other environmental regulations. It's possible that at some point in the future, local or national policy may place more carbon emission restrictions on coal-fired and gas-fired generation. Additionally, corporate and organizational use of an internal price on carbon is rapidly growing. An organization may choose to invest in renewable energy to reduce its GHG footprint in order to help mitigate the impact of these regulations.

Considerations for upfront investment cost. With PPAs, organizations may have no or low upfront capital costs associated with a renewable energy commitment. Considering the long-term contract and known power price under this type of agreement, a strong case can be made for renewable energy investment. Alternatively, if an organization can finance the project itself, tax credits can help reduce the burden of upfront capital costs.

What are the financial costs and risks of renewable energy?

Traditionally more expensive but costs are continuing to fall. Renewable energy power generation is on a path to become cost-competitive with, or cheaper than, conventional fuel power stations despite falling oil prices. For instance, solar PV module prices in 2014 were 75% lower than in 2009 and also benefited from decreasing installation costs.[7]

Payback thresholds. Depending on the installation cost, operating cost and project life, the payback period of a renewable energy project such as solar PV may not meet an organization's standard payback period of three years. At some organizations, the project may need to undergo special approvals or be bundled into a portfolio approach for energy investment in order to move forward.

Length of contracts. Some organizations may view the commitment to long-term contracts such as PPAs as a business risk. PPAs may be available for as little as one to three years, but a PPA that provides sufficient income for a new project to be constructed will typically be 15 years or longer.

Changing renewable energy policies. Some organizations may feel that potential changes in state or federal renewable energy policy present a risk to investment as many utilities and governments across the U.S. are still determining how to manage the influx of distributed generation to the grid. For example, the Nevada Public Utilities Commission decided in December 2015 to triple the fixed charges for solar customers and reduce the net metering credit solar customers receive by 75%.[8] The most controversial aspect of this decision was that these changes would apply retroactively, meaning that some 18,000 existing solar customers found themselves locked into contracts that may no longer be financially viable. Regardless of whether or not this decision may be modified in the future, it demonstrates the risk of policy changes to renewable energy investments.

Financing options and other payment programs and products for on-site and off-site projects

Cash

Some organizations prefer investing in a renewable energy project directly rather than using a PPA or lease financing. In this case, an organization will receive all the energy cost savings and tax credits without having to share any of the financial or environmental benefits. The organization will also have to pay for operations and maintenance costs throughout the life of the equipment, but these costs tend to be relatively low.

Power Purchase Agreement

A PPA is a long-term financial contract in which a third party owns, operates and maintains a renewable energy system, and the customer agrees to purchase the system electricity for a set length of time. PPAs provide low or no upfront capital costs and allow the organization to benefit from a stable and sometimes lower cost of electricity. The system owner receives tax credits and income from the sale of the electricity, and sometimes all environmental benefits as well. As of 2016, at least 33 states allowed third party PPAs for solar PV.[9]

Virtual PPAs are similar to traditional PPAs except they do not include the actual delivery of electricity to the buyer. Under a virtual PPA, an organization agrees to pay a project developer a specified rate over a contracted period of time for each MWh generated by the developer's project. The developer then generates and sells power onto the grid at spot market prices, turning the proceeds as well as the RECs over to the contracted company.[10] Since this is a wholly financial arrangement without any power delivery, the organization continues to purchase electricity from their local provider. Virtual PPAs are a good option if an organization has committed to sourcing a large amount of renewable energy, but cannot implement renewable energy on-site due to location constraints or state policy restrictions for traditional PPAs.

Lease

Leasing arrangements are common for rooftop solar and other on-site energy systems, such as CHP. Under this third party financing approach, customers can contract with energy project providers to purchase the use of a renewable energy system like windmills or solar panels. The customer pays a monthly "rent" in exchange for the right to use the energy system and reap its environmental benefits. The monthly lease payment is typically estimated based on the amount of electricity the system will produce. In some situations, organizations can "lease to own" their system.

Performance contracts

This method of financing shifts some or all of the risk to an outside vendor. A service provider, called an Energy Services Company (ESCO), pays the upfront costs of an energy savings project and receives the resulting savings. Alternatively, the ESCO pays a percentage of the upfront cost in exchange for a percentage of the resulting savings. Learn more about ESCOs in Chapter 8. Similar to ESCOs, an organization can pursue a Managed Energy Service Agreement (MESA). In a MESA, the outside firm invests in the renewable energy project and then takes full responsibility for the entire power bill, with the organization paying the MESA directly rather than paying a utility.

Loans and other financing methods

Organizations can apply for loans to finance their renewable energy project. Loans can come from banks or non-traditional sources such as Green Banks or PACE finance providers.

TABLE 17.1

Renewable energy financing comparison

	System ownership	GHG reduction	"Renewably powered" claim	Length of commitment	Renewable (RE), efficiency, or both?
Cash	✔	✔	✔	7-year depreciation	Both
Loan	✔	✔	✔	5–7 years	Both (RE more options)
PACE	✔	✔	✔	Essentially none	Both
Lease		ONLY IF YOU RETAIN RECS		15–20 years	RE
PPA		ONLY IF YOU RETAIN RECS		15–20 years	RE
ESA	✔	✔	✔	~10 years	Both

Source: Origin Climate

PACE is a means of financing investment for energy efficiency and renewable energy in buildings that ties loan repayment to the property tax bill. For example, an organization can apply for PACE financing for solar panel installation and pay back the loan through increased property taxes over the long term.

On-bill repayment is another option that provides the organization an alternative way to pay for the clean energy investment through regular repayment on its monthly utility bill. Table 17.1 compares the different renewable energy financing options.

Additional information

For more information on trends in renewable energy, see:

- MIT Energy Initiative, "The Future of Solar Energy," http://energy.mit.edu/research/future-solar-energy/
- NREL, "Status and Trends in the U.S. Voluntary Green Power Market (2014 data)," http://www.nrel.gov/docs/fy16osti/65252.pdf

For resources related to commercial implementation of renewable energy, see:

- U.S. EPA, "Guide to Purchasing Green Power," https://www.epa.gov/greenpower/guide-purchasing-green-power
- Department of Energy, "Business Energy Investment Tax Credit (ITC)," https://energy.gov/savings/business-energy%C2%ADinvestment-tax-credit-itc
- RE 100, http://there100.org/reports-briefings
- Business Renewables Center, http://businessrenewables.org/

Notes

1 Wall Street Journal, "Companies Go Green on Their Own Steam," March 2016. https://www.wsj.com/articles/companies-go-green-on-their-own-steam-1457483035

2 Utility Drive. "Solar and Wind Comprise 61% of 2015 capacity additions, gas contributes 35%," January 2016. http://www.utilitydive.com/news/solar-and-wind-comprise-61-of-2015-capacity-additions-gas-contributes-35/411813/

3 World Wildlife Fund, Ceres and Calvert Investments, "Power Forward 2.0: How American Companies Are Setting Clean Energy Targets and Capturing Greater Business Value," http://tools.ceres.org/resources/reports/electric-power/reports/power-forward-2.0-how-american-companies-are-setting-clean-energy-targets-and-capturing-greater-business-value/view

[4] GTMResearch, "U.S. Solar Market Insight: 2015 Year-in-Review Executive Summary," Figure 2.4. March 2016. https://www.greentechmedia.com/research/subscription/u.s.-solar-market-insight

[5] GreentBiz, "P&G, GM and Google take flight on wind power," February 2016. https://www.greenbiz.com/article/pg-gm-and-google-take-flight-wind-power

[6] U.S. Energy Information Administration, "Monthly Energy Review 2016," https://www.eia.gov/totalenergy/data/monthly/index.php?src%20=email

[7] International Renewable Energy Agency, "Renewable Power Generation Costs in 2014," January 2015. http://www.irena.org/documentdownloads/publications/irena_re_power_costs_2014_report.pdf

[8] Greentech Media, "Does Nevada's Controversial Net Metering Decision Set a Precedent for the Nation?" February 2016. https://www.greentechmedia.com/articles/read/nevada-net-metering-decision

[9] DSIRE Detailed Summary Maps, "Third-Party Solar Power Purchase Agreement Polices," http://www.dsireusa.org/resources/detailed-summary-maps/

[10] E&E Publishing. "With virtual power purchase agreements, companies go long on renewable energy," http://www.eenews.net/stories/1059996353

CHAPTER 18

Demand response and smart grid

Goals

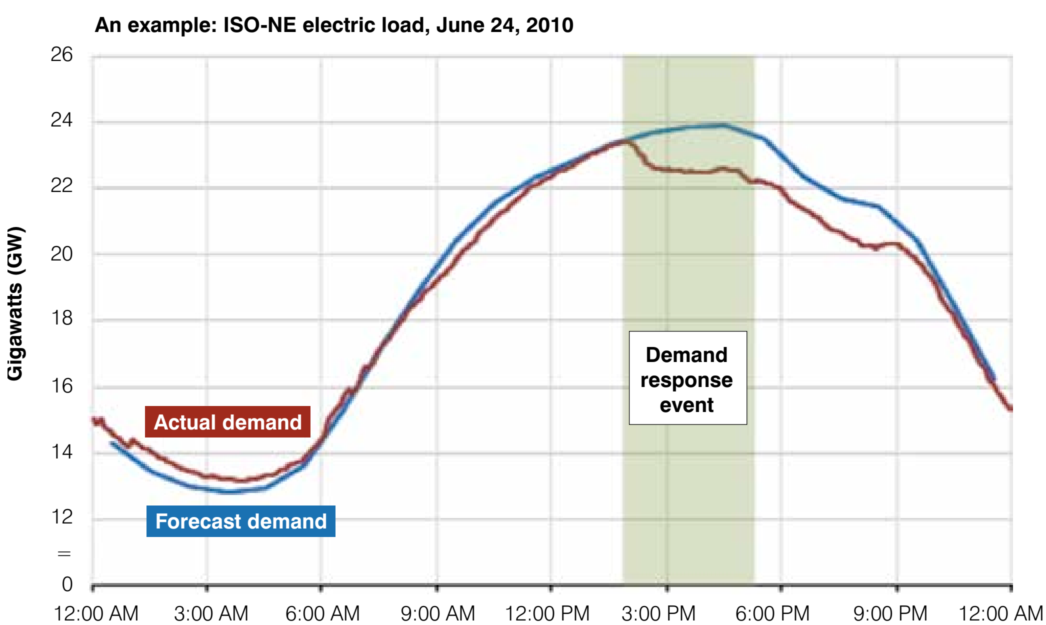
- Achieve a basic understanding of demand response (DR)
- Understand the components of a DR agreement with a utility or curtailment service provider
- Determine how to identify DR opportunities
- Understand smart grid and how DR and smart grid are related
- Evaluate the potential energy savings and revenue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

Overview

DR is the action taken by end users (customers) of a utility to temporarily reduce their energy usage in response to either price or system reliability triggers. Reliability issues occur when the electrical grid is at peak capacity and at risk of brownouts or blackouts. DR programs were

FIGURE 18.1

Demand response event



Source: U.S. Energy Information Administration, "Demand response can lower electric power load when needed" originally created by grid system operators as a means of preventing these disruptions and increasing resilience. However, DR programs now offer a unique opportunity for a customer to receive financial benefits for temporarily reducing their personal energy usage. Price triggers allow end users the option to reduce their electrical load based on high wholesale electricity prices. Figure 18.1 (page 84) demonstrates an example of a DR event.

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

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

With increasing technologies, DR has become an important component of a smart grid. Smart grid refers to the use of communication and information technology (IT) within the electrical grid that improves the flow of data between utilities and end users. With the increase in energy sub-metering technology, system controls and integrated appliances, DR will expand beyond being a resource for grid and price instability to become a critical component of the smart grid, enabling real-time signals between utilities and end users for targeting reductions in electricity consumption. Smart grid will also be critical to the integration of renewable energy sources into the electrical transmission system, addressing the need to balance the intermittent nature of renewable energy (i.e. cloudy days for solar energy and low wind for wind turbines). Smart grids are essentially computerizing the electric grid to allow utilities to adjust and control devices from a centralized location. Further integration of smart grids will revolutionize electricity and dramatically increase the efficiency and performance of the electric grid.

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

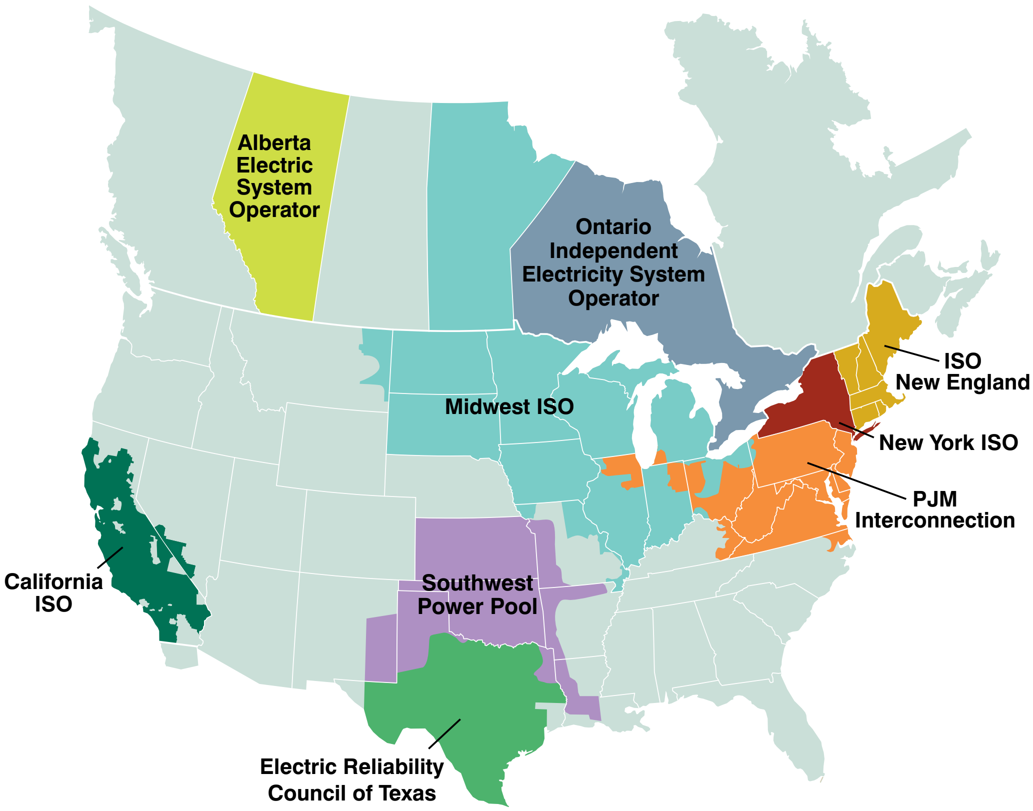
Additional analysis can be completed by determining what DR programs are available within an electrical service territory. Figure 18.2 (page 86) shows a map of the existing ISO/RTO organizations with mature DR programs. Note that if the facility is not within an ISO/RTO service territory, the DR program may be offered through the local electrical utility.

Building system information must first be collected to determine the load reduction potential and to help identify the types of temporary electric load reductions that can be implemented at the facility. Tactics for reducing demand for building systems are included in the next section. Sub-metering needs should also be taken into account, as DR programs require verification of the energy reductions using interval meters or other data collection devices. Consult with a specific DR program to determine the measurement and verification requirements. Lastly, it can be beneficial to develop a facility-level DR Action Plan to prepare and inform building operators of the program features and actions for a given facility.

As part of a DR Action Plan, identify key contacts within the organization. DR events are unpredictable and it is critical to have a communications protocol in place. The notice for DR events will come from the ISO/RTO or CSP via phone calls or email. Although the majority of DR is done by manual interventions, there are technologies that allow for automatic demand

FIGURE 18.2

U.S. map of ISO/RTO Councils



Source: Federal Energy Regulatory Commission, ISO/RTO Council

reductions. If a facility has the technology capability it may enroll in an Auto-DR program, in which the ISO/RTO/utility can send a trigger for reduction to an automated load control system (i.e., using a BMS to reduce temperature set-points for a building).

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

Strategies for reducing electrical load during a DR event

Lighting

- Reduce lighting in common areas. In addition to achieving energy savings, this strategy can be used to increase employee awareness of the facility's efficiency efforts.
- Reduce or turn off all lighting in spaces with adequate natural lighting.
- Encourage employees to identify and reduce unnecessary lighting in their work spaces.

HVAC

- Pre-cooling: Temporarily reduce the thermostat/chiller setpoint to 60°F until five minutes before a DR event, and increase the temperature to 85°F for the duration of the DR event.

- Thermostat setpoint adjustment: HVAC is one of the largest energy uses in commercial buildings. During a DR event, temporarily adjust the temperature setpoints either manually or through a BMS.
- Utilize window shading to reduce solar heat gain.

Plug loads

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

Vertical transportation

- Reduce the number of operating elevators and escalators.

Building controls

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

Process systems

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

Employee engagement

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

Distributed generation

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

Additional information

For additional information on DR, see:

- Lawrence Berkley Lab, Demand Response Research Center, https://drrc.lbl.gov/
- Federal Energy Regulatory Commission (FERC), https://www.ferc.gov/industries/electric/indus-act/demand-response.asp

- Department of Energy, Office of Electricity Delivery & Energy Reliability, https://energy.gov/oe/services/technology-development/smart-grid/demand-response
- ISO/RTO Council, "North American Wholesale Electricity Demand Response Program Comparison," http://www.isorto.org/ircreportsandfilings/2015-north-american-demand-response-characteristics-available

For more information on smart grids, see:

- Department of Energy, Smart Grids, https://energy.gov/oe/services/technology-development/smart-grid

CHAPTER 19

Employee engagement

Goals

- Realize operational and behavioral opportunities to reduce energy consumption
- Create and maintain cultural values and norms that support energy management and conservation
- Influence decision making and daily actions at all employee levels
- Understand how to utilize engagement through the *Environmental Employee Engagement Roadmap*

Overview

Regardless of where or how energy consumption occurs in an organization, one or more employees have affected that consumption through decision making and actions. Therefore, engaging employees throughout an organization in energy management is key to effectively identifying, implementing and maintaining lasting management and sustainability efforts.

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

Employee engagement is not just a supporting energy management strategy: It is an important driver in achieving lasting energy management success. As illustrated in the Virtuous Cycle of Strategic Energy Management (see Chapter 6), the actions of individuals within an organization serve to reinforce one another over time. Employee engagement efforts can be utilized to formalize and sustain this cycle and address organizational barriers as they arise.

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

Mechanisms for engaging employees include:

- Communications campaigns can be designed to increase awareness, provide motivation and deliver information on best practices, expected actions, corporate rationale and progress toward goals.
- Cross-functional teams can be utilized to optimize expertise and knowledge, decision making, capacity and influence. A cross functional energy management or "Green Team"

should have a skilled facilitator, clear goals and appropriate resources at hand to meet those goals.

- Education/knowledge management mechanisms can be put in place so that key individuals understand their roles and responsibilities and have access to appropriate knowledge and expertise to engage fully in a successful effort.
- Leadership development provided at various levels of an organization can be a key element in a successful energy management program. Leadership in this case refers to those who take responsibility for integrating energy management into their work, are willing to innovate and share best practices and are, or can be placed, in a position to positively impact and reinforce the decisions and actions of others.
- Incentives for, and controls on, decision making and behaviors can provide the accountability that individuals and groups need to prioritize and maintain efforts. Incentives take form through recognition programs, rewards and bonus structures, as well as less formal "pats on the back" for taking action and engaging in behaviors that result in reduced energy consumption. The use of incentives and controls requires reliable mechanisms for assessing performance and reliable and consistent follow through to be effective. Measurement does not need to be sophisticated, but the level of sophistication should match the level of reward or control applied to the measured result. For example, a financial bonus or formal discipline should not be applied to performance that cannot be quantitatively measured.

Tactics for reducing energy use

Decision making

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

Influence

Influence in organizations happens in a multitude of ways, on a number of levels. It can be challenging to identify individuals and groups who will influence others to make decisions and take actions that affect management efforts. A good place to start is to seek out those who have influence in other areas of concern. It is also helpful to first identify the target audience, and then pinpoint who can best reach that audience. When the influencers are identified, it is important to take time to gain their trust and buy-in, as well as understand how, why and what they need to influence the target audience. Creating a structured plan to reach and then utilize the buy-in of key influencers can open up opportunities to affect and reinforce decision making and behaviors on a large scale.

Behavior

In many work settings, energy consumption is impacted significantly by the day-to-day actions of employees. Research on the impact of behavior-based efficiency in the commercial and industrial sectors has been limited, but interest in this area is growing. Rates of efficiency impact are dependent on the way that the term "behavior" is defined. For some, this term simply addresses the way front-line employees interact with equipment and systems; however, others may include deeper processes such as purchasing decisions and formal operational changes. Additionally, it can be difficult to isolate the impact that behavior-focused efforts have on consumption, as other initiatives that affect energy use, such as system upgrades or operational changes, tend to occur simultaneously.

It is important to consider several factors when assessing how, and to what degree, to engage employees in behavior-based management efforts. The principal consideration will be the degree to which the employees can impact energy consumption. Understanding this is important to establishing the role of engagement and the desired results. In some settings, employees interface very little with equipment and system controls and have few other opportunities to affect consumption. For example, a small box retailer may have automated lighting and HVAC controls and allow limited variations in operational procedures, so its employees have little control over equipment selection or operational changes. In this situation, employees' influence over energy consumption is limited to minimal actions such as keeping doors closed, turning off monitors and minimizing hot water use.

In other settings, opportunities exist to increase or decrease significant amounts of consumption through employee actions. For example, hospitals, hospitality and commercial kitchen settings tend to have access to, and more control over, equipment, system controls and other operational considerations. For example, employees can run equipment too long or too hot for operating needs and reduce HVAC efficiency by adjusting setpoints inappropriately; conversely, they can assist in keeping doors closed, lights off and equipment shut down or unplugged when not needed. When this is the case, employee engagement efforts aimed at changing behavior can be very effective and beneficial.

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

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

▶ Top-down or bottom-up?

There are two principal dynamics by which energy management initiatives begin in companies: top-down and bottom-up. The most effective initiatives demonstrate elements of both approaches. In top-down approaches, management decides to make a strategic shift in the way the company captures value from wasted energy. This typically leads to investments in centralized resources or the establishment of new company policies and employee communication efforts. Top-down initiatives have the potential to create significant momentum for change through the actions of one or a few key decision makers, but bottom-up strategies that influence organizational culture are also essential in maintaining this momentum. When creating an effective bottom-up plan, it is important to determine if employee culture is generally accepting of, and enthusiastic about, directives from upper management, or if grassroots efforts are more often embraced. Organizational change literature has shown that without a bottom-up strategy that encourages the employee base to take ownership of top-down initiatives quickly, energy management initiatives can lose momentum and fail to produce lasting improvements.[1]

Integrating an employee engagement program into an organization

Developed by EDF, TD Bank and BrownFlynn, the *Environmental Employee Engagement Roadmap* (EEE Roadmap) provides a three-phase approach to integrating employee engagement into an organization. The goal of the EEE Roadmap is to accelerate engagement by linking successful programs to business results. The phases to the EEE Roadmap are portrayed in Figure 19.1.

The three phases of integrating an employee engagement program can be broken down as follows:

- *Phase 1:* Define a key goal in the EEE program and work backwards to define quantitative performance metrics to measure improvement.
- *Phase 2:* Increase engagement by encouraging large numbers of employees to perform tasks with quantifiable outcomes.
- *Phase 3:* Employees "transform" as they become engaged and ask others to join them to increase results. This enthusiasm should be utilized to further achieve goals.

FIGURE 19.1

Three phases of integrating employee engagement

Source: TD Bank, EDF Climate Corps, and BrownFlynn, *Environmental Employee Engagement Roadmap*

Success metrics

Whether evaluating the impact and value of employee engagement through decision making, influence or behavior, when considering the value of any employee engagement effort, a vision for success and the metrics with which to measure performance should be established. As

TABLE 19.2

Quantifying the degree of employee engagement

Levels	Definition of engagement level	Measurable proxy (examples)	How to capture
Transformed	Transformed, deeply committed, naturally takes many actions on behalf of environment, asks others to take actions on behalf of the environment	• Frequency of environmental actions • Purchases of environmentally friendly products • Comfort speaking with other employees, customers, family, friends about environment • Number of employee environment teams	Employee survey, physical counts or estimates
Active	Energized and takes first action on behalf of the environment	• Total amount of water bottles, waste, composting, paper or energy • Number of volunteer hours	Physical counts or estimates, engagement software
Connected	Emotionally connected to the environment	• Level of pride in company's environmental accomplishments • Level of commitment to company due to participation in environmental programs	Employee survey, engagement software
Aware	Aware of the environment	• Percent of employees who are aware of company's environmental objectives, programs, initiatives, etc.	Employee survey
Un-engaged	No awareness	• Percent of employees who are aware of company's environmental objectives, programs, initiatives, etc.	Employee survey

Source: TD Bank, EDF Climate Corps, and BrownFlynn, *Environmental Employee Engagement Roadmap* previously discussed, the value may be seen directly in relation to reductions in consumption, but it can be exceptionally challenging to measure it. It can be difficult to isolate the consumption effects of changes in employee decisions and behavior from those provided by system upgrades, operational changes and many other factors that impact consumption. As noted earlier, employee engagement may provide value by advancing and reinforcing the value of top-down initiatives. Additionally, value may be found in less directly related benefits, such as employee motivation and retention, which can result when employees feel the organization's value of stewardship aligns with their own, whether through public-facing or internal statements. The EEE Roadmap provides a clear and organized categorization of engagement levels, which can be used to develop measurable metrics to quantify success, see Table 19.2 (page 92).

The complete EEE Roadmap is available online at http://edfclimatecorps.org/sites/edfclimatecorps.org/files/eeeroadmapfinal.pdf

Additional information

For more information on employee engagement and behavior change, see:

- Precourt Energy Efficiency Center, https://peec.stanford.edu/resources/readings/foundational
- Raytheon, "Employee Engagement in Energy Conservation (case study)," https://www1.eere.energy.gov/manufacturing/pdfs/webcast_20100805_achieving_total_employee_engagement.pdf
- ENERGY STAR, 2012 National Building Competition, https:www.energystar.gov/index.cfm?c=buildingcontest.battle_resources

Notes

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

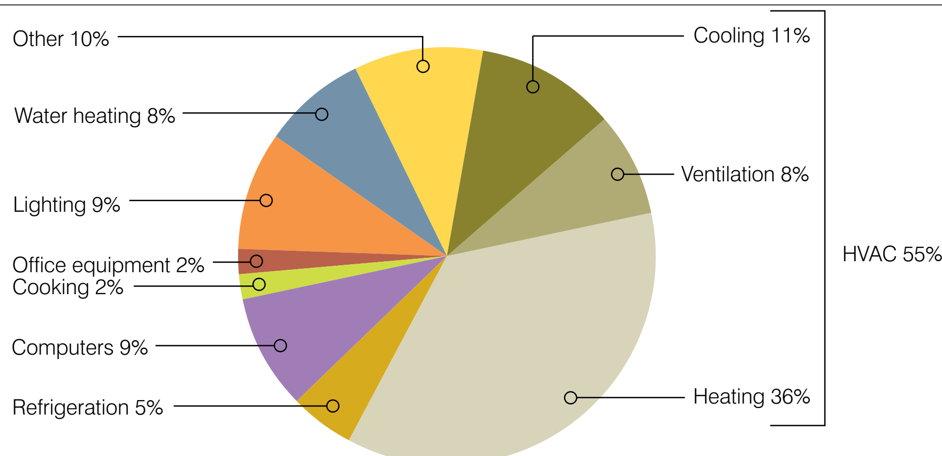
APPENDIX A

Energy consumption of U.S. commercial buildings by type

The U.S. EIA conducts the CBECS every four years. The survey compiles data about energy use, expenditures and characteristics of commercial buildings in the U.S. This appendix includes figures detailing the end uses of energy in each commercial building type surveyed by the EIA: education, food sales, food service, healthcare, lodging, retail, office, public assembly, public order and safety, religious worship, service, warehouse, other and vacant. Each figure is accompanied by the text provided by the CBECS to define each building classification. All data and accompanying text is sourced from the EIA.[1,2]

FIGURE A.1

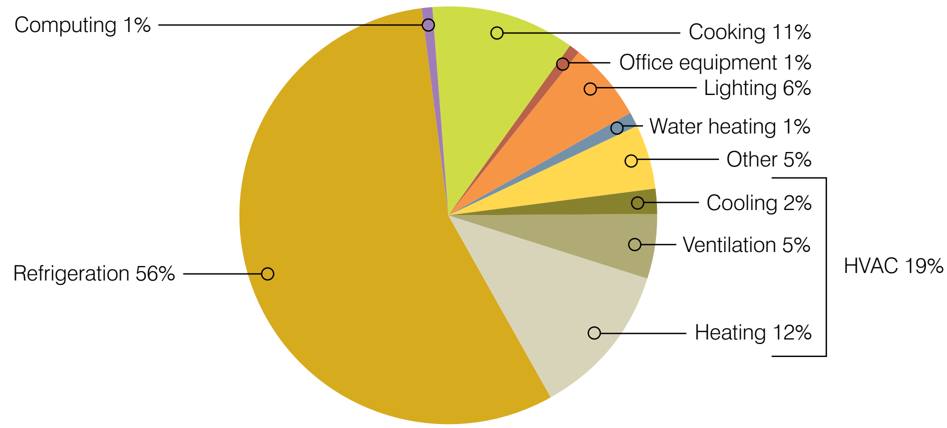
Energy use for education buildings



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

FIGURE A.2

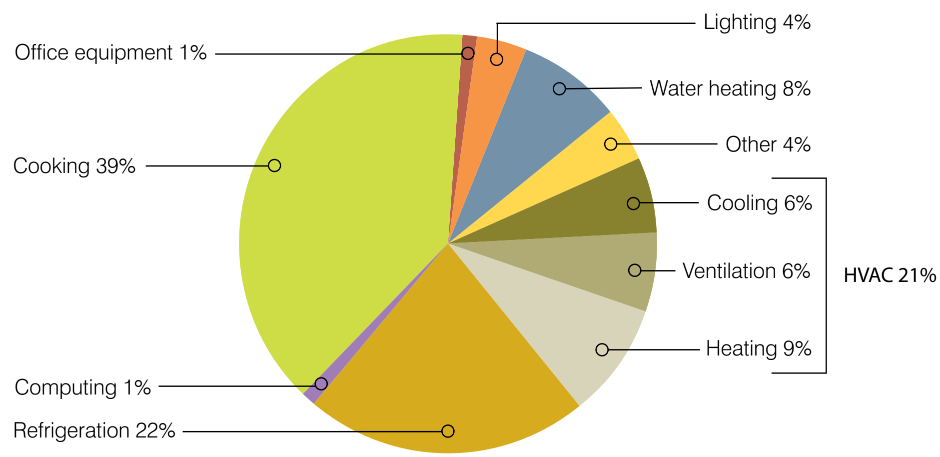
Energy use for food sales buildings



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

FIGURE A.3

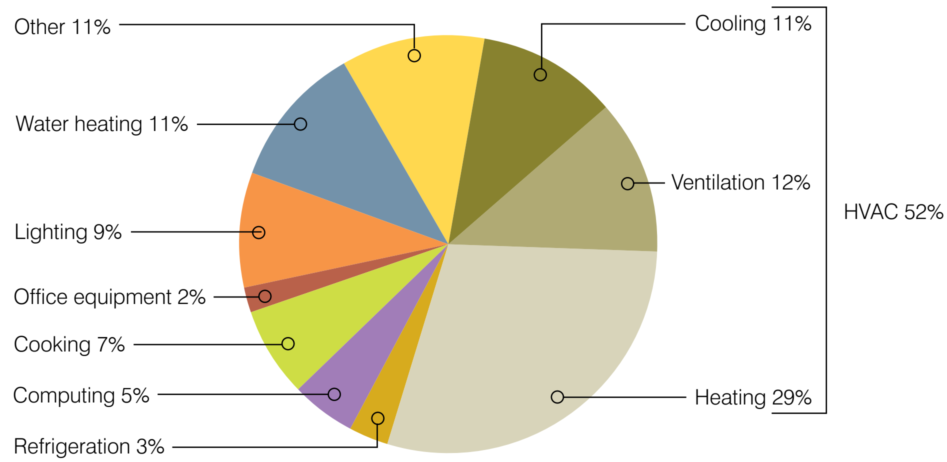
Energy use for food service buildings



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

FIGURE A.4

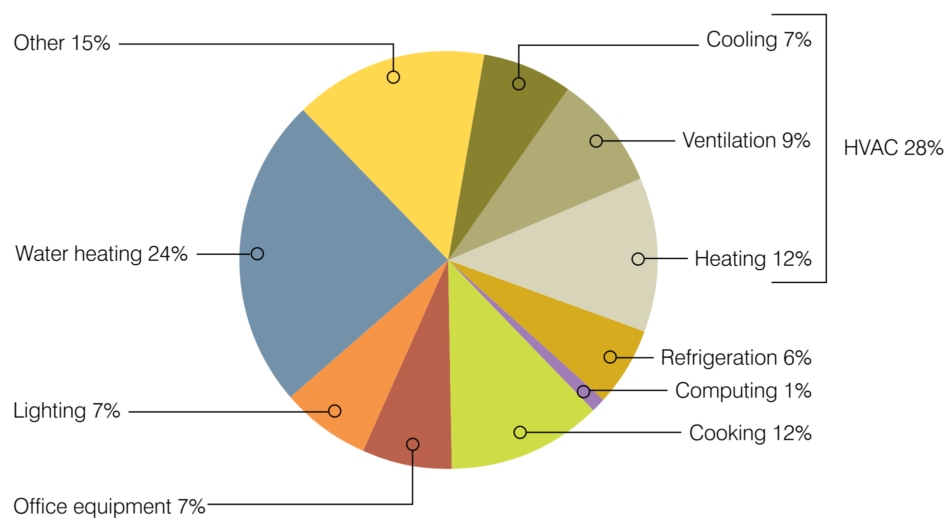
Energy use for healthcare buildings



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

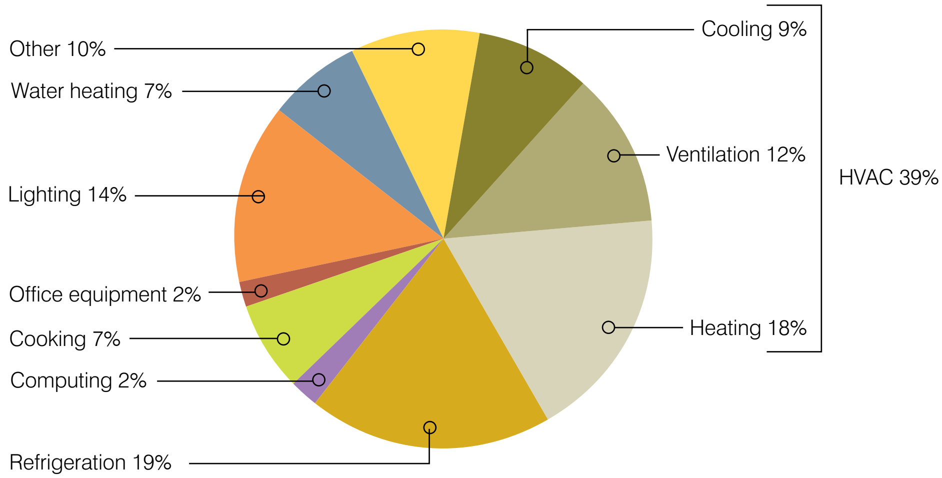
Energy use for lodging buildings



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

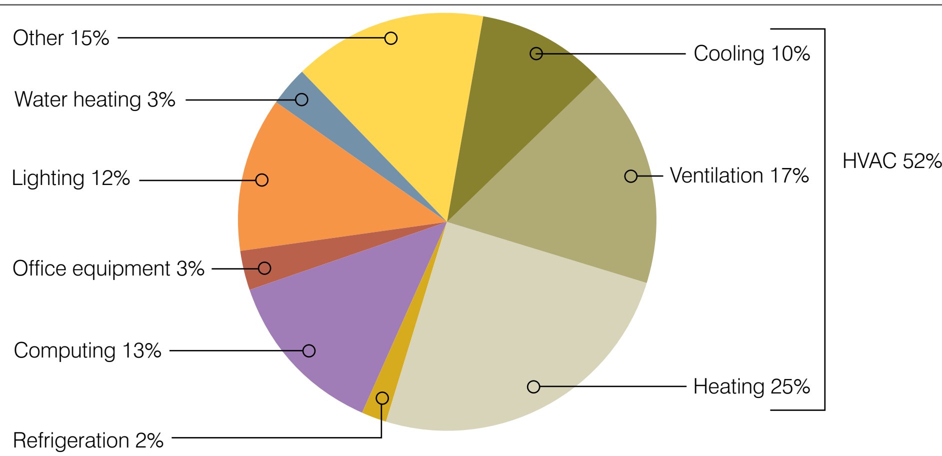
Energy use for retail buildings



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

FIGURE A.7

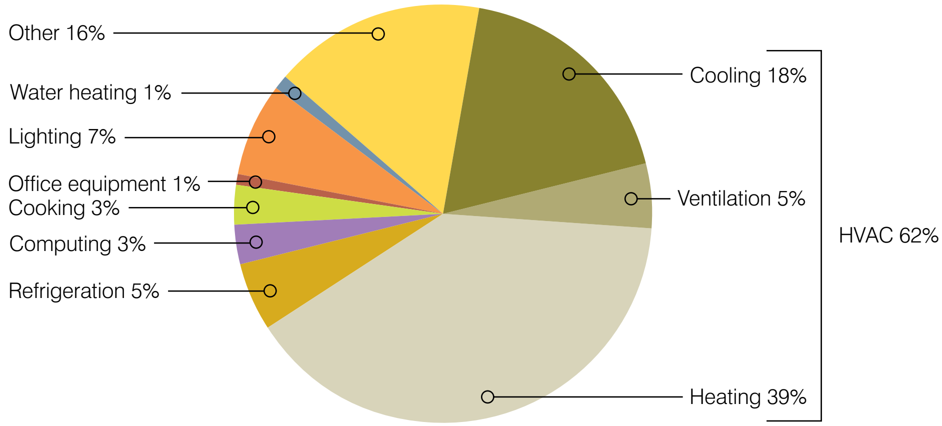
Energy use for office buildings



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

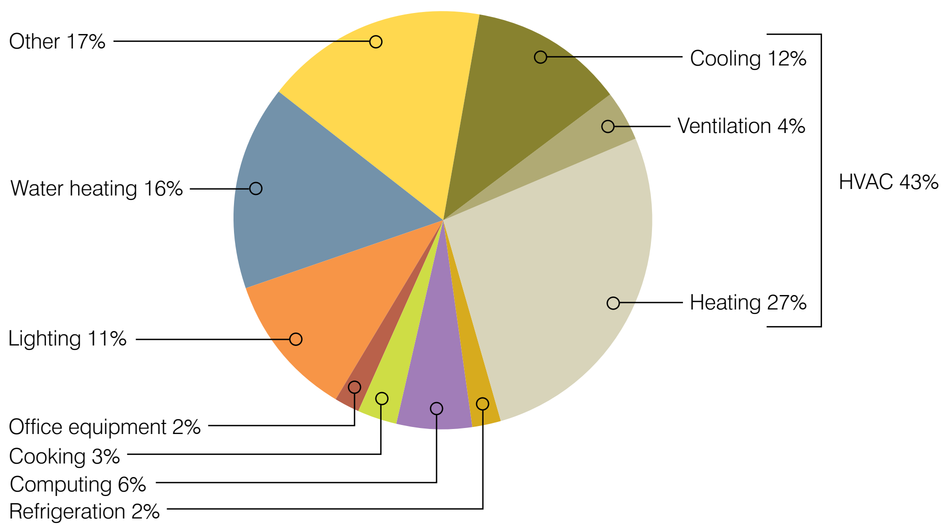
Energy use for public assembly buildings



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, nightclub), library, funeral home, student activities center, armory, exhibition hall, broadcasting studio, transportation terminal.

FIGURE A.9

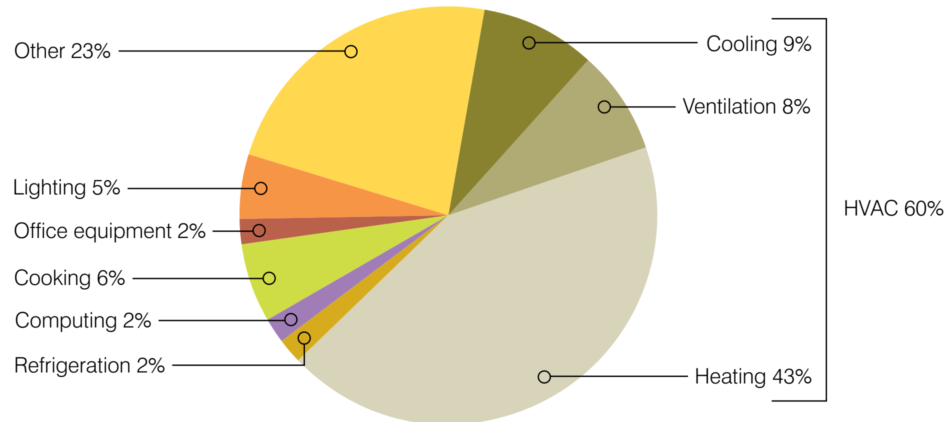
Energy use for public order and safety buildings



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

FIGURE A.10

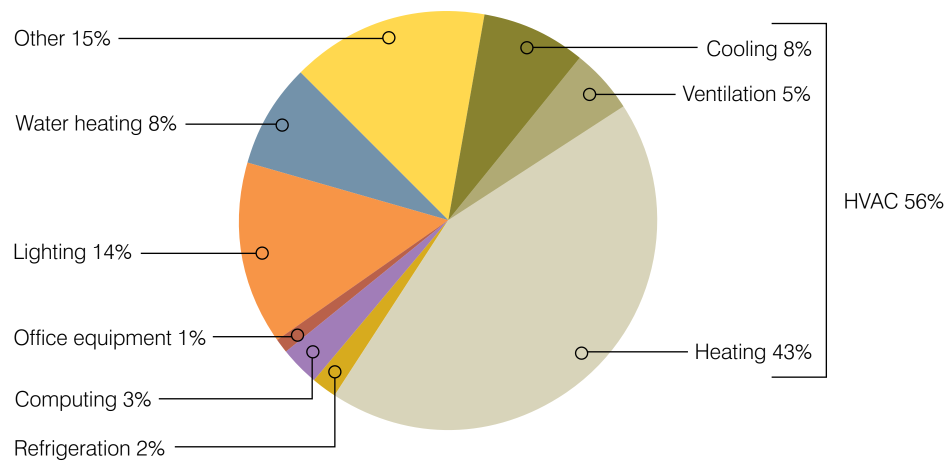
Energy use for religious worship buildings



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

FIGURE A.11

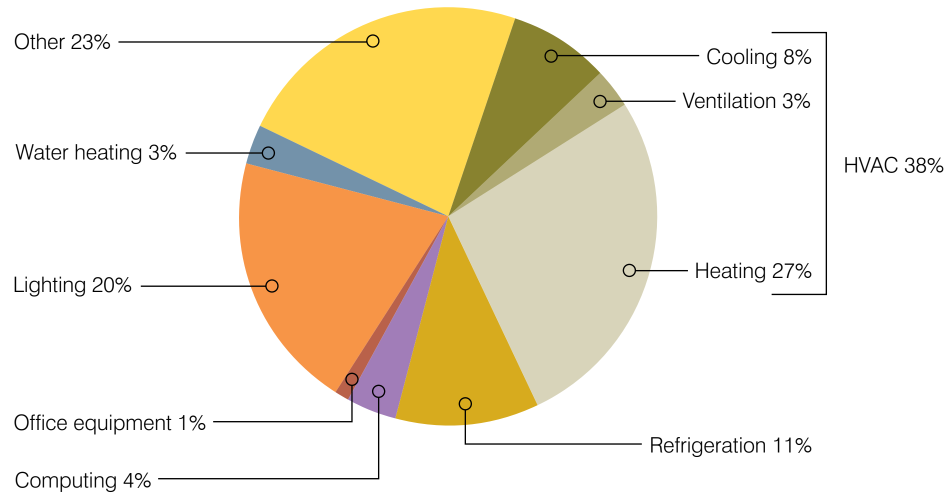
Energy use for service buildings



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

FIGURE A.12

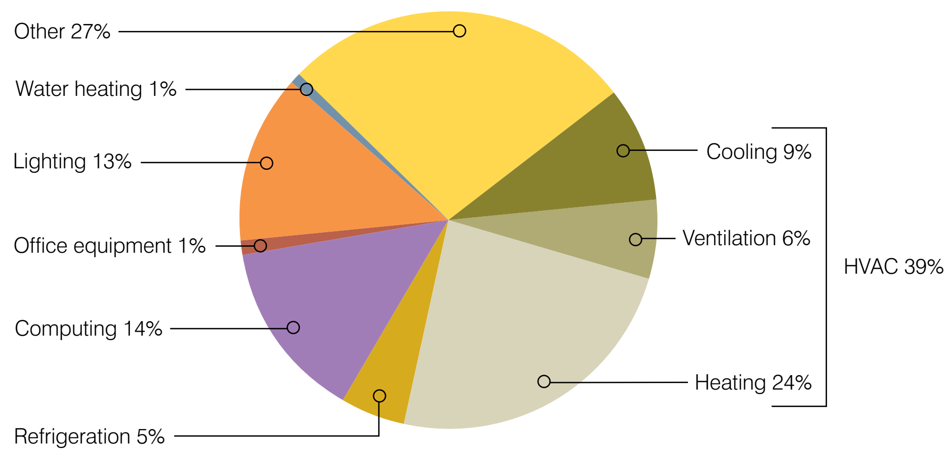
Energy use for warehouse and storage buildings



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

FIGURE A.13

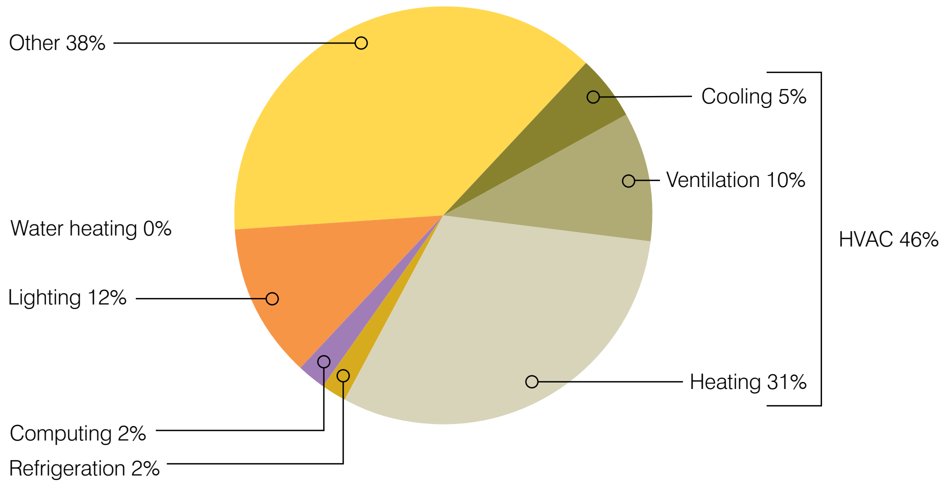
Energy use for other buildings



Buildings that are industrial or agricultural with some retail space; buildings having several different commercial activities that, together, comprise 50% or more of the floor space, 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 floor space was vacant than was used for any single commercial activity at the time of interview. Therefore, a vacant building may have some occupied floor space.

Notes

[1] Energy Information Administration, "Commercial Buildings Energy Consumption Survey,"Table E1. Major Fuel Consumption (BTU) by End Use for All Buildings, May 2016. http://www.eia.gov/consumption/commercial/data/2012/index.cfm?view=microdata

[2] Energy Information Administration, "Commercial Buildings Energy Consumption Survey," Buildings Type Definitions, https://www.eia.gov/consumption/commercial/building-type-definitions.cfm

APPENDIX B

HVAC information

Packaged AC units vs. centralized HVAC systems

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

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

Performance measurements

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

- Cooling capacity is rated as the amount of heat energy a cooling unit can remove from a space per hour, expressed in Btu per hour. One ton of cooling capacity will remove 12,000 Btu of heat per hour.

- Energy Efficiency Ratio (EER) is the ratio of the cooling capacity (Btu/hr) to the power input value (watts) at any given set of rating conditions expressed in Btu/watt-hour. The current standard is an EER of 11.0 for systems with a capacity of 65 to 135 thousand Btu/hour (kBtu/hr).

- Coefficient of Performance (COP) is defined differently depending on function. For cooling, COP describes the ratio of the rate of heat removal to the rate of energy input in consistent units, for a complete cooling system as tested under a nationally recognized standard. For heating, it is the ratio of the rate of heat delivered to the rate of energy input in consistent units, for a complete heat pump system as tested under designated operation conditions.

COP is particular to heat pumps, whether water or air source. Heating efficiency is given in COP and the cooling efficiency is given in EER or SEER. Conversion: COP= EER * 3.4.

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

- 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.

- 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, which is expressed in watt-hours.

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

Additional information

For more information on HVAC optimization, see:

- Non-technical introduction to HVAC: “Energy Efficiency in Industrial HVAC Systems,” 2003. http://www.p2pays.org/ref/26/25985.pdf
- Southern California Edison, “HVAC Optimization,” https://www.hvacoptimization.com/
- 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 EPRI Office Complexes Guidebook, Innovative Electric Solutions. Chapter 6, Heating, Ventilating, and Air-Conditioning (HVAC). December 1997. tr-109450, p. 195.

2 Air Conditioning and Refrigeration Institute. “Standard for Performance Rating of Unitary Air Conditioning Equipment and Air Source Heat Equipment,” 2006.

APPENDIX C

Lighting information

Lighting functions

When considering options for lighting efficiency improvements, it is important to identify the function for which the lighting is needed. 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. Desk lamps are a typical example of task lighting.
- **Accent lighting** draws attention to special features or enhances the aesthetic qualities of an indoor or outdoor environment. Common locations that benefit from accent lighting are 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

In the lighting industry, the term "lamp" is used to describe an electric light source, which includes bulbs and tubes. Common light sources include:

- 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, which also produces waste heat.
- Tungsten halogen lamps are slightly more energy efficient and last longer than standard incandescent lamps. 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** are very commonly used in business applications; these lamps are generally identified as T12 and T8, referring to the size of the tube's diameter. T12s are 12/8 inch in diameter, while T8s are 8/8, or one inch. T8s are typically more efficient than T12s.

- 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.
- LEDs are solid-state light sources that deliver a direct beam of light at a very low wattage. The unique advantages of LEDs include compact size, long life, ease of maintenance, resistance to breakage and vibration, good performance in cold temperatures, lack of infrared or ultraviolet emissions and instant-on performance. In addition, LEDs emit light in a specific direction, which reduces the need for reflectors and diffusers that trap light. Due to recent advances in technology, dimming and color control have become additional benefits of LEDs.
- HID lamps have a longer life and provide more light per watt than any other light source. HID bulbs are commonly used for outdoor security and landscape lighting. Mercury vapor lamps, which originally produced a bluish-green light, were the first commercially available HID lamps. Today, they are also available in a color-corrected whiter light. Increasingly, the more efficient high-pressure sodium and metal halide lamps are replacing mercury vapor lamps. Standard high-pressure sodium lamps have the highest efficacy of all HID lamps, but they produce a yellowish light. High-pressure sodium lamps that produce a whiter light are now available, but their efficiency is somewhat lower than traditional high-pressure sodium lamps. Metal halide lamps are less efficient but produce an even whiter, more natural light. Colored metal halide lamps are also available.

Guidelines for lighting design

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

1. **Improve visual quality of the task.** Identify specific visual tasks and recommend appropriate luminance, including task lighting.
2. **Improve geometry of space and cavity reflectance.** Use the light and color of the room to increase the use of natural light; rearrange furniture for optimal lighting.
3. **Improve lighting quality.** Cut veiling reflections through more indirect light distribution and reduce glare.
4. **Optimize lighting quantity.** Balance levels of ambient and task lighting and ensure adequate light levels for tasks being performed.
5. **Harvest/distribute natural light.** Daylighting improves the visual environment and results in increased productivity and energy savings. It is important to shade windows to prevent glare and heat gain and to control the amount of daylight entering the building. Daylight can be redirected to where it is needed and be integrated with electric lights.
6. **Optimize technical equipment.** Lamps, ballast, reflectors and other technology must be optimized for maximum performance.
7. **Control, maintain and educate.** Proper maintenance of equipment is a crucial component to keeping technology in the best shape possible.

Additional information

For more information on lighting design optimization, see:

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

APPENDIX D
Water heating information

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

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

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

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

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

Solar water heaters use energy from the sun to heat water. Solar water heaters are designed to serve as pre-heaters for conventional storage or demand water heaters. While the initial cost of a solar water heater is high, it can save a lot of money over the long term. On a LCC 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 access the hot water from the bathroom. If the pipe has a ¾ 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 to prevent both the loss of water as well as the loss of Btu is the installation of tankless heaters adjacent to the hot water applications. 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.[2]

Additional information

For an introduction to facilities water management, see:

- James Piper, "Water Use: Slowing the Flow," 2003. http://www.facilitiesnet.com/maintenanceoperations/article/Water-Use-Slowing-the-Flow-Facility-Management-Maintenance-Operations-Feature--1969

Notes

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

[2] Benjamin Stein, *Mechanical and Electrical Equipment Buildings*, 9th Edition, pp. 601–603.

APPENDIX E

Energy use by miscellaneous equipment

Depending on the equipment present in the organization's building, there may be opportunities for energy savings in equipment beyond those previously mentioned. 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 two kWh used by office equipment, another one kWh is used by miscellaneous equipment.[1] The following are the top ten users of energy in their survey:

TABLE E.1

Energy use by miscellaneous equipment

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

Source: LBNL, 2007

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

APPENDIX F

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 California Energy Commission at http://www.energy.ca.gov/

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


Adobe

From 2001 to 2004, Adobe undertook 30 energy conservation and related projects. It 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 EPA's 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 to 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 EPA's ENERGY STAR label for each of its three buildings, with scores of 78, 84 and 87 (on a scale of 100).

TABLE F.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 F.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 STREET, 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 efficiency retrofit project. Swinerton's office space at 260 Townsend Street, San Francisco was originally built in 1984 with 67,000 square feet of office space, 28,000 square feet of covered parking and 19,000 square feet of terraces.

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

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

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

Swinerton

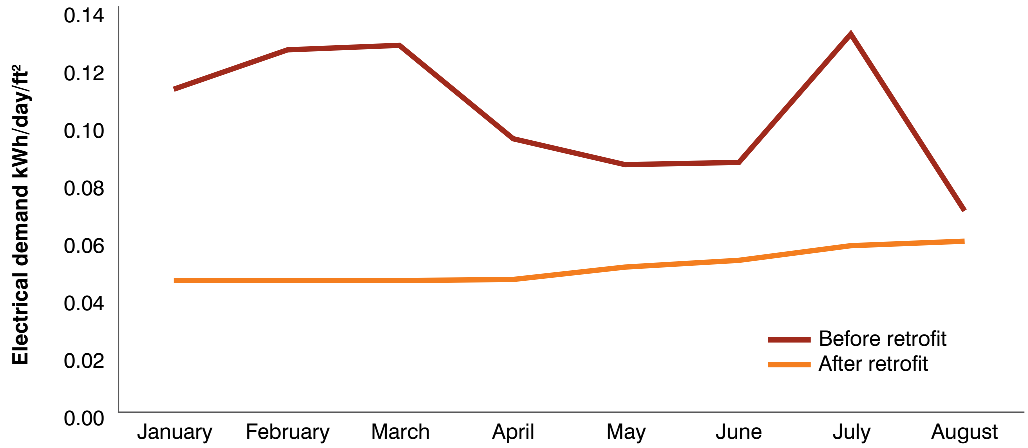
Building management system

Prior to the Swinerton retrofit, the 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 onto specific groups based on usage. This

FIGURE F.1

Electrical demand for 260 Townsend before retrofit and after retrofit



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

Lighting retrofit

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

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

Transportation

Swinerton's headquarters at 260 Townsend has access to a variety of public transportation options. It is located next to six bus stops, the Municipal Railway ("Muni") N-Judah Train and the Southbay commuter rail CalTrain. Alternative transportation is further encouraged by reserved access to parking for van pools, 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 employee use around the city. All of these efforts reduce individual driving to the workplace and in the city. Moreover, these efforts may have value-added employee health benefits such as reduced stress and improved fitness.

Water efficiency

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

CASE STUDY 3: 100 PINE STREET, SAN FRANCISCO

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

Mathew Grimm

California's energy crisis of 2001 kick-started efficiency efforts at 100 Pine when the building management hired 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 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. For example, the building management added a section called "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 includes:

- A reduction of 1,200,000 kWh between the years 2000 and 2002 through fluorescent lighting upgrades and improved usage of the building EMS
- 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 F.3 (page 114). Each of the four improvements being considered have paybacks between 1.3 and 3.1 years, with estimated total annual cost savings of over $500,000 plus incentives from the local utility (PG&E).

TABLE F.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 G

Demand response agreements

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

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

APPENDIX H

Microgrids

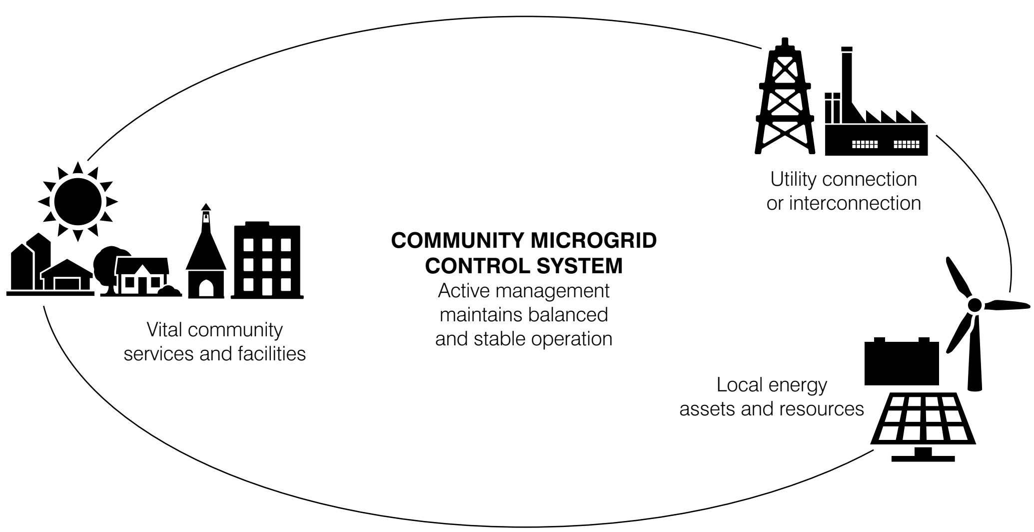
A microgrid is an energy system comprised of localized energy sources that usually operates synchronously with the traditional centralized grid. When connected, a microgrid maintains the same voltage as the centralized grid; however, in the event of an issue, the microgrid can be separated from the centralized grid and operate as an independent entity by using energy from its own distributed local sources.

Despite its name, a microgrid can range in size from a single facility to an entire city or island. Because it can operate independently from the grid, it can not only serve as a strategy for energy and cost savings during DR events, but also as an electrical backup in the event of an emergency. As severe weather events have become more frequent in recent years, energy resiliency is a key concern and microgrids can provide much needed energy security and reliability. For example, after it suffered the loss of 90% of its electrical power in Superstorm Sandy in 2012, the City of Hoboken commissioned an EDF Climate Corps fellow to design a comprehensive toolkit for establishing a clean energy microgrid which can be seen at http://edfclimatecorps.org/sites/edfclimatecorps.org/files/hoboken_casestudy.pdf

Microgrids can be "clean" microgrids if they incorporate renewable energy sources, such as solar and wind instead of using diesel generators and fossil fuels. Clean microgrids can be considered even more resilient than a typical microgrid, because they don't depend on fossil fuel delivery, which can be disrupted in crisis situations. Figure H.1 illustrates a microgrid that

FIGURE H.1

Community microgrid control system



Source: Microgrid Institute

is integrated into a community control system. The local energy assets, including solar, wind and storage, would make this microgrid clean.

Additional Information

For more information on microgrids, see:

- Department of Energy, "The Role of Microgrids in Helping to Advance the Nation's Energy System," https://energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-system
- Department of Energy, "How Microgrids Work," https://www.energy.gov/articles/how-microgrids-work
- NREL, Technology Development, http://www.nrel.gov/tech_deployment/microgrids.html
- Microgrid Institute, "About Microgrids," http://www.microgridinstitute.org/about-microgrids.html

Glossary

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

ADR: See *automated demand response*.

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

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

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

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

BAS: See *building automation system*.

BMS: See *building automation system*.

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

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

BTU: See *British thermal unit*.

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

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

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

capital investment: Funds in a firm or enterprise for the purposes of furthering its business objectives; it may also refer to a firm's acquisition of capital assets or fixed assets such as manufacturing plants and machinery that is expected to be productive over many years.

capital expenditures: Money spent by a business or organization on acquiring or maintaining fixed assets, such as land, buildings and equipment.

carbon dioxide equivalent (CO_2e): The concentration of carbon dioxide that would cause the same level of radiative forcing as a given type of concentration of greenhouse gasses such as methane, nitrous oxide and perfluorocarbons.

CFL: See *compact fluorescent lamp*.

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

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

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

CSP: See *curtailment service provider*.

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

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

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

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

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

DG: See *distributed generation*.

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

dimmer: See *dimming controls*.

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

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

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

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

DR: See *demand response*.

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

EIS: See *energy information system*.

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

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

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

EUI: See *energy use intensity*.

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

fluorescent: See *fluorescent tube lamp*.

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

fuel cell: Fuel cells convert the chemical energy of hydrogen or another fuel into electricity by way of an electrochemical process rather than a combustion process. Fuel cells emit no traditional air pollutants and are efficient forms of energy generation; however, they can only be considered a renewable energy resource if they operate on a renewable energy fuel.

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

global warming potential (GWP): A relative measure of how much heat a greenhouse gas traps in the atmosphere compared to the amount of heat trapped by a similar mass of carbon dioxide.

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

GRF: See *green revolving fund*.

Greenhouse Gas Protocol: Global standards for how to measure, manage and report greenhouse gas emissions, developed by the World Resources Institute and World Business Council for Sustainable Development.

GWP: See *global warming potential*.

heating, ventilation and air conditioning (HVAC): The system used to provide heating and cooling services to buildings.

HID: See *high-intensity discharge*.

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

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

HVAC: See *heating, ventilation and air conditioning*.

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

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

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

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

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

IRR: See *internal rate of return*.

ISO: See *independent system operator*.

IT: See *information technology*.

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

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

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

KPI: See *key performance indicator*.

kW: See *kilowatt*.

kWh: See *kilowatt-hour*.

LCC: See *life cycle cost*.

LED: See *light emitting diode*.

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

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

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. See *load curtailment*.

load centers: Centers that receive electricity from generators and distribute the electricity to homes and buildings.

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

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.

MACRS: See *Modified Accelerated Cost Recovery System*.

M&V: See *measurement and verification*.

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

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

MWh: See *megawatt-hour*.

Modified Accelerated Cost Recovery System (MACRS): Tax deprecation system in the U.S. under which the capitalized costs of tangible property is recovered over a specified life by annual deduction deprecation that is computed under declining balance switching to straight line or straight line.

net metering: A billing mechanism that allows solar system owners to feed excess electricity back into the grid and receive a credit on their electricity bill.

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

NPV: See *net present value*.

OBR: See *on-bill repayment*.

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

on-bill repayment (OBR): Requires the customer to repay the investment through a charge on their monthly bill, but with this option, the upfront capital is provided by a third party, not the utility.

operating expenses: Expenditures that a business incurs to engage in any activities not directly associated with the production of goods and services; same as selling, general and administrative expenses, not depreciated over time.

PACE: See *Property-Assessed Clean Energy*.

payback: See *simple payback*.

peak demand: See *peak load*.

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

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

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

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

power purchase agreement (PPA): A financial contract in which a third party owns, operates and maintains a renewable energy system and the customer agrees to purchase the system electricity for a set length of time.

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

PPA: See *power purchase agreement*.

Property-Assessed Clean Energy (PACE): Financing option for energy efficiency, renewable energy and water conservation upgrades to a building where the initial investment is funded by governmental or other inter-jurisdictional authorities and is paid back over time by the property owners.

PUE: See *power utilization effectiveness*.

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

REC: See *renewable energy credit*.

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

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

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

renewable energy: Energy that is collected from resources which are naturally regenerated over a short period of time, such as solar, geothermal, biomass, wind and tides.

renewable energy credit (REC): A tracked and verified certificate that represents the environmental benefits of carbon reduction created by adding 1 megawatt-hour of renewable electricity to the grid.

renewable portfolio standard (RPS): State level regulation that requires or sets goals for a specified percentage of customer electricity to be supplied by renewable resources.

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.

reserve margin: The backup electricity that grid operators plan for when forcasting energy needs in the event of power failure.

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

ROI: See *return on investment*.

RPS: See *renewable portfolio standard*.

RTO: See *regional transmission operation*.

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

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

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

solar photovoltaic: Solar panel systems comprised of solar cells that convert solar energy into electricity.

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

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

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

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

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

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

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

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

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

time of use pricing: A variable rate structure that charges for energy depending on the time of day and the season the energy is used.

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

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

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

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

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

UPS: See *uninterruptible power supply*.

variable frequency drive (VFD): A type of adjustable-speed drive used to control motor speed and torque by varying motor input frequency and voltage.

VFD: See *variable frequency drive*.

virtual power purchase agreements: Long-term contracts for renewable energy systems without the delivery of electricity where a company agrees to pay the project developer a fixed rate over a contracted period of time, while continuing to purchase electricity from a local grid. In exchange, the developer generates and sells power onto the grid at spot market prices, turning the proceeds over to the contracted company.

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

watt: See *kilowatt*.

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