7. Reducing Supplemental Loads

Revised August 2007

7.1 Overview

Reducing supplemental loads is the third stage in the building upgrade process. The staged approach (**Figure 7.1**) accounts for interactions among all the energy flows in a building and produces a systematic method for planning upgrades that maximize energy savings. When the staged approach is performed sequentially, each stage includes changes that affect the upgrades performed in subsequent stages, thus setting up the overall process for the greatest energy and cost savings possible. In this upgrade sequence, supplemental load reductions are completed before heating and cooling loads can be determined.

Supplemental load sources are secondary load contributors to energy consumption in buildings—typically people, computers, lights, and the building itself. These loads can adversely affect heating, cooling, and electric loads. However, the effect of supplemental loads can be controlled and reduced through strategic planning and implementing energy-efficient upgrades. With careful analysis of these sources and their interactions with HVAC systems, equipment size and upgrade costs can be reduced. These upgrades can increase HVAC energy savings and reduce wasted energy.

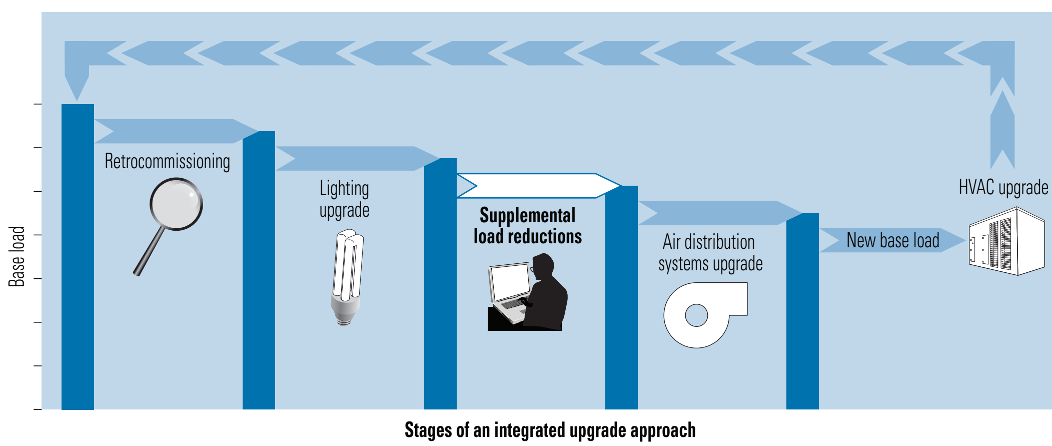
This chapter helps identify these load sources and illustrates strategies that can mitigate their negative impact on energy performance: First assess the supplemental-load sources in a building to determine reduction opportunities. Then contact vendors, contractors, or engineering consultants to specify upgrades. Finally, install energy-efficient upgrades to reduce supplemental loads on heating, cooling, and electrical systems.

The best ways to reduce supplemental loads include:

- Reducing equipment energy use
- Upgrading the building envelope by improving insulation, fenestration, and roofing

Figure 7.1: Staged approach to building upgrades

The staged approach to building upgrades accounts for interactions among all the energy flows in a building. Each stage affects the upgrades performed in subsequent stages, thus ensuring the greatest energy and cost savings possible. Reducing supplemental loads affects heating, cooling, and electric loads.



Courtesy: E SOURCE

Reducing heating, cooling, and electric loads through these measures, added to the reductions already achieved through the Retrocommissioning and Lighting Upgrade stages, allows installation of smaller, lower-first-cost HVAC equipment in the Air Distribution and Heating and Cooling Systems stages. If possible, do not install HVAC equipment until all loads have been reduced and the impacts on HVAC systems can be measured directly. If HVAC equipment installation cannot be delayed, take the time to predict the magnitude of load reductions from upgrade projects.

7.2 Reducing Equipment Energy Use

Electric-powered equipment obviously affects electric loads. It is also important to remember that for many types of equipment, much of the electricity used in a space will ultimately end up in that space as heat. Thus, reducing the energy use of electric equipment not only reduces electric loads but also reduces cooling loads and, as with lighting, provides an opportunity to replace that heat more efficiently, when needed, with gas heat or electric heat pumps. Office equipment and, in many facilities, kitchen equipment, can be cost-effectively upgraded with more efficient products and controls. The best way to ensure that this happens is with a corporate policy that encourages purchasing energy-efficient equipment. Employee training programs can also help ensure that equipment is used efficiently.

Corporate Purchasing Policies

By purchasing and specifying energy-efficient products, organizations can cut energy use, achieve enormous cost savings, and help reduce pollution and greenhouse gas emissions. To ensure that new equipment purchases favor high-efficiency models, energy management programs should adopt a procurement policy as a key element for their overall strategy.

Instituting an effective policy can be as easy as asking procurement officials to specify ENERGY STAR–qualified products, such as office equipment, in their contracts or purchase orders. This can be made simple by inserting model procurement language (customized as necessary) into procurement contracts for energy-consuming products and systems. The language should specify the performance criteria used for ENERGY STAR–qualified and other high-efficiency products. For many products not covered under ENERGY STAR, such as ice machines, contracts can include recommendations that the Department of Energy provides to federal government procurement officials.

Procurement contracts typically specify the desired equipment along with other vendor requirements to ensure the equipment operates efficiently. For example, vendors may be required to properly configure energy-saving features and provide customer support for power-management features to ensure that they remain properly enabled and are repaired if a malfunction occurs.

EPA provides purchasing and procurement resources that can help organizations obtain energy-efficient ENERGY STAR products. These resources include lists of qualifying products, key product criteria, drop-in procurement language, and savings calculators. Visit the ENERGY STAR Purchasing & Procurement web site at www.energystar.gov/purchasing for more information. For products not covered under ENERGY STAR, the U.S. Department of Energy's Federal Energy Management Program (FEMP) offers its own recommendations. Both ENERGY STAR– and FEMP-recommended products use 25 to 50 percent less energy than their traditional counterparts, reduce fossil fuel use, and produce fewer greenhouse gas emissions. See the FEMP Energy-Efficient Products page at www1.eere.energy.gov/femp/procurement/eep_modellang.html.

Office Equipment Efficiency Measures

In the business world, office equipment is the fastest growing electric load. However, much of the energy used is wasted because equipment is left on when not in use throughout the workday, at night, and on weekends. Office equipment (whether mechanical, electrical, or electronic) also generates heat in the conditioned space which, although useful when space heating is needed, can generally be supplied more efficiently through gas-fired space heating or electric heat pumps.

A corporate procurement policy that mandates ENERGY STAR–labeled equipment can reduce electric loads from office equipment and space cooling loads. Virtually all office equipment manufacturers offer a wide range of ENERGY STAR models, including copiers, printers, mailing machines, fax machines, monitors, computers and workstations, scanners, and multifunction devices. Office equipment with the ENERGY STAR label saves energy and money by powering down and entering "sleep" mode or turning off when not in use and achieving higher efficiency when in use (see **Table 7.1**). Products that meet the ENERGY STAR specifications use about half as much electricity as conventional equipment. See the ENERGY STAR Office Equipment web site at www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductCategory&pcw_code=OEF.

Energy-efficient equipment with the ENERGY STAR label costs the same as comparable nonlabeled equipment and produces significant energy savings, as shown in **Table 7.2**. The estimated savings are per unit and can be multiplied to estimate savings for an office with hundreds of energy-efficient products.

Table 7.1: Performance specifications for ENERGY STAR–labeled office equipment

Office equipment labeled ENERGY STAR often must be more efficient than nonlabeled equipment when in active operation as well as during periods of inactivity. In some cases, there are additional requirements.

Equipment	ENERGY STAR specifications
Computers	Require improved efficiency over all operation modes due to use of highly efficient power supplies. Automatically enter a low-power sleep mode within 30 minutes of inactivity.
Copiers	Require improved efficiency when the product is in use. Also power down when not in use to a low energy consumption level. Depending on the speed, may be required to print double-sided pages, reducing both copying and paper costs.
Fax machines	Require improved efficiency when the product is in use. Automatically power down after 5 minutes of inactivity. Combination printer/fax machines consume half as much energy when idle as two stand-alone products.
Laptops	Require improved efficiency over all operation modes due to use of highly efficient internal and external power supplies. If left inactive, enter a low-power mode and may use 15 watts or less.
Monitors	Require improved efficiency when they are in active mode. Use 2 watts or less in sleep mode and 1 watt or less in off mode. Use up to 85 percent less electricity than standard models.
Multifunction devices	Offer copying as well as printing, faxing, scanning, and/or other capabilities. Automatically power down after 15 to 60 minutes of inactivity, depending on equipment speed. May require automated duplexing, depending on the speed.
Printers	Require improved efficiency when the product is in use. Automatically power down after 5 to 60 minutes of inactivity, depending on equipment speed. May require automated duplexing, depending on the speed.
Scanners	Require improved efficiency when the product is in use. Automatically power down after 15 minutes when not in use.

Source: EPA

Table 7.2: ENERGY STAR office equipment estimated savings

Office equipment labeled ENERGY STAR typically costs no more than nonlabeled equipment and produces significant energy savings when considering the many pieces of equipment in a typical office building.

Equipment	Annual energy savings per unit (kWh)	Annual cost savings per unit ($)[a]
Computers and monitors	200 to 370	20 to 37
Copiers	236	24
Fax machines	101	10
Printers	45	4

Note: a. Based on $0.10/kWh electric rate;
kWh = kilowatt-hours.

Source: EPA, Lawrence Berkely National Laboratory

In many offices, there is also a growing use of energy-consuming devices that are not covered by ENERGY STAR—such as personal coffee pots, cup warmers, fans, under-the-desk heaters, audio equipment, and computer peripherals. Although each device draws only a small amount of power, the total can be significant. Companies can have policies that ban such items or at least educate employees about wise use—turning devices off or uplugging them when not in use.

Besides purchasing energy-efficient equipment, it is also important to ensure people use the energy-saving settings. For computers and monitors this step can be accomplished using the power-management settings of networked work stations via three approaches.

Have employees enable the existing power-management features on their computers and turn off computers at night. Most computer equipment sold today can be set to enter a low-power sleep mode after a period of inactivity. Unfortunately, most users do not take advantage of this feature. Note that the power-management setting that puts the monitor to sleep is different from the screen saver—monitors still use full power while a screen saver is running.

This approach is inexpensive: Meet with information technology (IT) staff, energy-management staff, and executive management staff to explain the plan. Then send e-mails to employees explaining how to enable power management on their computers and urging them to do so. Unfortunately, it is difficult to ensure compliance with power-management policies or measure the energy savings. And given data indicating that only a small percentage of computers currently have power-management settings enabled, it is likely that this approach will only be marginally successful. Even within the fraction of employees who do comply with the policies, any savings will likely degrade over time as computers get replaced and users disable power-management settings.

Have the IT department develop and deploy login scripts that control power-management settings. Using login scripts to control power-management settings can help ensure compliance and sustained savings, but scripts pose their own problems. Perhaps the biggest hurdle is that the IT department will rarely be motivated solely by the prospect of energy savings to create a script flexible enough to accommodate the variety of hardware, operating systems, and users found on a company's network. Because scripts tend to be static one-size-fits-all solutions, they are likely to establish such lenient power-management settings (so that the settings will work for all equipment) that they capture little of the potential energy savings. Or more stringent scripts might alienate some employees if settings interfere with their work habits. Scripts also provide no information on the level of energy savings.

Use third-party software to establish and implement a computer power-management policy across the company network. Several software packages target energy savings in computer networks (see Sidebar). Each package has advantages and disadvantages, and any of them might be the best choice for a given organization. For example, if the company wants to control monitors only, the U.S. Environmental Protection Agency's free EZSave software may be the right choice. On the other hand, if a workforce has diverse schedules and computer usage patterns, one of the products that offer group-specific power-management settings may be the most appropriate. For help selecting a power management solution, visit the ENERGY STAR web site at www.energystar.gov/index.cfm?c=power_mgt.pr_power_management.

Kitchen Efficiency Measures

Most commercial buildings have small kitchen areas where occupants can prepare coffee, lunch, or snacks. Microwave ovens, coffee machines, and refrigerators are common in these areas. Microwave ovens and stoves generally consume energy in direct proportion to the need for warming foods, refrigerators run continuously, and coffee machines may be left on longer than necessary. Vending machines are typically lighted and often refrigerated continuously, consuming energy 24 hours per day. Because this equipment is located within conditioned space, its use of electricity also generates heat that contributes to cooling loads.

To reduce energy use and heat generation, purchase ENERGY STAR–labeled kitchen equipment such as refrigerators, water coolers, and vending machines. ENERGY STAR refrigerators contain high-efficiency compressors, improved insulation, and more precise temperature and defrost mechanisms to improve efficiency. They use at least 15 percent less energy than required by current federal standards and 40 percent less energy than conventional models sold in 2001.

A standard hot and cold bottled water cooler can use more energy than a large refrigerator. But an ENERGY STAR model requires about half as much energy as a standard unit, which can save building and business owners more than 1,600 kilowatt-hours (nearly $130 annually) on utility bills per water cooler.

CASE STUDY: Computer Power Management Cuts Costs at Queensborough Community College

Queensborough Community College in New York has about 12,000 students. College staff installed Verdiem Corp.'s SURVEYOR™ network energy manager software on about 850 computers. Most are "administrative" computers—used by instructors and administrative personnel. The rest are used in computer labs in some of the academic departments.

Before enforcing power-management settings at the Queensborough facilities, Verdiem had estimated annual energy savings of 111 kilowatt-hours (kWh) per administrative computer and almost 390 kWh per academic computer (due primarily to longer idle times) based on the time these two sets of equipment were spending in the on, low-power, and off states. About three months after a power-management policy was activated, Verdiem analyzed the usage data and verified savings of 129 kWh each for the administrative computers and 317 kWh for the academic units. If, as planned, another 1,050 computers were moved into a power-management group, weighted average savings would amount to about 240 kWh per computer annually. At $0.10/kWh the annual savings were roughly $46,000, which amounts to an estimated payback period of about one year for the software licenses and installation.

ENERGY STAR–qualified new and rebuilt vending machines incorporate more efficient compressors, fan motors, and lighting systems that can reduce energy use by 40 percent compared to standard models. They also come with onboard software that puts the machine into low-energy lighting and refrigeration modes during times of inactivity, which can cut energy use by another 20 percent.

Water heating for kitchen and bathroom sinks is another energy consumer and heat generator. On a lifecycle basis, gas-fired tank water heaters are likely the least expensive and most energy-efficient technologies to own and operate. They typically cost less to operate than electric versions because natural gas and propane are usually much cheaper (per Btu) than electricity, and gas units sized at 100 gallons or fewer are less expensive to buy than most other types of heaters because they are mass produced. In some circumstances, such as where gas is not available or there are no venting options, electric heaters are the only viable option.

Employee Energy Conservation Training

Building occupants can do their part to minimize loads and costs by turning off equipment (including ENERGY STAR devices) at night and on weekends. Influencing employee behavior—energy related or otherwise—requires understanding some psychology. Simply issuing "thou shalt" memos or directives might alter behavior to a certain extent, but successful and sustainable awareness and behavior programs have all of these elements in common:

- *Effective communication.* Successful programs clearly communicate energy-management goals and the reasons why the change in behavior is desired (see sidebar). Program managers must develop or procure the materials to spread the word—such as posters, videos, or pamphlets—and decide how to distribute the information. Successful programs also have easy-to-use mechanisms for gathering employee input and returning feedback from management regarding how employee input is helping the organization accomplish its goals. Some companies use monthly e-mails to solicit ideas, others hold monthly or quarterly meetings with employees, and some do both.

- *Measurement.* Successful programs regularly measure and track energy use, and communicate this information to employees.

- *Reward and recognition.* Successful programs give credit where credit is due. Rewards and recognition give employees a true sense of accomplishment and help to build a personal sense of ownership in the program.

- *Leadership by example.* Successful programs recruit energy champions. Employees who see executives, upper management, and peers that they respect "walking the walk" are significantly more likely to adopt a change and sustain the effort.

The ENERGY STAR web site also offers ideas and examples to help companies build energy-awareness programs (see sidebar).

CASE STUDY: State Farm Energy Awareness Program

At State Farm, an insurance provider, sharing information is a key part of the company's energy conservation efforts. Communication among regional offices is done both formally and informally. Formal sharing includes scheduled training classes, company triennial audits, and company maintenance manuals. Informal sharing is done in unit meetings, site visits, and consultations.

Weekly staff meetings held at the corporate office facilitate both formal and informal sharing of energy information. At these meetings, employees can share ideas and practices, provide support to each other in an informal setting, and solve problems that get raised. Meetings include open discussions, staff presentations, formal training, and vendor presentations. Staff members are often assigned to present information on specific energy-conservation topics. Meeting attendees include the engineers and technicians that service the 28 regional offices, three data support centers, three warehouses, 11 corporate buildings, and 600 field claim offices.

RESOURCES: Employee Energy-Awareness Programs

The ENERGY STAR web site can help energy and facility managers develop successful employee energy-awareness programs. The ENERGY STAR Guidelines for Energy Management includes a step for creating a communications plan (www.energystar.gov/index.cfm?c=implement_plan.communication_plan). To help with the plan, the ENERGY STAR Challenge Toolkit features ideas, examples, and templates that can be customized to help spread the word to employees, customers, and stakeholders.

7.3 Upgrading the Building Envelope

The building envelope includes windows, doors, walls, the roof, and the foundation. Heat always flows from the warmer side of the building shell to the colder side. The most commonly discussed parameters of heat flow through the building envelope, in or out, are conduction, infiltration, and solar radiation. Conduction is heat flow through a material from hot to cold. This phenomenon explains why the handle on a stove pot becomes hot, and why people insulate walls. Infiltration is a form of convection in which heat flows via air movement. This phenomenon explains why occupants feel cold when the door is open on a winter day, and why caulking small cracks around windows improves comfort. Radiation is heat flow over a distance from hot to cold, the way the Sun's heat reaches Earth. Building occupants use window shades in summer to block radiation.

Controlling these heat flows requires insulation, good sealing materials and techniques, and proper maintenance. Mechanical heating and cooling make up the heat lost (or gained) through conduction, infiltration, and solar radiation (see Chapter 9, "Heating and Cooling"), but these gains and losses can be controlled by various components of the building envelope.

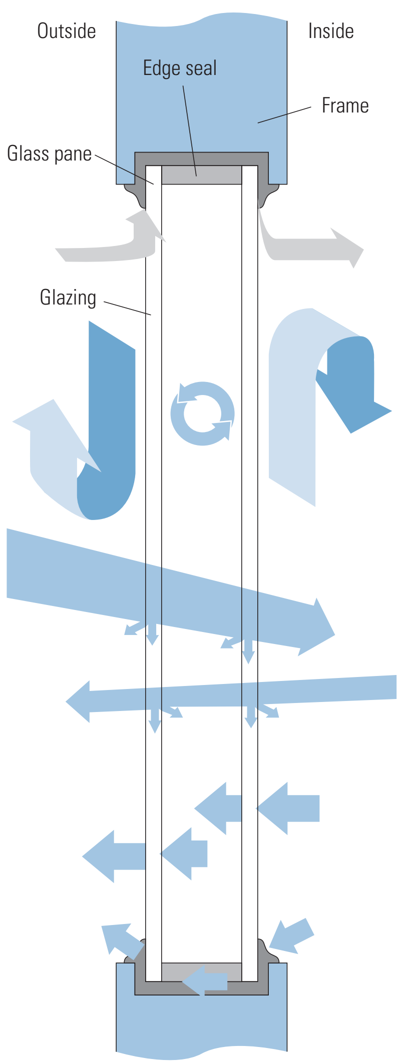
Conduction (roof, walls, windows). Conductivity depends on the materials used in the building shell. Insulation slows, but does not stop, heat flow through walls and roofs. R-value indicates how well an insulation barrier impedes heat flow—the larger the R-value, the less heat flows through a wall or roof by conduction in a given amount of time. Windows typically have a very low R-value, although storm windows or double-pane windows that feature an insulating air space between the panes can raise window's R-value (**Figure 7.2**). For more information see the Walls and Roofs page of the U.S. Department of Energy Building Technologies Program at www1.eere.energy.gov/buildings/commercial/walls.html.

Infiltration. In older buildings, heat often leaks through breaks in insulation or around windows. This infiltration can greatly reduce the insulation's effectiveness, so R-values alone do not fully describe the energy efficiency of a wall or roof.

All buildings allow some level of uncontrolled airflow through the building envelope. Infiltration paths include seals around operable windows, cracks or seams in exterior panels, doorjambs, and shell penetrations such as holes for wiring or roof curbs for HVAC equipment. Air flowing into or out of these leakage paths is driven by pressure differences caused by HVAC equipment between the inside and outside of the building, between windward and leeward sides

Figure 7.2: Window heat flow

Heat flows through a window via conduction, infiltration, and radiation. Convection also permits heat flow at the window surface.



Infiltration
Air leaks around the frame, around the sash, and through gaps in movable window parts. Infiltration is foiled by careful design and installation (especially for operable windows), weather stripping, and caulking.

Convection
Convection takes place in gas. Pockets of high-temperature, low-density gas rise, setting up a circular movement pattern. Convection occurs within multiple-layer windows and on either side of the window. Optimally spacing gas-filled gaps minimizes combined conduction and convection.

Radiation
Radiation is energy that passes directly through air from a warmer surface to a cooler one. Radiation is controlled with low-emissivity films or coatings.

Conduction
Conduction occurs as adjacent molecules of gases or solids pass thermal energy between them. Conduction is minimized by adding layers to trap air spaces, and putting low-conductivity gases in those spaces. Frame conduction is reduced by using low-conductivity materials such as vinyl and fiberglass.

Courtesy: E SOURCE

of the building, and between upper and lower floors (natural convection, commonly called the chimney effect). As discussed in Chapter 5, "Retrocommissioning," to reduce cooling loads in buildings with mechanical ventilation systems it is desirable to minimize uncontrolled air leakage through caulking and weather stripping. *Controlled leakage*, in which incoming outdoor air exchanges heat with exhaust air, is covered in Chapter 8, "Air Distribution Systems."

Solar Radiation. Solar radiation can have an enormous influence on heating and cooling requirements. The sun often makes perimeter spaces uncomfortably hot, creates glare, and fades fabrics. Handled properly, however, this incoming solar radiation can reduce lighting loads (see the daylighting section Chapter 6, "Lighting"). Reducing solar gain (heating caused by solar radiation) without sacrificing all of the light available for daylighting offers very profitable opportunities for cooling-load reductions and energy savings.

Heat can also be radiated out of the building through the windows in winter if outdoor temperatures are much lower than room temperature. Yet, the amount of heat lost through radiation is far less significant than other types of heat gain or loss.

Windows

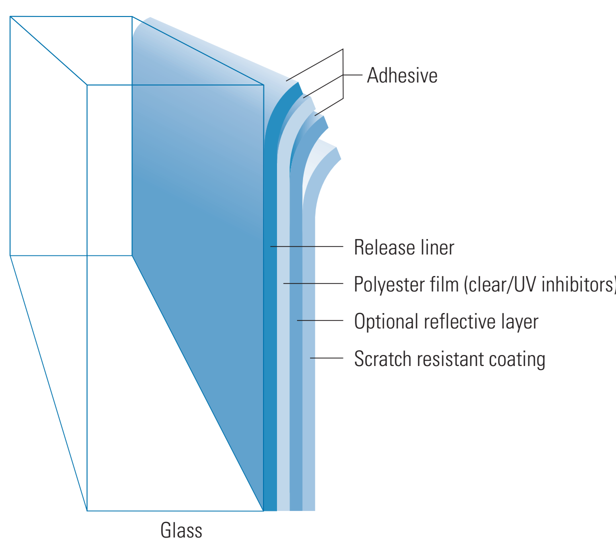
Window films, window shading, and high-performance windows can reduce heat flow through a building's windows.

Window Films

Window films are thin layers of polyester, metallic coatings, and adhesives that save energy by limiting both the amount of solar radiation passing through the window and the amount of internal heat escaping. Window films can be retrofitted to existing windows to reduce heat gain from solar radiation and provide low-cost cooling load reduction (**Figure 7.3**). They can be applied directly to the interior surfaces of all types of glass and generally last 5 to 15 years.

Figure 7.3: Window films

Window films can be retrofitted to existing windows to reduce heat gain due to solar radiation and provide a low-cost cooling load reduction.



Courtesy: E SOURCE; adapted from EPA

During the heating season, in a typical 24-hour period more heat escapes through windows than comes in from the Sun; the extent depends on the local climate and the R-value of the window. Window films can help reduce this costly heat loss by reflecting indoor radiant heat back into the room. During the cooling season, even when drapes and blinds are closed, much of the Sun's heat passes through the glass into the room. Window films can address this problem by reducing solar heat gain at the window.

Window films save energy by generally improving the balance of heating and cooling systems and by allowing HVAC downsizing. They are likely to be cost-effective where:

- Windows account for greater than 25 percent of the building's outer surface area.
- The building is not well shaded.
- Windows on the south and west sides of the building receive direct sunlight.
- The building has single-pane windows (multiple-pane windows can also benefit from window films to a lesser extent).
- Windows are not tinted, colored, or imbued with reflective coatings.
- The building is located in a sunny climate.
- Fan systems and cooling equipment can be downsized following peak cooling load reductions.

It is not always economical to install window films everywhere. For old, drafty, single-pane windows, complete window replacement—although more expensive—might be more appropriate if the windows are in poor condition. It also can be most cost-effective to install window films only on the south and west sides of a building. Window films typically cost between $1.35 and $3 per square foot, installed. Proper installation is important to avoid bubbling, cracking, peeling, and even film-induced glass breakage, so buy films with a material and installation guarantee of 5 to 10 years. For more information, see *Glazing Types* from the Efficient Windows Collaborative at www.efficientwindows.org/gtypes.cfm.

Window Shading

Physical shading can also reduce the solar cooling load imposed by windows—exterior and interior shading are among the best ways to keep the Sun's heat out of buildings located in sunny climates (**Figure 7.4**). Properly placed shades also make daylighting systems more effective by eliminating glare.

Common shading techniques include:

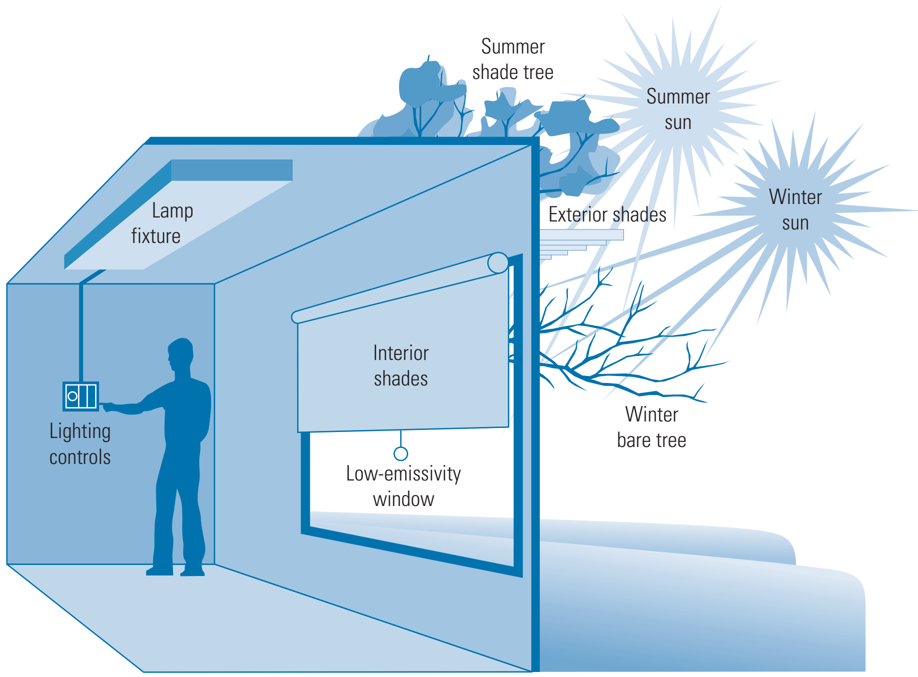
Interior shading. Venetian blinds and other operable shades are low-cost and effective solutions for keeping out sunlight. More sophisticated systems, sometimes installed between two panes of window glazing, automatically open and close shades in response to the cooling load imposed by sunlight.

Low-emissivity (low-e) coatings. Available with many window systems, low-e coatings insulate better than bare windows, while allowing as much solar heat gain as possible.

Exterior shading. Overhangs, awnings, shade screens, roller blinds, and vegetation can provide exterior shading that also reduces the glare from direct sunlight striking glass. Overhangs and awnings can be particularly beneficial because they admit light from the low winter sun (when sunlight is beneficial for heating and lighting) and tend to block the higher summer sun when solar gain is less desirable. Awnings are popular on low-rise commercial buildings.

Figure 7.4: Shading strategies

Buildings in sunny areas can benefit from a variety of shading techniques.



Courtesy: E SOURCE; adapted from EPA

Fiberglass or metal shade screens are often cost-effective for low-rise commercial applications and are capable of reducing solar heat gain up to 80 percent compared to unshaded clear glass. A shade screen is a specially fabricated screen of sheet material with narrow louvers formed in place to prevent solar radiation from striking a window—the louvers are so small that only extremely small insects can pass through. The air space between the exterior shade screen and the window helps carry away heat absorbed by the shade before it can be transferred through the window.

Exterior roller blinds offer another effective exterior shading method. These are a series of slats, typically horizontally oriented, made of wood, steel, aluminum, or vinyl. Like interior shades, they can be raised or lowered as needed to control the amount of sunlight entering a building space. In warm temperatures during sunny hours, they can be lowered to function as an insulating barrier, limiting incoming sunlight and reducing heat gain. In cold weather they can be raised to allow desirable heat gain. Partially rotating the blinds allows some daylight and air to enter between the slats. Studies indicate roller blinds can improve the R-value of the window area from the standard 0.88 for uncovered single-pane glass to 1.75 with a lowered blind. However, this shading technique can be expensive, and it alters the exterior appearance of a building.

When selecting shading system colors, remember that light colors are better at reflecting solar radiation. A dark awning, for example, may necessitate venting to allow heat dissipation.

Finally, deciduous trees are also very effective at providing shade. During the winter when they are bare, they allow sunlight to pass through; in summer they leaf out and provide shade. The best location for deciduous trees is due west of west-facing windows. East, southeast, and southwest sides of buildings are also good locations. Plant trees within 20 feet of windows and allow them to grow at least 10 feet higher than the window.

High-Performance Windows

Windows almost always represent the largest source of unwanted heat loss and heat gain in buildings. This is because even the best windows provide less insulation (have lower R-values) than the worst walls or roofs, and because windows represent a common source of air leakage. Windows also admit solar radiation.

Although eliminating windows is generally impractical, replacing the complete window can be economically feasible in some situations, particularly as part of an extensive renovation. Window replacements can offer benefits superior to lesser improvements such as films, shading, and weather stripping.

Many window or glazing systems of buildings built in the 1960s and 1970s are beginning to fail. Often, these failing systems are single-pane glass. A building with windows that need replacement presents an excellent opportunity to use the latest in advanced window design, which can pay for itself in just a few years.

Options for new window products include:

- *Spectrally selective glass.* This type of glass can maximize or minimize solar gain and shading depending on the chosen selectivity.
- *Double-glazed, low-e systems.* Layers of low-e film are stretched across the interior air space between glass panes, and windows with this feature offer R-values as high as 8.
- *Gas filled windows.* Using argon or krypton gas between glass panes, this technology minimizes the convection currents and conduction through the gas-filled space, reducing overall heat transfer through the window.
- *Electrochromic windows.* When integrated with a daylighting control system, these windows can preserve the view outside while varying their tint to modulate transmitted light, glare, and solar heat gain. Sensors that adjust tint can automatically balance comfortable lighting with energy efficiency to reduce energy use and peak demand. Compared to efficient low-e windows with the same daylighting control system, electrochromic windows can reduce annual peak cooling load by 20 percent and lighting energy use by 50 percent when controlled for visual comfort. Occupants prefer electrochromic windows due to perceived reductions in glare. For more information on this technology see *Advancement of Electrochromic Windows* from the Lawrence Berkeley National Laboratory at http://windows.lbl.gov/comm_perf/Electrochromic/electroSys-cec.htm.

Architects and facility planners now have a vast selection of new window types available that not only meet stringent energy performance requirements but also satisfy aesthetic concerns. For more information see the Fenestration page of the Commercial Buildings section of the U.S. Department of Energy Building Technologies Program at www1.eere.energy.gov/buildings/commercial/fenestration.html.

Roofs

Measures that can be employed to reduce heat flow into and out of a building through the roof include roof insulation, cool roofs, and green roofs.

Roof Insulation

Much of a building's heat losses and gains occur through the roof, so there are often significant energy-savings opportunities related to roof efficiency. **Figure 7.5** shows a typical commercial-building roof consisting of insulation sandwiched between materials that provide support and weatherproofing. The best way to reduce heat transfer through the roof is to maximize R-value by adding thermal insulation.

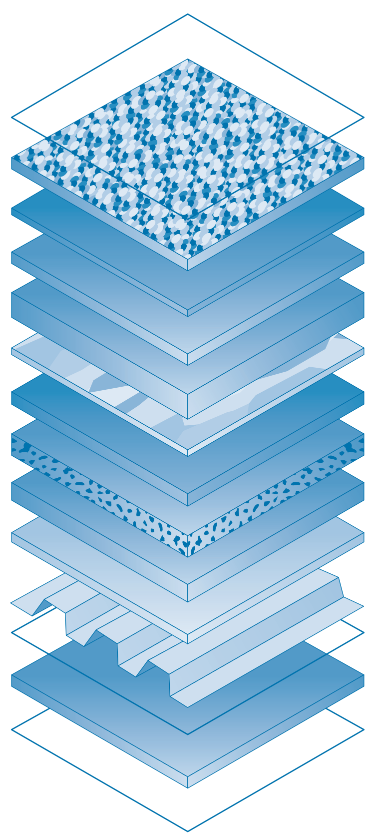
When replacing a roof, it is always a good idea to incorporate insulation as part of the renovation. Rigid board insulation, typically two inches thick, can be applied to the outside surface of the roof before applying the new roof covering. This technique works well with roof replacement and new construction, but it is generally not cost effective to apply insulation to the outside surface of an existing roof.

Insulation can also go beneath a roof if it has an attic or crawlspace. Such applications use fiberglass blanket or "batt" insulation, blowing insulation such as spray-on urethane or fiberglass foam, or blown-in loose cellulose or fiberglass. In most cases, roof insulation for buildings with vented attic spaces is applied to the attic floor as fiberglass batts or blown-in loose insulation.

For buildings with unvented attics or no attic, or in buildings where foot traffic might damage attic floor insulation, apply insulation to the inside roof surface, using either rigid board or spray-on foam insulation. Also avoid using attic floor insulation when water pipes are present—sometimes heat flow from the occupied space below is needed to prevent attic pipes from freezing during the heating season.

Figure 7.5: Roofing composition

A roof system consists of a deck for support, insulation to slow the transfer of energy through the roof, and a roof covering and membrane for weather protection.



Courtesy: E SOURCE; adapted from EPA

Uninsulated structural members can reduce the effectiveness of building-envelope insulation by as much as 20 percent. It is important to insulate structural members of the roof—particularly those made of metal—to avoid significant heat loss in a building that is otherwise well insulated. However, in flat-roofed buildings with exterior roof insulation, this is not necessary. For more information see *Roof Insulation Guideline* from the New Buildings Institute at www.newbuildings.org/guidelines.htm.

Cool Roofs

Cool roofs feature a highly reflective outer surface that reduces the amount of heat conducted through the roof. On a sunny day, ENERGY STAR–labeled cool roof products typically lower the roof surface temperature by 50° to 70° Fahrenheit (F), thereby decreasing the amount of heat transferred into a building (see sidebar).

Benefits of cool roofs include:

- *Downsized air-conditioning equipment.* A cool roof can reduce peak cooling demand by up to 40 percent in warm climates, although in cold climates the heating load penalty may offset the cooling energy savings. Typical energy savings run around 20 percent, with simple payback periods of a few years.
- *Extended roof life.* Cool roofs tend to last longer because they are less susceptible to thermal expansion and contraction. Less heat absorption also helps the roof resist degradation by ultraviolet light and water.
- *Reduced heat island effect.* Nonreflective roofs can heat the air around them in a process known as the heat island effect. This phenomenon can raise the cooling demands of buildings and vehicles in a wide area, contributing to smog, elevated ambient temperatures, and associated health problems.

Energy savings from installing ENERGY STAR– or Cool Roofs Rating Council–labeled roof products (see sidebar) depend on the local climate, existing insulation levels, the type of roof replaced, the type of roof installed, and maintenance. In the best applications, cool roofs have no incremental cost and deliver a nearly instant payback. In the wrong applications, the payback may be unacceptably long. Generally cool roofs are most cost-effective when:

- A roof is being installed as part of new construction or needs to be replaced on an existing building.
- Older, inefficient HVAC equipment needs to be replaced.

CASE STUDY: Texas Cool Roof Yields Big Savings at Target

Installing a reflective roof membrane on a 100,000-square-foot Target retail store in Austin, Texas, reduced the average summer daily maximum roof-surface temperature from 168° to 126° Fahrenheit. This temperature reduction cut the building's total air-conditioning energy use by 11 percent and peak air-conditioning demand by 14 percent. Researchers at Lawrence Berkeley National Laboratory estimate that this cool roof installation will save about $65,000 over the course of its useful life. According to the building manager, the difference in labor and materials costs for installing a white thermoplastic roof instead of a black rubber roof was negligible, so that the payback for this system was immediate.

- The building is a flat-roofed, low-rise, air-conditioned commercial facility.
- There is little or no existing roof insulation.
- The climate is hot and sunny, at least in summer.

To help determine whether a cool roof is the right choice, see **Figure 7.6** or use the ENERGY STAR Roofing Comparison Calculator at www.roofcalc.com/.

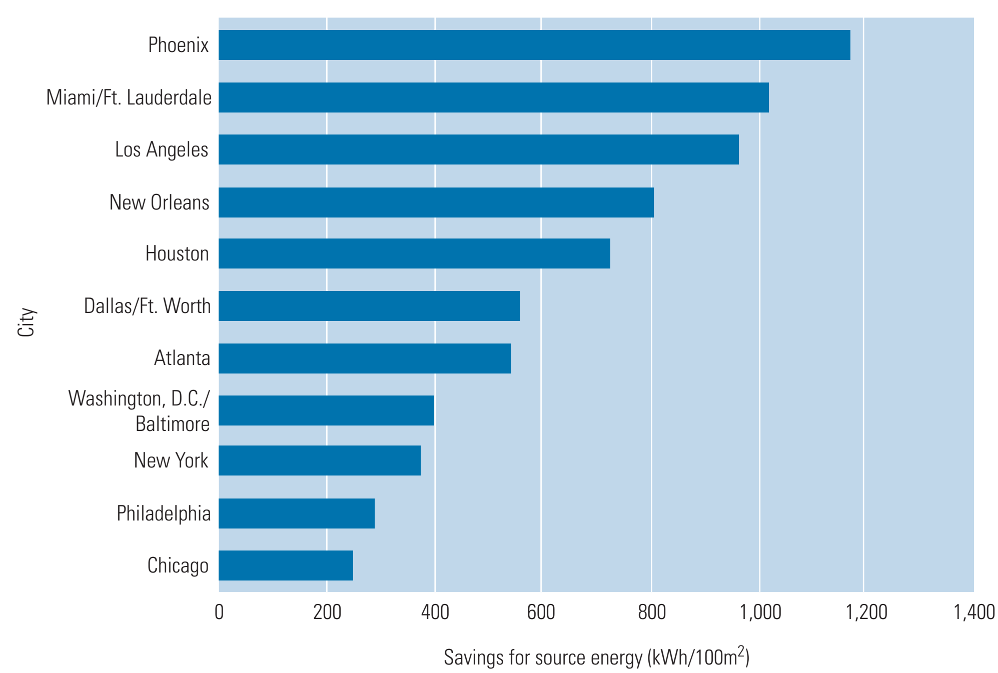
RESOURCES: Cool Roofs

Two complementary U.S. labeling programs can help people select cool roofing materials. Roofing products can qualify for the ENERGY STAR label in two categories: low-slope roofing products must have an initial solar reflectance of at least 0.65; and steep-slope roofs must have an initial reflectance of at least 0.25. After three years, these products must maintain a reflectance of at least 0.50 and 0.15, respectively. To see a list of qualifying products visit www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products.

The Cool Roofs Rating Council (CRRC), an independent organization dedicated to providing credible energy-performance rating information about roof surfaces, also has a labeling program. The CRRC label is based on reflectance and emittance, and is verified through third-party testing. The label is used much like the yellow efficiency labels found on appliances that help consumers determine where the product falls in the range of available products. To see a directory of CRRC-rated products, visit www.coolroofs.org/products/search.php.

Figure 7.6: Energy savings from cool roofs on commercial buildings

Cool roofs perform differently in different climates: they save the most in warmer climates and at lower latitudes.



Notes: kWh/100m² = kilowatt-hours per 100 square meters.

Courtesy: E SOURCE; data from David Eijadi et a

Green Roofs

Green roofs can be traced at least as far back as the hanging gardens of Babylon. More recently, they have been popular in Europe for the last few decades. In Germany an estimated 12 percent of all flat roofs are green, and the German green roof industry is growing 10 to 15 percent per year. In North America, however, green roofs are still rare.

Green roofs are a fairly simple concept: Take a flat roof, add some protective layers and soil, and create a system that allows rooftop vegetation to grow while protecting the underlying roof. Conventional roof gardens use pots and planters, but true green roofs allow for much more extensive cultivation of plant life across wide expanses of rooftop. Functionally, a green roof replaces the vegetated footprint that was destroyed when the building was constructed. In fact, several municipalities across North America are encouraging green roofs to mitigate storm-water overflow.

Green roofs and rooftop gardens save energy by mitigating the heat island effect. On warm summer days, urban heat islands are 6° to 8°F hotter than surrounding areas, and therefore have higher cooling loads.

Green roofs produce cooling in four ways:

- The soil provides a layer of insulation.
- Transpiration from the plants cools the rooftop just as sweating cools our bodies.
- The trees and other plants shade the roof.
- A green roof surface does not absorb much heat, so it emits less heat back into the surrounding air.

Much like cool roofs, green roofs save energy by mitigating the heat entering a building in summer and by reducing heat loss in winter. And like other types of cool roofs, green roofs last longer because they are more resistant to damage from sunlight and thermal stresses.

The cost-effectiveness of green roofs is still being evaluated through research. Green roofs save energy and have lower maintenance costs, but they also carry a cost premium ranging from $5 to $20 per square foot over conventional roofing and cool roofs.

For more information visit Green Roofs from the U.S. Environmental Protection Agency at www.epa.gov/hiri/strategies/greenroofs.html and Green Roofs for Healthy Cities, a green roof infrastructure industry association, at www.greenroofs.net.

Photovoltaic Panels

Photovoltaic (PV) panels generate electricity while absorbing solar radiation and, depending on their placement, reducing solar heat gain. PV panels can be mounted flush on the surface of a roof, supported at an angle off of the roof, or integrated into the building envelope as a structural or skin element. This latter approach is known as building-integrated PV and may take the form of traditional shingles, flat roof membranes, roof tiles, building facades, or glazing for skylights or atria.

Much of a building's exterior surface area has the potential to generate about 1 to 3 kilowatts of peak power for every 10 square meters, depending on building design. Besides reducing solar heat gain through the shell, PV technologies offer the advantage of providing the greatest power generation capacity in the afternoon, coincident with peak space-cooling needs. Because of their high cost—typically $6 to $10 per watt—photovoltaic systems are not yet widely used.

That situation could change if the industry achieves its 10-year goal of getting the cost down to $3 per watt.

For more information see Photovoltaics from the U.S. Department of Energy Solar Energy Technologies Program at www1.eere.energy.gov/solar/photovoltaics.html.

7.4 Summary

Many opportunities exist for reducing supplemental electric and heating loads in a building, thereby paving the way for smaller, lower-first-cost equipment in fan and HVAC systems. Here are the best savings strategies:

- Purchase ENERGY STAR–labeled equipment through a corporate purchasing policy.
- Develop a training program to encourage energy-conservation behavior among employees. Employees can make significant contributions to load reduction by turning off equipment when it is not in use and enabling energy-saving settings for computers and monitors.
- Upgrade the building envelope with high-performance windows, window films, shading, upgraded roof insulation, or a cool roof.

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