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ENERGY STAR BUILDINGS℠ MANUAL

Stage Three
Other Load Reductions

Stage Three
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Stage Three

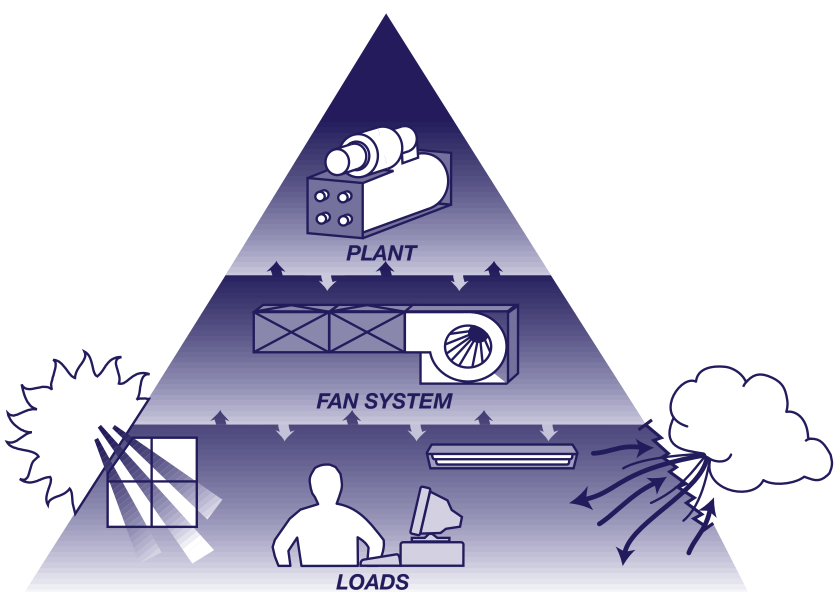
Other Load Reductions Overview

The heat flow diagram (Figure 1) illustrates how, in Stage Three—Other Load Reductions of the Energy Star Buildings[SM] program, you will be further reducing the three types of loads in your buildings (heating, cooling, and electrical). Different load sources generate heating, cooling, and electrical loads. As the heat flow diagram illustrates, because these load sources interact with the HVAC system, reducing these loads in Stage Three, as well as in previous Stages, will reduce the size and first cost of upgrading heating and cooling equipment in Stages Four and Five.

Stage Three Strategy

- Reduce heating, cooling, and electrical loads to allow the installation of smaller and lower first-cost HVAC equipment in Stages Four and Five.
- If possible, delay the installation of HVAC equipment until **all** loads are 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 Stages One through Three.

Figure 1: Heat Flow In Buildings



Heat Flow In Buildings: Building Systems Interactions

Figure 1 shows the interaction of heating, cooling, and electrical loads with the HVAC equipment. Arrows indicate heat flow pathways. Reducing heating, cooling, and electrical loads reduces the demand on HVAC equipment, thus saving energy.

The Best Ways To Save

- Ventilation Upgrades
  - Control ventilation rates to minimum requirements
  - Install air side cooling economizer cycle
- Equipment Upgrades
  - ENERGY STAR® office equipment
- Building Envelope Upgrades
  - Window films and/or shading
  - Roof insulation

Take Action!

1. Assess the load sources in your building to determine where loads can be reduced.
2. Contact vendors, contractors, or an engineering consultant to specify upgrades for these systems.
3. Install upgrades to reduce heating, cooling, and electrical loads.

Load Sources

By completing Stage One—Green Lights, you have already implemented some significant cooling and electrical load reductions by installing high-efficiency lighting. Stage Two—Building Tune-Up further reduces all three types of loads. Stage Three explores and identifies additional load reductions that can not only save energy and money immediately, but will further increase savings when upgrading heating and cooling equipment in Stages Four and Five.

We have briefly introduced the three types of loads in all buildings and the benefits of reducing them. Below we discuss the load sources—that is, the individual building characteristics that contribute to heating, cooling, and electrical loads. The magnitude of these loads is determined by the following load sources:

- Lighting
- Occupants
- Ventilation Systems
- Equipment
- Building Envelope

Many load sources affect more than one load type. Windows, for example, affect your cooling and heating loads. Lighting affects all three.

Lighting

Typically, 70 to 80 percent of the electrical energy used by lighting ends up in the conditioned space as heat. Thus, by upgrading to more efficient lighting in Stage One—Green Lights, you have reduced your electrical and cooling loads. By removing heat generated by your lighting system, the least efficient and most expensive type of heating, you will have the opportunity to convert to more efficient gas heat or electric heat pumps where necessary.

The electrical load of lighting systems in office space ranges from 1 watt per square foot (W/sf) or less for efficient lighting to more than 2 W/sf for older systems. Stage One—Green Lights seeks to reduce both the connected electrical load (kW) and energy consumption (kWh) of lighting equipment. Proven technologies provide equal light output with reduced electrical input and better color rendition. Lighting controls can significantly reduce operating hours and costs when spaces are unoccupied. (For further detail, see Stage One—Green Lights.)

Sample Calculation: Cooling Bonus

Replacing standard fluorescent lights with T8 lamps and electronic ballasts and adding occupancy sensors could save 300,000 kWh per year of electricity in a typical 100,000-sf office building. Furthermore, the cooling system removes less heat from the lights, and the additional cooling energy savings is approximately 41,000 kWh per year for a **cooling bonus** of 14 percent.

(Assumptions: 1 W/sf savings, 3,000 lighting operating hours per year, cooling efficiency of 0.6 kW/ton, 80% of lighting waste heat removed by cooling system)

Occupants

You have undoubtedly noticed that when a small room is filled with people, it tends to become warmer. People emit heat primarily through breathing, perspiration, and, to a lesser extent, through radiation. An average adult will generate 400 to 600 Btu of heat per hour. This heat translates into an increased cooling load on your cooling systems.

As a practical matter, it is difficult to change the contribution occupants make to the energy balance in a building. Nevertheless, it is important to assess this contribution accurately and recognize that improvements to distribution systems and space conditioning equipment will lessen its effect on cooling loads and associated costs.

Ventilation Systems

Buildings with mechanical cooling-air distribution systems generally mix a portion of outdoor air with return air from the space to maintain an acceptable level of indoor air quality (see Figure 2). Outside air requirements for maintaining occupant health and comfort vary depending on the type of facility, the level of occupancy, and other factors. In the summer, hot and humid ventilation air increases cooling loads. In the winter, cold ventilation air increases heating loads.

At times, many buildings require air-conditioning although the outside air is relatively cool and dry. During these times, increased amounts of outside air can reduce the cooling load.

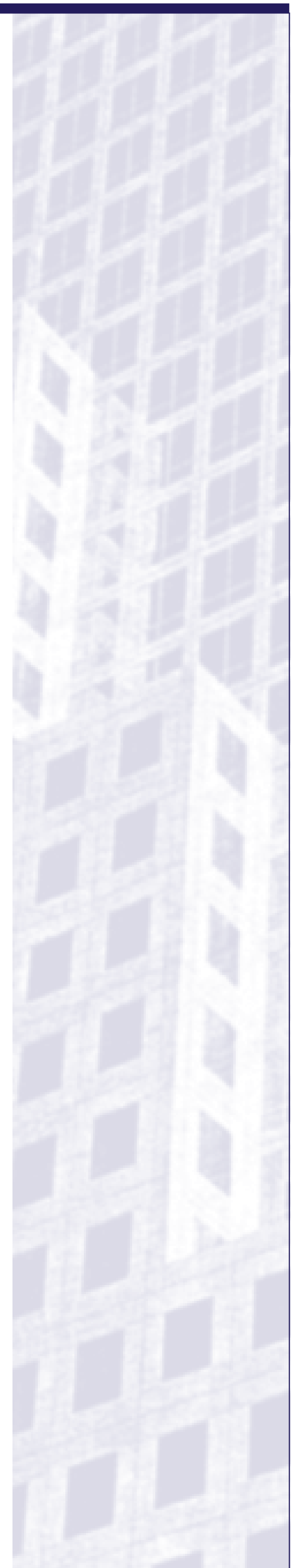
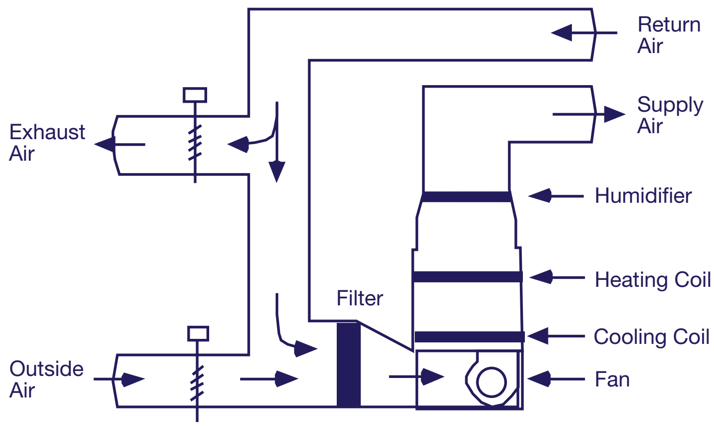


Figure 2: Central Air System



History Of Ventilation Requirements

Building codes dictate minimum ventilation rates. Interestingly, code-mandated rates have changed significantly over the years in response to events and new understandings about the impact of outside air quantities on energy consumption and occupant comfort.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has updated its recommended ventilation rates periodically. Prior to 1973, ASHRAE recommended a standard of 15 to 25 cubic feet per minute (cfm) of outside air per person. After the oil crisis of the mid-1970s, a new awareness of the energy costs for treating outside air led to ASHRAE Standard 62-1981.

ASHRAE Standard 62-1981 defined ventilation air requirements and allowable contaminant levels. Striking a compromise between indoor air quality concerns and energy consumption concerns, Standard 62-1981 recommended a minimum of 5 cfm of outside air per person in a nonsmoking environment and 20 to 35 cfm of outside air per person in a smoking environment. At times, the reduction in outside air requirements for nonsmoking spaces led to an increase in indoor air quality complaints. The current ASHRAE Ventilation Standard 62-1989 requires at least 15 cfm of outside air per person (and more for many types of spaces) and a maximum CO_2 concentration of 1,000 ppm. (Table 1 summarizes the history of ventilation requirements.)

Partly because of lower ventilation rates set in ASHRAE Standard 62-1981, complaints of discomfort and poor health, phenomena now referred to as Sick Building Syndrome and Building Related Illnesses, increased. This led ASHRAE to raise its ventilation requirements closer to its previous levels. Depending on space use, ASHRAE Standard 62-1989 requires minimum outside ventilation rates of 15 to 25 cfm per occupant, allowing for a “moderate” amount of smoking, while 60 cfm of outside air per occupant is required for smoking lounges.

Table 1: Historical Outside Air Requirements

Outside air per person	*cfm*
Industry Standard 1973	15–25
ASHRAE Standard 62-1981	> 5
ASHRAE Standard 62-1989	>15

With the increased use of chemical-based products, building materials, and furnishings that contribute to indoor pollution and health and comfort complaints, ASHRAE has concurrently tried to address contaminants not produced by occupants in its ventilation requirements. The current Standard 62-1989 allows the user to establish ventilation requirements based on a separate procedure that analyzes specific contaminants. Currently, ASHRAE is developing a new standard that integrates requirements for occupant odor (cfm per occupant) and for pollution from other sources (cfm per square foot) into a single calculation for the required minimum ventilation rate.

Equipment

Equipment powered by electricity will, of course, affect your electrical loads. It is important to remember, however, that for many types of equipment, much of the electrical use in a space will ultimately end up in that space as heat. Thus, improving the efficiency of your electrical equipment not only reduces your electrical loads but also reduces your cooling load and, as with lighting, allows you the opportunity to replace that heat more efficiently, when needed, with gas heat or electric heat pumps.

Office Equipment

Office equipment (whether mechanical, electrical, or electronic) that consumes energy generates heat in the conditioned space. A typical non-ENERGY STAR-compliant computer and color monitor draw a continuous electrical load of 150 watts or more (*ASHRAE Journal*, Sept. 1991). Moreover, the heat they generate can be provided to the space more efficiently when needed.

Example: Computer Load Reduction

Typical load reduction (for 10 ENERGY STAR-compliant PCs and monitors): 1,000 watts

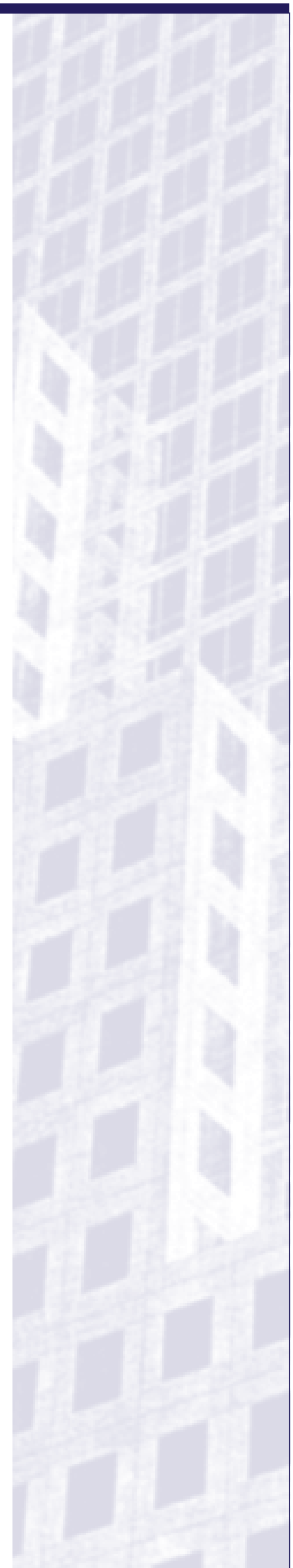
Replacing 10 PCs with ENERGY STAR-compliant models represents a reduction of 3,413 Btu/h no longer lost to the conditioned space. So, at $0.08 per kWh, 8 hr. per day, the heating cost was $0.64 per day.

Assuming gas costs $0.80 per therm and contains 100,000 Btu/therm, with a heating efficiency of 75%, *the new heating cost is $0.29 per day*.

Heating Cost Savings: 54%

Kitchens

Most commercial buildings have small kitchen areas for occupants to 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, whereas 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 a day. Because this equipment is located within conditioned space, its electricity usage leads to heat generated in the space.

Domestic Hot Water

Small domestic hot water tanks are often located in bathrooms or cabinets within the conditioned space. Larger units may be located in mechanical rooms where some of the heat generated by mechanical room equipment may reach the space conditioning system. Heat loss from tanks occurs 24 hours a day.

Building Envelope

Building envelope components include windows, doors, walls, the roof, and the foundation. Heat 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. Insulation, building design and materials, and maintenance (such as caulking and weather-stripping—see Stage Two—Building Tune-Up) all determine the levels of these heat flows. Ventilation rates determine the magnitude of the ventilation load as discussed previously. Mechanical heating and cooling are used to make up the heat lost (or gained) through conduction, infiltration, and solar radiation.

Heat Transfer Basics

How does heat travel? As you know from experience, heat will always move from warm to cold. You may not, however, recognize the three ways in which heat travels.

Conduction is heat flow through a material from hot to cold. This phenomenon explains why the handle on a stove pot becomes hot. It also explains why we add insulation to walls.

Infiltration, a form of convection, is heat flow by movement of air. This phenomenon explains why we feel cold when the door is open on a winter day. It also explains why we fill small cracks around windows with caulking.

Radiation is heat flow over a distance from hot to cold. This phenomenon explains how the sun's warmth reaches earth. It also explains why we use window shades in summer.

Conduction (Roofs, Walls, And Windows)

The materials used in the building shell determine the level of conductivity. Insulation slows, but does not stop, the flow of heat through walls and roofs. R-value is a measure of insulation that allows a comparison between walls and roofs. The larger the R-value, the more insulation the wall or roof provides and the less heat that flows through from conduction in a given time. Similarly, storm windows or double-pane windows rely on an insulating air space between the panes of glass (see Figure 3).

Infiltration

It is likely in older buildings that heat will leak through breaks in insulation or around windows. This kind of air leakage, called infiltration, can greatly reduce the effectiveness of insulation.

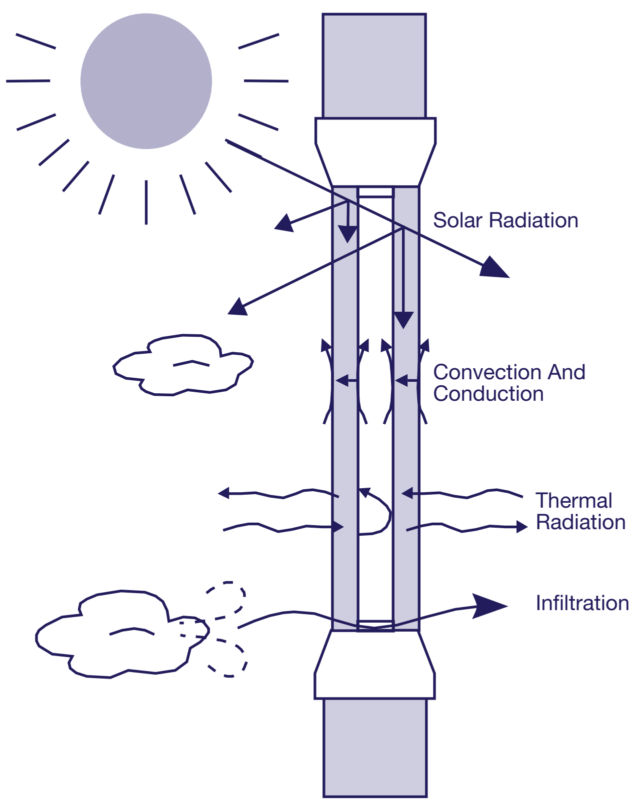
Thus, R-values alone do not fully describe the energy efficiency of a wall or roof.

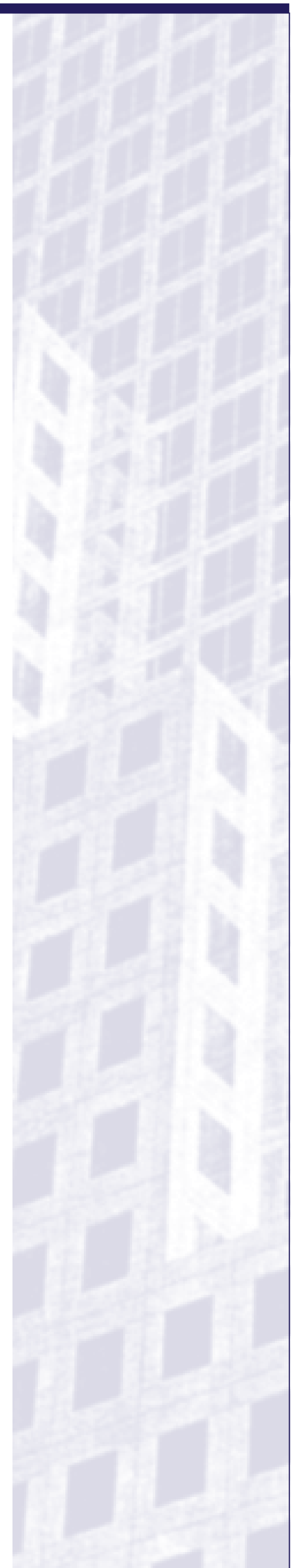
All buildings allow some level of uncontrolled air flow through the building envelope. Infiltration paths include seals around operable windows, cracks or seams in exterior panels, doorjambs, and shell penetrations such as holes for wiring or roof curbs for HVAC equipment. Air flowing into or out of 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 of the building, and between upper and lower floors (called the chimney effect) of the building. In buildings with mechanical ventilation systems, it is desirable to minimize uncontrolled air leakage to reduce cooling loads.

Solar Radiation

The sun’s influence on the heating of a building is a concept that has been recognized for a long time.

Figure 3: Window Heat Flow





Now, in houses with a south aspect, the sun's rays penetrate into the porticoes in winter, but in summer, the path of the sun is right above the roof so that there is shade. If, then, this is the best arrangement, we should build the south side loftier to get the winter sun, and the north side lower to keep out the cold winds.

Socrates, 360 B.C.

Solar radiation can have an enormous influence on the heating and cooling required in a space. The sun often makes perimeter spaces uncomfortably hot, and it also creates glare and fades fabrics. Reducing solar gain (heating caused by solar radiation) 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 that of other types of heat gain or loss.

Load Reduction Opportunities

As the heat flow diagram (Figure 1) illustrates, load reductions made in Stage Three can significantly and positively affect equipment modifications that will be made in Stages Four and Five.

Stage Four—Fan System Upgrades addresses fan systems, which can usually be rightsized to a smaller capacity or operated more efficiently as a result of load reductions in Stages One through Three.

Sample Calculation: Chiller Cost Reduction

Looking again at the chiller energy savings in a 100,000-sf building, the 1 W/sf reduction in lighting load would allow a chiller capacity reduction of approximately 23 tons (assuming that 80 percent of the waste heat reaches the conditioned space). If you assume a typical chiller cost of $450 per ton, then you could figure on reducing the first cost of a new chiller by more than $10,000 based on the 23-ton reduction. Other load reductions would further reduce the chiller size requirement.

Stage Five—Heating And Cooling System Upgrades addresses heating and cooling equipment that also can be rightsized, usually to a smaller capacity, and/or operated more efficiently as a result of load reductions in Stages One through Three.

As you make upgrades in Stage Three, keep in mind the potential for both future energy savings and lower first costs in Stages Four and Five. A thorough job done in Stage Three will pay back more than once.

Distribution System Benefits

Distribution system motor size may be reduced with smaller cooling loads. A fan motor, for example, would cost $26 less for every ton of reduced cooling load. (Assumptions: motor cost @ $65/hp x 1 hp/1,000 cfm x 400 cfm/ton = $26/ton)

Load Reduction Strategy: ENERGY STAR Office Equipment

In the business world, office equipment constitutes the fastest growing portion of electrical loads. However, much of this energy is wasted because equipment is left on when not in use throughout the workday, at night, and on weekends.

Electrical loads from office equipment, as well as cooling loads, can be reduced by the use of ENERGY STAR-compliant office equipment. Virtually all office equipment manufacturers offer a wide range of ENERGY STAR-compliant models, including copiers, printers (and some 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 off mode when not in use. Products that meet the ENERGY STAR specifications use about half as much electricity as conventional equipment.

Energy-efficient equipment with the ENERGY STAR label or name has the same purchase price as comparable non-ENERGY STAR equipment. After purchase, however, the savings can add up quickly, as shown in Table 2. Remember that the estimated savings below are per unit and will be much larger for an office with hundreds of energy-efficient products.

Table 2: ENERGY STAR Office Equipment Savings

Product	*Estimated Annual Savings/Unit*
Large Copier (plus $650 if double-sided copying feature is used)	$130
Printer	$40
Computer and Monitor	$20
Fax	$15

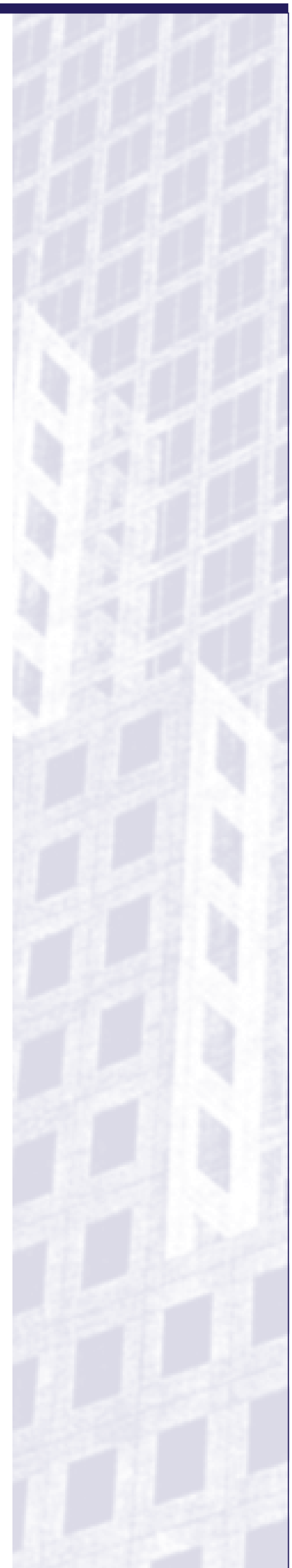
Source: Lawrence Berkeley Laboratories.

All ENERGY STAR-compliant equipment produces less heat by powering down when not in use. This reduces your cooling load, and thus your air-conditioning costs, and contributes to a cooler and more comfortable workspace. In addition, building occupants can do their part to minimize loads and costs by turning off equipment (both ENERGY STAR and non-ENERGY STAR models) at night and on weekends.

Managing Your Office Equipment

Here are four steps organizations should take to ensure that they realize the benefits offered by ENERGY STAR-compliant office equipment.

Check Equipment Specifications – Look for and request the ENERGY STAR label when purchasing new equipment. It may appear on the product itself, in advertisements and promotional materials, or on the packaging. If the label isn't visible, ask the manufacturer, reseller, integrator, or retail salesperson if the model meets the ENERGY STAR specifications.



For older, existing models in the office, check to see if they have power management or other energy-saving features. Although they may not meet the ENERGY STAR specifications, these features will provide some energy savings if activated. In addition, controlling devices are available for non-ENERGY STAR computers, monitors, and printers. These external hardware units are designed to reduce the energy consumption of older computers, monitors, or printers by turning them off when not in use. To request a list of controlling device manufacturers and their products, call the ENERGY STAR hotline at 1-888-STAR YES.

Ensure Proper Equipment Setup – Confirm with the appropriate information systems or support staff that the equipment is installed properly with the power-management features enabled. Each employee has different work habits and should be encouraged to adjust the time settings to accommodate individual work patterns. If the computer power-management feature is not compatible with the network environment, disable the feature on computers, but continue to use it on all of the monitors. Monitors consume 80 percent of the energy used by the two components.

Set a Corporate Policy – Inform employees that ENERGY STAR is a corporate or organizational policy through training materials. Short e-mail and voicemail messages can be sent to employees providing them with ENERGY STAR information as well as updates on the air pollution reductions resulting from their using energy-efficient equipment. Displaying ENERGY STAR posters in copy rooms, lounges, and other areas can also help to remind employees to use the energy-saving features and to turn off their equipment at the end of the day.

Educate Employees – Educate employees so that they understand what power management is and why it is important. Here are some examples of issues that you should focus on:

Is "Sleep" the same as "Off?" No. Sleeping equipment still draws some electricity, so turn it off when not in use for long periods of time.

Will the power-management feature shorten the lifetime of my computer or monitor? No. Heat is a leading cause of equipment failure. When the power-management feature is used, the computer generates less heat, so it may last longer and have improved reliability. In addition, manufacturers have increased the reliability of components, such as hard drives and microprocessors, that "cycle" when power management is used.

Does a screen saver help save energy? No, but there are screen savers available that won't interfere with the power-management features. If screen savers are used in the office, be sure to choose those that will display images for a predetermined period of time and then enter the sleep mode. Graphical screen savers are primarily for entertainment and are not energy-efficient features.

Table 3: Energy Star Office Equipment

Equipment	*Energy Star Specifications*
Computers	Automatically enter a low-power sleep mode after a period of inactivity. Efficiency specifications based on power supply.
Copiers	Depending on copier speed, automatic power-down and shutoff to 5–20 watts or less after 30–90 minutes of inactivity. Separate specifications available for large format copier models. Recommended automatic double-sided copying on medium- and high-speed models.
Fax Machines	Automatically power down to 15–45 watts after 5–15 minutes of inactivity, depending on fax speed.
Monitors	Automatically enter two successive low-power modes of 15 watts and 8 watts after 15–30 minutes of inactivity.
Multifunction Devices	Automatically power down to 30–200 watts after 15–120 minutes of inactivity, depending on equipment speed. Automatic double-sided copying on machines that copy at 44 pages or faster per minute. Efficiency specifications to increase in 1999.
Printers	Automatically power down to 15–45 watts, depending on print speed.
Scanners	Automatically power down to 12 watts or less when not in use.

Energy Star Specifications

Computers – Energy Star-labeled computers automatically enter a low-power sleep mode after a period of inactivity. The newest Energy Star specifications allow workstations to qualify for the Energy Star label. Most Energy Star-compliant computers are compatible with the primary network environments (for example, Novell NetWare, Banyan Vines, and LAN Manager). Consult with the manufacturer before purchasing a computer to ensure it is designed to be compatible with your particular network environment.

Monitors – Beginning in January 1998, Energy Star-labeled monitors will automatically enter two successive low-power modes of 15 watts and 8 watts. In addition to reducing wasted energy, Energy Star-compliant monitors emit fewer electromagnetic fields when sleeping because most of their electronic components are turned off.

Printers/Fax Machines – Typically, printers and fax machines are left on 24 hours a day, although they are active for only a small percentage of that time. To conserve energy, Energy Star-compliant printers and fax machines, after a period of inactivity, automatically enter a low-power mode of 15 to 45 watts, depending on product speed. Approximately 95 percent of the printers and fax machines available in the United States meet the Energy Star criteria. When purchasing new equipment, consider a combination printer/fax machine, which consumes half as much energy when idle as two stand-alone products.

Copiers – Energy Star-labeled copiers include a low-power mode and an off mode. About 70 percent of U.S.

black-and-white copier models carry the ENERGY STAR label. Even if a copier is used frequently during business hours, the auto-off feature will save energy by turning off the copier at night and on weekends. The average office worker uses 10,000 sheets of copy paper each year. Selecting the double-sided copying (or duplexing) feature will reduce waste, save paper, and cut mailing and storage costs.

Scanners – Scanners that qualify for the ENERGY STAR label automatically enter a low-power mode of 12 watts or less when not in use. When the user wants to scan another image, the machine will "wake up" and resume activity.

Multifunction Devices – ENERGY STAR-labeled multifunction devices offer copying as well as printing, faxing, scanning, and/or other capabilities. To reduce wasted energy, they automatically enter a sleep mode of 30 to 200 watts (depending on output speed) after a period of inactivity. High-speed multifunction devices also include an automatic double-sided copying feature.

Load Reduction Strategy: Control Ventilation Rates To Minimum Requirements

If your building was designed and built before the mid-1970s and there have been no substantial modifications of equipment or controls, the chances are good that energy savings can be achieved not only through improved equipment efficiency but also by improving the control of outside air. This can be done by controlling outside air to the minimum required for health and comfort when outside air is an energy burden and by increasing outside air delivery when outside air can provide free cooling or nighttime precooling. In most cases, any opportunity to save energy by increasing the delivery of outside air will also tend to improve the building's air quality.

A testing, adjusting, and balancing contractor (see Stage Four—Fan System Upgrades) can be engaged to determine the quantities of outdoor air provided by your air-handling units at both full-load and part-load conditions. These quantities can be compared to occupancy levels to determine the recommended ventilation rates per occupant. If they exceed ASHRAE Standard 62-1989, which is 15 cfm per occupant for office spaces without significant sources of pollution (see Load Sources), reducing the rates to the minimum required, particularly during occupied hours in the summer, could result in substantial energy savings.

CO_2 Sensors And Time Clocks

Because occupants are most often the primary source of CO_2 in buildings, CO_2 is sometimes used as a surrogate for determining levels of occupant-related contaminants. Accordingly, there is some interest in using CO_2 sensors to control outdoor air ventilation. When CO_2 levels are low, outdoor air ventilation rates are reduced to save energy, and, when CO_2 levels are high, outdoor air rates are increased to reduce occupant-related contaminants. Because demand-controlled ventilation using CO_2 sensors does not account for other sources of pollution, it is important to be aware of other sources that may create indoor air quality problems. Although the opportunities to reduce cooling and heating loads with CO_2 monitoring can be significant, the risk of causing occupant discomfort is also significant. Thus, ENERGY STAR Buildings recommends obtaining outside expertise to implement this load reduction.

Time clocks that automatically reduce ventilation rates during unoccupied periods can greatly reduce the energy load in buildings. If your building does not currently have nighttime setback of the ventilation system, consider investing in time clocks.

Load Reduction Strategy: Air Side Cooling Economizer Cycle

There are times when increasing outside air beyond ASHRAE 62-1989 requirements will lower cooling loads.

It is often possible, through the use of an economizer, to use outside air to cool a space either totally or partially. An economizer consists of local controls and dampers capable of delivering 100 percent outside air. Air side economizers come in two types: dry-bulb and wet-bulb economizers. A dry-bulb economizer is activated by outdoor air temperature. When the temperature is below a certain setpoint, the outside air damper opens to its maximum aperture to allow 100 percent outside air in. A wet-bulb economizer operates in the same manner; its only difference is that both temperature and relative humidity are measured. If you are familiar with the saying "it's not the heat, it's the humidity," you can understand why relative humidity is important.

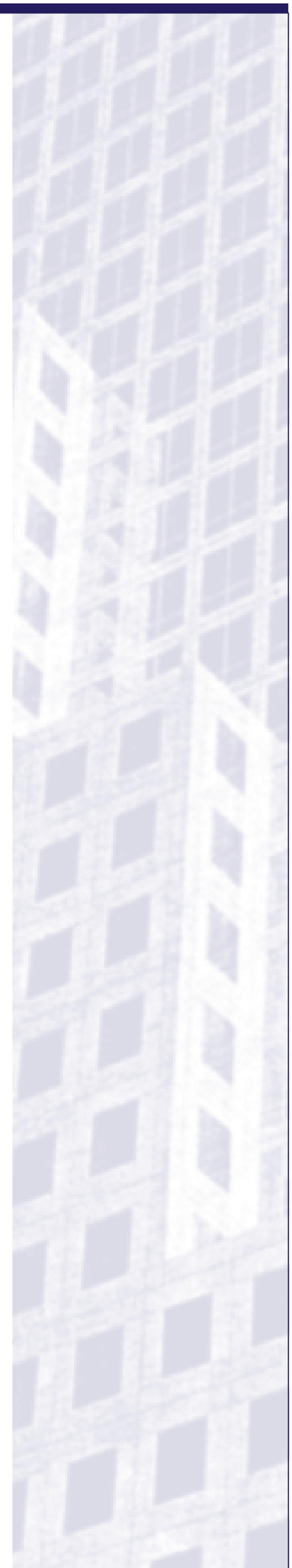
Table 4: Economizer Savings

Climate	*Savings (%)*
Humid-climate commercial buildings	25
Temperate-climate commercial buildings	50
Desert-climate small commercial buildings	12–20
Arid-climate small commercial buildings	30–40
Temperate/coastal-climate small commercial buildings	>70
Los Angeles commercial buildings	15–65
San Francisco commercial buildings	40–80
Fresno commercial buildings	30–45

Source: E SOURCE, *Space Cooling Technology Atlas*, Sec. 6.3.1.

In a practical sense, it is difficult to measure relative humidity accurately over a long period. For this reason, dry-bulb economizers, which measure temperature alone, are common.

Do not assume a building uses outside air economizing just because dampers, temperature sensors, and controls are installed. Outside air dampers, along with sensors, are prone to malfunctioning. Again, underscoring the importance of the Five Stage Approach, Stage Two—Building Tune-Up is designed to identify and fix equipment problems so that systems such as outside air economizers work properly.



Load Reduction Strategy: Night Precooling

Night precooling, another ventilation control strategy, is an energy-efficient way of cooling your building in lieu of mechanical refrigeration cooling. Night ventilation is an effective means of cooling in regions where nighttime temperature is low and daytime cooling loads are significant (*Passive Solar Journal*, vol. 2, no. 2). This strategy can be considered as a flushing method, whereby cold outdoor air is introduced during the night to flush internally generated heat out of a building.

Night precooling can save significant energy. Studies have shown that cost savings range from 5 percent in Phoenix, Arizona, to 18 percent in Denver, Colorado, for a typical office building. Additionally, peak demand reduction can also be achieved through night precooling. Simulation analyses have shown that precooling a 100,000-sf 3-story building in Sacramento, California, would save up to 12.6 percent in energy and cause a peak demand reduction of 31.3 percent (E SOURCE, *Space Cooling Technology Atlas*, Section 6.3).

Load Reduction Strategy: Minimize Kitchen Equipment Loads

When buying kitchen equipment such as refrigerators, buy the most energy-efficient model available in your size. If you have vending machines, they are typically lit continuously, consuming energy 24 hours a day. If possible, put such lighting on timers or replace them with more efficient lights. With some vending machines, it is possible to put the entire machine on a timer.

Load Reduction Strategy: Reduce Domestic Hot Water Heat Loss

Heat loss from domestic hot water tanks occurs 24 hours a day. Reducing heat loss from the tanks with either added insulation or installation of a higher efficiency unit also reduces the load on air-conditioning systems. For electric hot water tanks, an insulation wrap is both easy to install and pays for itself quickly. Another option is point-of-use heaters that have no tank and therefore no standby losses.

Load Reduction Strategy: Window Films

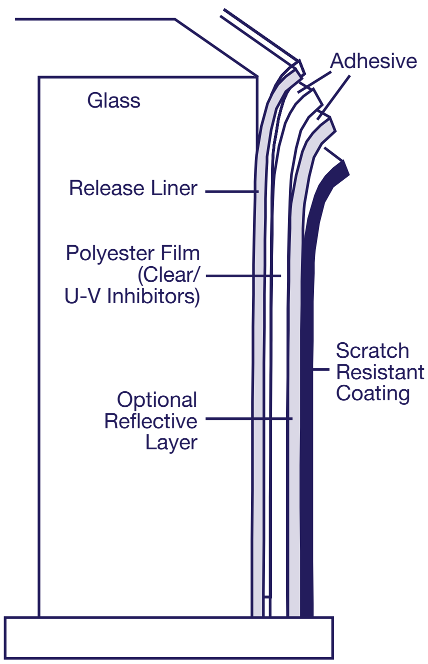
Window films can be retrofitted to existing windows to reduce heat gain due to solar radiation and provide a low-cost cooling load reduction (see Figure 4).

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 windows and the amount of internal heat escaping through windows. They can be applied directly to the interior surfaces of all types of glass and generally last 7 to 12 years.

Typically, in the heating season, more heat escapes from most windows than comes in from the sun (on a 24-hour basis); 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. In 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 address this problem by reducing solar heat gain at the window.

In short, window films save energy by reducing radiation and other forms of heat transfer through windows, by allowing better balance in heating and cooling systems and by providing opportunities for HVAC downsizing.

Figure 4: Window Films



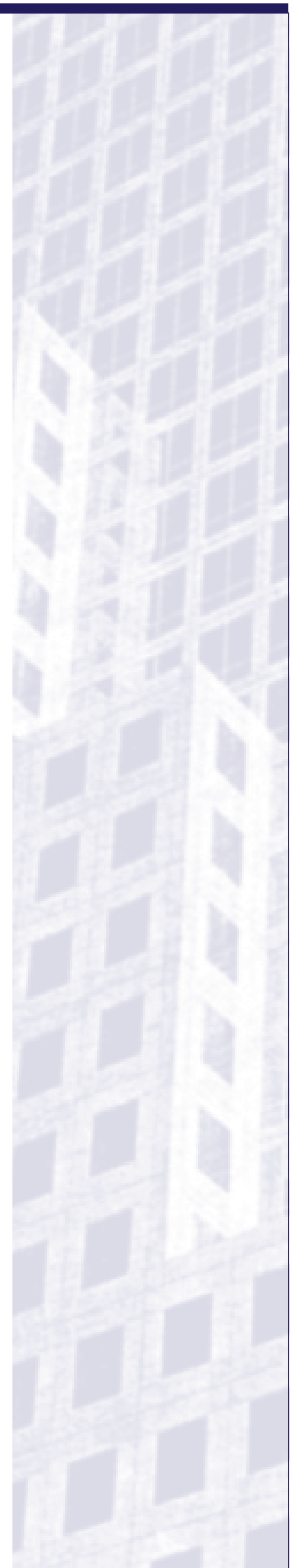
Window Films: Cost Effective For Your Building?

Apply the following criteria to your building. The more criteria your building meets, the more profitable window films can be.

- ✓ The amount of window space on the building is large compared to the total surface area (that is, greater than 25 percent of the surface area).
- ✓ The building is in a sunny location with little natural shade.
- ✓ Windows on the south and west sides of the building receive direct sunlight.
- ✓ Windows have single-pane glass. (Note: Even buildings with better insulated, double-pane windows may profit from window films.)
- ✓ Windows are clear; they have no tint, color, or reflective coating.
- ✓ The building is in a geographical area that has many sunny days.

Fan systems and cooling equipment can be downsized following peak cooling load reductions.

There are several economic considerations in regard to window film installations. For old, drafty, single-pane windows, complete window replacement is another option. Although this option is more expensive than window film installation, it may be more appropriate depending on your window condition. It may be most cost effective to install window films only on the south and west sides of the building. Window films typically cost between $1.35 and $3 per square foot, installed. Improperly installed films can, however, bubble, crack, peel, or even cause the glass to crack, so it is worthwhile to buy films with a material and installation guarantee of 5 to 10 years.



Load Reduction Strategy: Window Shading

Other ways to reduce the solar cooling load imposed by windows involve physical shading. Exterior and interior shading are among the best ways to keep the sun's heat out of a building. In warm climates, buildings in sunny areas can benefit greatly from a variety of shading techniques (see Figure 5).

Interior Shading

Venetian blinds and other operable shades are a low-cost and effective solution for keeping out the sun. More sophisticated systems, sometimes even located between two panes of window glazing, automatically open and close shades in response to the cooling load imposed by the sun.

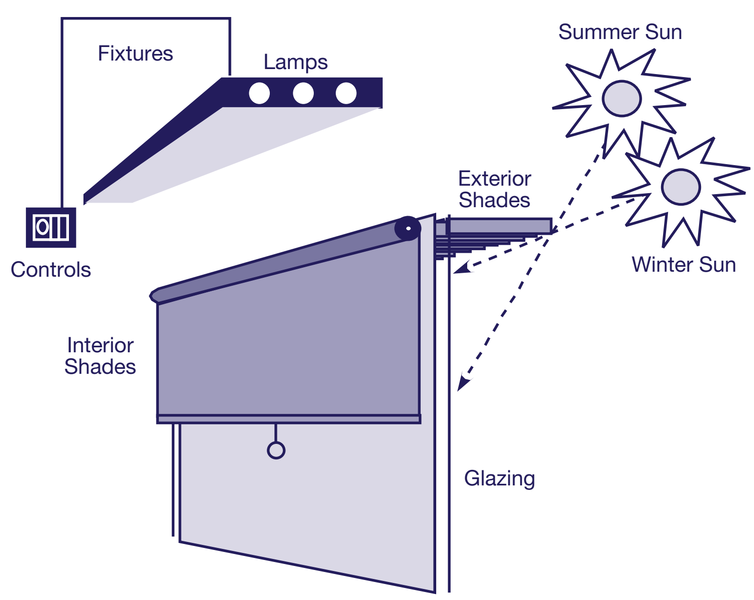
Exterior Shading

Properly applied, overhangs and awnings can be particularly beneficial. During winter, when the sun is low in the sky, sunlight is beneficial for heating and lighting the inside of a space while the windows are not shaded. During summer, when the sun is high in the sky, overhangs or awnings keep sunlight off the window.

Exterior shading techniques are also an excellent way of reducing glare produced when sunlight strikes glass directly.

Awnings are popular exterior shading devices on low-rise commercial buildings. Fiberglass or metal shade screens are often cost effective for low-rise commercial applications and are capable of reducing solar heat gain up to

Figure 5: Shading Strategies



80 percent in comparison to unshaded clear glass. Air space between exterior shades and windows helps carry away heat absorbed by the shade before it can be transferred through the window.

Exterior roller blinds are one effective method of exterior shading. Exterior roller blinds 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. Similarly, they can be raised in cold temperatures during sunny hours for desirable heat gain. Partially raising the blinds allows some daylight and air to enter between the slats. Experimentation has shown that these blinds can improve the R-value of the window area from the standard 0.88 for uncovered 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, be sure to remember that light colors are better at reflecting solar radiation. A darker awning may require venting to allow heat dissipation.

Shading With Vegetation

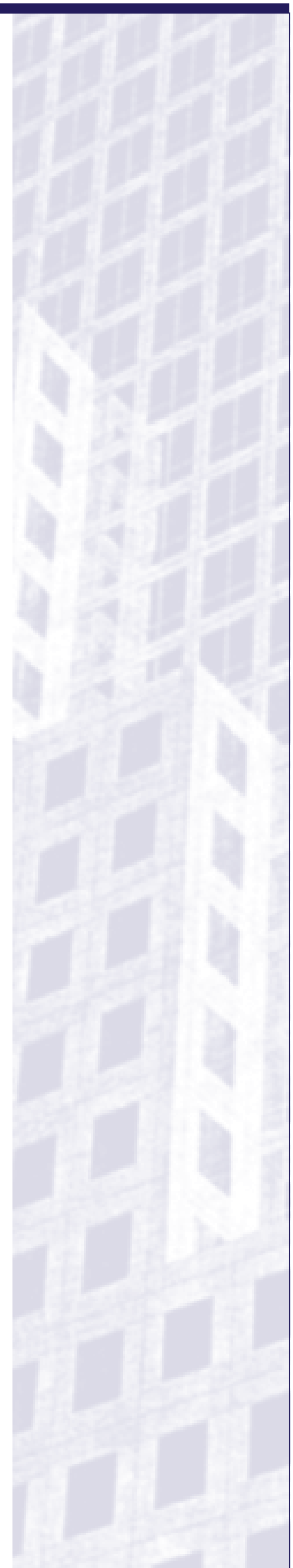
Finally, deciduous trees are also very effective at providing shade: During the winter they are bare, allowing sunlight to pass through, but during summer they shade the building.

Load Reduction Strategy: Roof Insulation

A significant portion of a building's heat loss and heat gain occurs through its roof. Energy-efficiency measures that slow the rate of energy transfer through the roof therefore provide opportunities for significant energy savings. The most effective means of reducing the heat transfer rate through the roof is to maximize R-value by adding thermal insulation.

In buildings undergoing roof replacement, it is always a good idea to incorporate roof insulation as part of the renovation. Rigid board insulation, typically two inches thick, can be applied to the exterior surface of the roof prior to the application of the new roof covering. This technique works well with new roof construction as well. However, it is generally not cost effective to apply insulation to the outside surface of an existing roof unless the roof itself is being replaced.

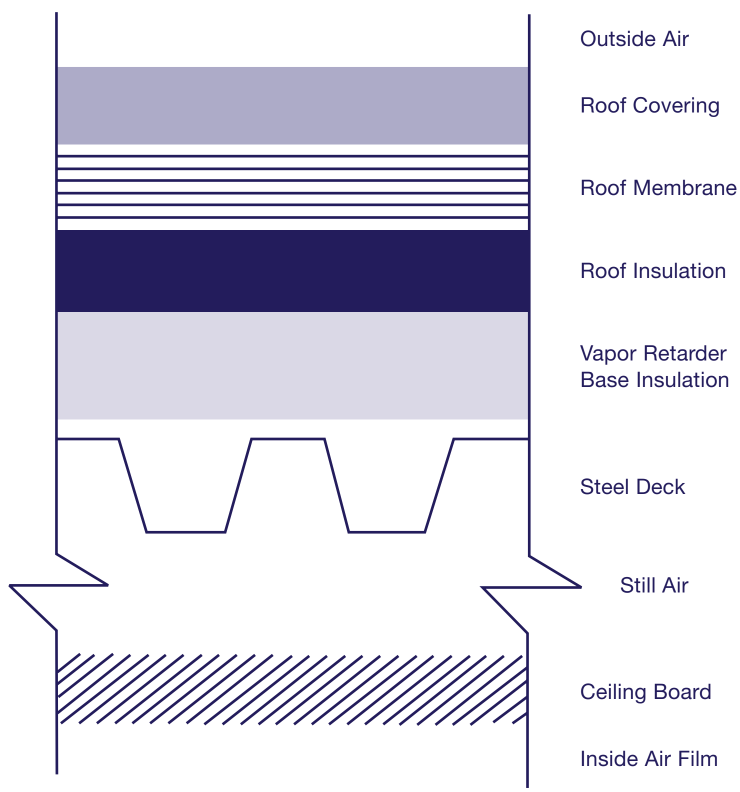
Where there is an attic or crawlspace below the roof, there are other options. Roof insulation types used in such applications include fiberglass blanket or "batt" insulation; blowing insulation, typically a spray-on urethane or fiberglass foam; or blown-in loose cellulose or fiberglass. In most cases, roof insulation for buildings with vented attic spaces is applied to the attic floor, in the form of either 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. Attic floor insulation is also inappropriate in the presence of any type of water pipe in the attic space. Because the insulation reduces the heat flow from the occupied spaces upward to the attic, the attic space is at a lower temperature, increasing the likelihood that your pipes may freeze and burst during the heating season.

In well insulated buildings, the relative significance of heat loss through uninsulated structural members, particularly those made of metal, increases. This effect reduces the effectiveness of the insulation by as much as 20 percent. It is important to consider insulating these structural members (see Figure 6) as well as the building envelope components, unless, as with flat roofs, the roof insulation is on the exterior of the building.

Figure 6: Roofing Layers



Additional Strategies

There are many additional strategies for reducing loads. Some are only cost effective, however, when viewed as part of the incremental costs of replacing old equipment for reasons unrelated to energy efficiency. Other technologies are emerging and may become more cost effective in the future.

Load Reduction Strategy: 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 (lower R-value) than the worst walls or roofs, and because windows represent a common source of air leakage. Windows also admit solar radiation. Of course, we neither want nor need to eliminate windows.

While improvements such as films, shading, and weather-stripping have already been discussed, replacing the complete window offers some additional benefit and is economically feasible in some situations, particularly as part of an extensive renovation.

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, as found in 68 percent of commercial space and 52 percent of office space in the United States. If your building has windows needing replacement, this presents an excellent opportunity to use the latest in advanced window designs, which offer paybacks in only a few years.

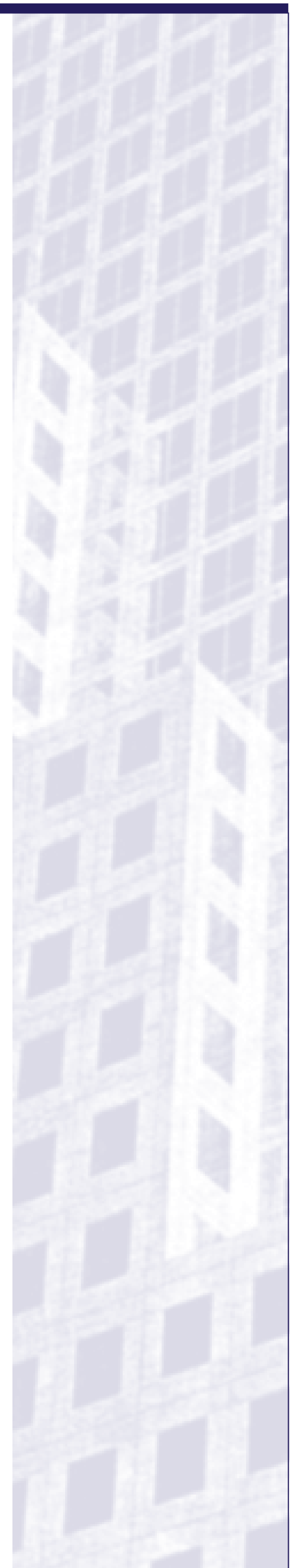
Here are some new technologies to look for:

- **Low-emissivity** (low-e) coatings provide better insulation, while letting in as much solar heat gain as possible.
- **Spectrally selective** glasses can maximize or minimize solar gain and shading depending on the product chosen.
- **New double-glazed systems** with layers of low-e film stretched across the interior air space have become available, which offer R-values as high as 8.

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.

Load Reduction Strategy: Energy Recovery Strategies

Heat recovery is one of the most beneficial ways of optimizing energy efficiency during building operations. Exhaust air from HVAC systems is a primary source of useful waste heat. During most of the year, energy is consumed to heat, cool, humidify, or dehumidify the air supply. Exchanging the energy between the outdoor air introduced into the building and the air exhausted from the building reduces the energy required to condition the outdoor air. Several heat recovery technologies are available, including rotary heat wheels, plate and frame heat exchangers, runaround coils, and heat pipes.



Each of these technologies is suited to specific applications. Consult vendors and engineers to determine the best match for your building. Depending on the application and technology type, these systems can recover 50 to 80 percent of the energy used to heat or cool ventilation air brought into the building.

Load Reduction Strategy: Desiccant Dehumidification

As new building codes require more outside air to be circulated into buildings, the amount of humidity that an air-conditioning system must remove has increased substantially. Conventional cooling systems consume more and more energy removing moisture, often overcooling the air below its dewpoint just to get the water out.

Recently, new desiccant-based cooling systems have emerged on the market. Desiccants are materials that absorb moisture from their surrounding space. Most people know them as small, usually white, packets found in the packaging of electronics and dried foods. Desiccant materials used in building applications can be regenerated. In other words, the moisture is driven out of them by the application of heat, whereupon they can be reused to absorb more water from the air. The heat is generally derived from gas, steam, or waste heat from the building.

The best applications for desiccant cooling systems are buildings with large dehumidification loads, long hours, and those in warm and humid climates—for example, hospitals, swimming pools, or supermarket fresh-produce areas. The cost of gas or waste heat used for regeneration is typically much lower than the cost of electricity used for conventional dehumidification.

Load Reduction Strategy: Building Integrated Photovoltaics

Photovoltaic (PV) panels generate electricity while absorbing solar radiation and reducing solar heat gain through the roof. A newly emerging Building Integrated PV (BIPV) technology is the use of PV roofing materials that can be installed much like traditional shingles or flat roof membranes, and involve little or no unusual engineering design.

Recently, buildings have incorporated PV cells mounted on clear building materials both to generate power and allow some light transmission through the panels to provide daylight to the space below. Such a system was installed at the Olympic Natatorium, built for the 1996 Olympic Games, at Georgia Institute of Technology.

With PV materials becoming available for roofs and walls, as well as other products that allow through some visible light, a large proportion of a building's exterior surface area has the potential to provide power generation of approximately 0.5 to 1 kW peak for every 10 square meters, depending on construction and orientation. In addition to reducing solar heat gain through the shell, BIPV technologies offer the advantage of providing the greatest power generation capacity coincident with the time of day when space cooling needs are greatest.

Load Reduction Strategy: Daylighting And Light Pipes

Once the most efficient electric lighting sources are implemented, reduce lighting operating hours for additional energy savings. The use of daylight sensors is the first step toward eliminating or reducing electric lighting operation when there is enough available daylight from windows along building perimeters during occupied hours.

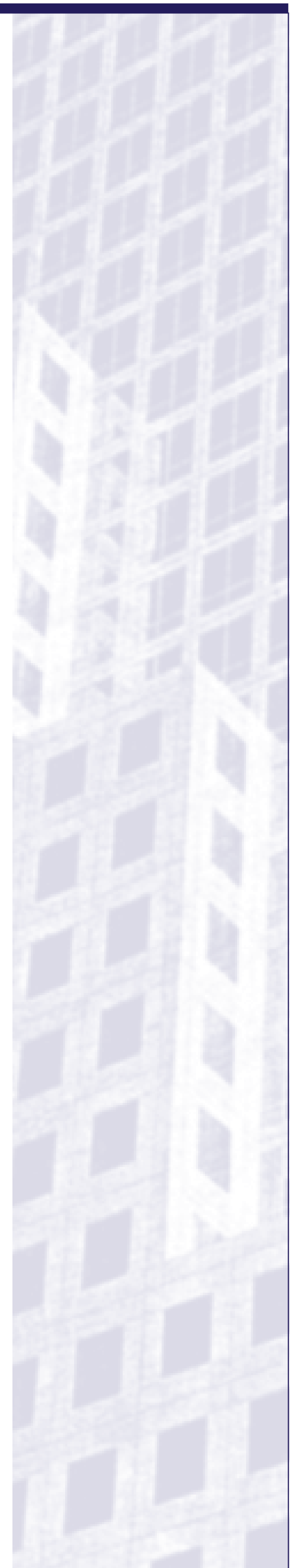
It is often possible to shade windows enough to reduce heat gain and glare substantially (see shading discussion above) while still providing enough daylight to eliminate electric light usage for much of the workday. Exterior light shelves can be used to reflect light onto the ceiling of the space without absorbing much solar heat. Lighting in parts of the space away from the window or light source can be increased using reflective surfaces or louvers.

What about interior building spaces, particularly those below the top floor where skylights are not feasible? Emerging and experimental technologies offer the potential to "pipe" light from roof- or wall-mounted collectors to interior spaces that do not have windows. One advantage of piping light is the potential to use either the daylight collector or a high-efficacy light source to light the whole system depending on daylight availability.

Load Reduction Strategy: Solar Windows (Chromogenic Glazings)

Research is currently under way to develop glazings that change automatically in response to changing temperature and/or light level conditions—similar, for example, to sunglasses that darken in sunlight. One technology being investigated is a treatment that turns glass cloudy as temperatures rise. Another technology uses an electrical current to alter the spectral selectivity of the glass. Strategically selected and positioned sensors thus control what the window is doing at any given time. A third effort is focusing on the embedding of thin-film amorphous PV material into glass while retaining light transmission so that the window becomes a miniature electric power plant.

None of these chromogenic technologies is commercially available at this time, but all are showing promise. In just a few years, window technology may indeed be vastly different from today's.



Summary

Stage Three—Other Load Reductions identifies numerous opportunities for further reducing your loads and allowing the installation of smaller, lower first-cost equipment in Stages Four and Five. To recap, here are your best savings opportunities:

- Ventilation Upgrades
  - Control ventilation rates to minimum requirements
  - Install air-side cooling economizer cycle
- Equipment Upgrades
  - Use ENERGY STAR office equipment
- Building Envelope Upgrades
  - Add window films and/or shading
  - Upgrade roof insulation

Next Steps

- Assess your load sources to determine where loads can be reduced.
- Implement upgrades to reduce loads and allow the installation of smaller equipment in Stages Four and Five.
- If possible, delay the installation of HVAC equipment until all loads can be reduced and the impacts on HVAC systems can be measured directly.

Glossary

AHU
See *air-handling unit*.

air-handling unit (AHU)
Equipment used to distribute conditioned air to a space. Includes heating and cooling coils, fans, ducts, and filters.

air side systems
Equipment used to heat, cool, and transport air within building HVAC systems.

ASHRAE
American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

balancing
Process of measuring and adjusting equipment to obtain desired flows. Applies to both air side and water side systems.

ballast
Power-regulating device that modifies input voltage and controls current to provide the electrical conditions necessary to start and operate gaseous discharge lamps.

British thermal unit (Btu)
A unit of energy equivalent to the amount of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit.

Btu
See *British thermal unit*.

calibration
Process of adjusting equipment to ensure that operation is within design parameters.

carbon dioxide
Colorless, odorless, incombustible gas formed during respiration, combustion, and organic decomposition. Increasing amounts of carbon dioxide in the atmosphere are believed to contribute to the global warming phenomenon.

CFCs
See *chlorofluorocarbons*.

cfm
Cubic feet per minute.

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

chlorofluorocarbons
Chemical compounds consisting of carbon, hydrogen, chlorine, and fluorine, once used widely as aerosol propellants and refrigerants. Believed to cause depletion of the atmospheric ozone layer.

coil, condenser
A heat exchanger used to condense refrigerant from a gas to a liquid.

coil, cooling
Heat exchanger used to cool air under forced convection, with or without dehumidification. May consist of a single coil section or several coil sections assembled into a bank.

coil, fan
A device that combines a heat exchanger and a fan in a single unit that conditions air by forced convection.

coil, heating
Heat exchanger that heats air under forced convection. May consist of a single coil section or several coil sections assembled into a bank.

control
Device that analyzes the difference between an actual process value and a desired process value and brings the actual value closer to the desired value.

dampers
Single- or multiple-blade devices, either manually or automatically opened or closed, that control the flow of air.

DEHP
Di (2-ethylhexyl) phthalate, an insulator used to replace PCBs in ballast capacitors starting in 1979. DEHP is listed as a hazardous waste in its pure form, but, according to RCRA, it is no longer considered hazardous once used in a lighting ballast.

demand charges
Fees levied by a utility company for electric demand.

demand, electric
Electrical power delivered to a system at a given time or averaged over a designated period. Expressed in kilowatts.

demand ventilation
Method of controlling the amount of outdoor air intake based on carbon dioxide levels in a space.

desiccant
A material that absorbs moisture from its surrounding environment.

domestic hot water
All hot water consumed in a building that is used for purposes other than heating a space.

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

efficiency
Ratio of power output to power input.

Energy Star label
EPA's trademark symbolizing excellence in energy efficiency.

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

exhaust air
Air removed from a building and not reused.

glazing
Glass set or made to be set in frames.

glazing system
A configuration of materials with a transparent or translucent element designed to admit sunlight.

GPM
Gallons per minute. A measure of water flow rate.

heat exchanger
A device that transfers heat from one fluid to another.

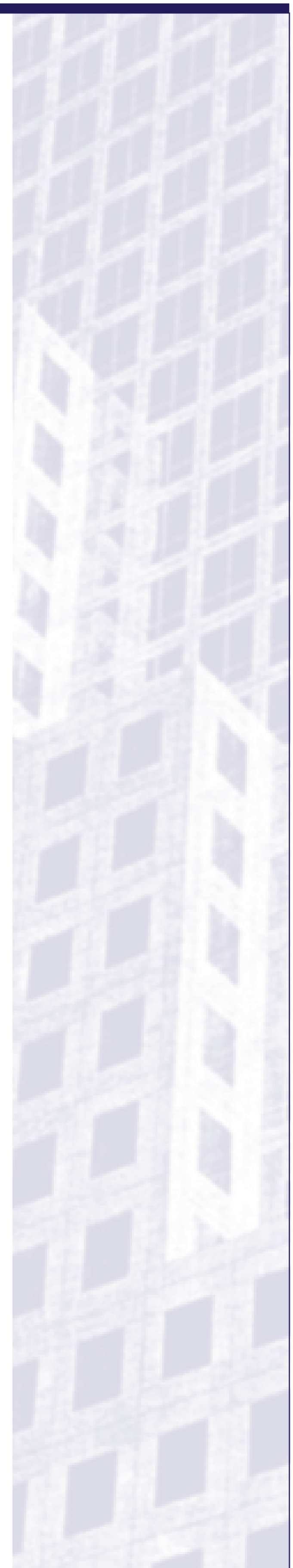
heat, latent
The heat required to change the phase of a substance (that is, liquid to gas or gas to liquid).

heat pump
Device that extracts heat from one medium and transfers it to another portion of the same medium or to a second medium at a higher temperature.

heat, sensible
The heat required to change temperature without changing phase.

hp
Horsepower. A unit of mechanical power.

HVAC
Heating, ventilating, and air-conditioning.



IAQ
Indoor air quality.

infiltration
Air that leaks into a building through the building shell.

kilowatt (kW)
Unit of power equal to 1,000 watts.

kilowatt-hour (kWh)
Unit of electric consumption equal to the work done by 1 kilowatt acting for 1 hour.

kW
See *kilowatt*.

kWh
See *kilowatt-hour*.

load
The demand upon the operating resources of a system. In the case of energy loads in buildings, the word generally refers to heating, cooling, and electrical (or demand) loads.

maintenance
An ongoing process to ensure equipment operates at peak performance.

nitrogen oxides
Chemical compounds that contain nitrogen and oxygen. They react with volatile organic compounds in the presence of heat and sunlight to form ozone and are a major precursor to acid rain.

occupancy sensor
A device that detects the presence or absence of occupants and controls operation of equipment accordingly.

payback
See *payback, simple*.

payback, simple
Also known as *payback*. Measurement of the elapsed time between an initial investment and the point at which accumulated savings are sufficient to offset the initial investment.

PPM
Parts per million. A unit of concentration.

roof curb
A raised and reinforced area on a roof for mounting equipment.

setpoint
Desired temperature, humidity, or pressure in a space, duct, etc.

shell, building
See *envelope, building*.

space
The distinct area to which conditioned air is delivered.

timeclock
The control device used to turn equipment on and off at set times of the day.

ton
Unit of cooling capacity equal to 12,000 Btu/hr.

transformer
A device that reduces the incoming line voltage, usually to a standard level, so that it may be used to operate electrical equipment in a building.

tune-up, building
The purposeful sequence of maintenance and operational improvements, undertaken at a specific point in time, designed to reduce energy use, heating loads, and cooling loads of existing facilities.

W/sf
Watts per square foot.

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To learn about EPA's ENERGY STAR Buildings Partnership,

visit our Web site at
http://www.epa.gov/buildings.

To request a catalog of available materials or for more information, call the ENERGY STAR hotline at 1-888-STAR YES.