



## SUPPLEMENTAL LOAD REDUCTIONS

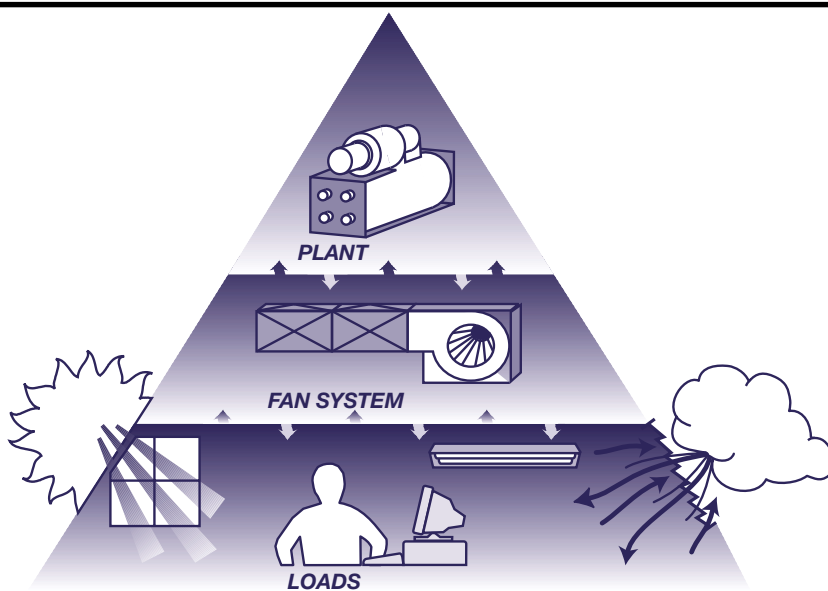
### Overview

Supplemental load sources are secondary load contributors to energy consumption in buildings. Some typical supplemental load sources are people, computers, lights and the building itself. These loads can adversely effect heating, cooling and electrical loads. However, the effect of supplemental loads can be controlled and reduced through strategic planning and implementing energy efficient upgrades.

The heat flow diagram (Figure1) illustrates how supplemental load sources effect the heating, ventilation, and air-conditioning (HVAC) system. With careful analysis of these sources and their interaction with HVAC systems, you can reduce equipment size and cost associated with upgrades. These upgrades can increase HVAC energy savings and reduce wasted energy.

Supplemental Load Reductions section will help you identify these load sources and provide strategies to mitigate their negative impact on energy performance. “Best Ways to Save” and “Take Action”, will provide you with checklists for reducing supplemental loads. “Load Reduction Strategy”, will discuss various technologies, equipment and activities that provide opportunities for reducing supplement loads.

**Figure 1: Heat Flow In Buildings**



**Heat Flow In Buildings: Building Systems Interactions**

Figure 2 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.



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### Supplemental Load Reductions Strategy

- Reduce heating, cooling, and electrical loads to allow the installation of smaller and lower first-cost HVAC equipment in Fan Systems and Heating and Cooling Systems.
  - 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 upgrade projects.
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### ***The Best Ways To Save***

- Ventilation Upgrades
  - Control ventilation rates to meet minimum requirements
  - Install air side cooling economizer cycle
  - Utilize energy recovery equipment (i.e., heat pipes and heat wheels)
- Equipment Upgrades
  - ENERGY STAR® labeled office equipment
- Building Envelope Upgrades
  - Window films and/or shading
  - Roof insulation

### ***Take Action!***

1. Assess supplemental load sources in your building to determine reduction opportunities.
2. Contact vendors, contractors, or an engineering consultant to specify upgrades for supplemental load sources.
3. Install energy efficient upgrades to reduce the effect of supplemental load sources on heating, cooling, and electrical systems.

### *Load Sources*

In the first stage of the upgrade process, Recommissioning, you had an opportunity to assess, plan and perform some reductions to the primary and secondary energy loads in buildings. The next step completing high-efficiency lighting upgrades, you achieved even more significant cooling and electrical load reductions. The third step in the process is Supplemental Load Reductions, which explores and identifies additional load reductions that can not only save energy and money, but will further increase savings when upgrading equipment for Fan Systems and Heating and Cooling Systems.

We have briefly introduced the three primary types of loads in all buildings and the benefits of reducing them. Next we discuss the supplemental load sources—that is, the



individual characteristics that contribute to heating, cooling, and electrical loads. The magnitude of the effect on heating, cooling and electrical loads is determined by the following load sources:

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

Supplemental load sources affect more than one primary 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. Upgrading to energy efficient lighting can reduce electrical and cooling loads, by eliminating heat generated by the lighting system; an inefficient and expensive form of heating.

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. The Lighting stage 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 by turning off lighting when spaces are unoccupied. (For further detail, see Lighting Chapter, Automatically Control Lighting.)

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#### **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)

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### **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 generates a load on your cooling system.

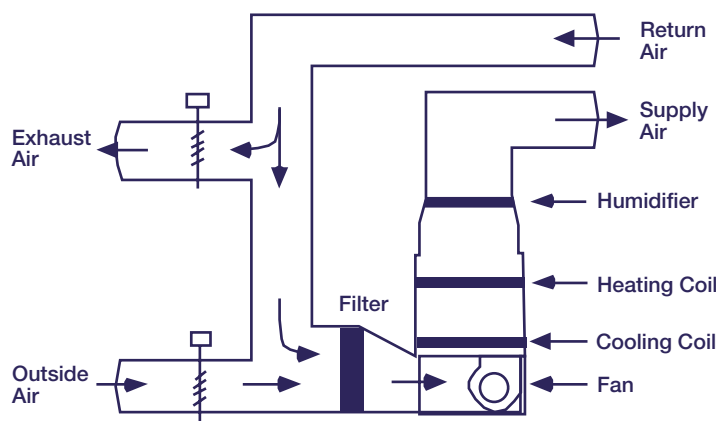
It is difficult to change the contribution occupants make to the energy balance in a building. Nevertheless, it is important to assess this contribution accurately and recognize that improvements to distribution systems and space conditioning equipment will lessen its effect on cooling loads and associated costs, while still maintaining or improving occupant comfort.

### **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. (Consult local building codes for outside air requirements; many locations have adopted ASHRAE Standard 62-1989 as part of their code for ventilation and some are beginning to consider ASHRAE Standard 62-1999.) In the summer, hot and humid ventilation air increases cooling loads. In the winter, cold ventilation air increases heating loads.

Many buildings require air-conditioning although the outside air is relatively cool and dry, due to internal or supplemental loads. An economizer cycle can be used to increase amounts of outside air to reduce mechanical cooling load.

**Figure 2: Central Air System**





## **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 labeled computer and color monitor draw a continuous electrical load of 120 watts or more (*User Guide to Power Management for PCs and Monitors*, Lawrence Berkeley National Laboratory, January 1997). Moreover, the heat they generate can be provided to the space more efficiently when needed.

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#### **Example: Computer Load Reduction**

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

Replacing 10 PCs with ENERGY STAR labeled 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%**

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### *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 weatherstripping—see Recommissioning) 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.

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### **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.

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### *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 demonstrates the relative resistance to heat flow through a solid. The larger the R-value, the more insulation the wall or roof provides and the less heat that flows through that wall or roof by 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) to achieve their increase in R-value.

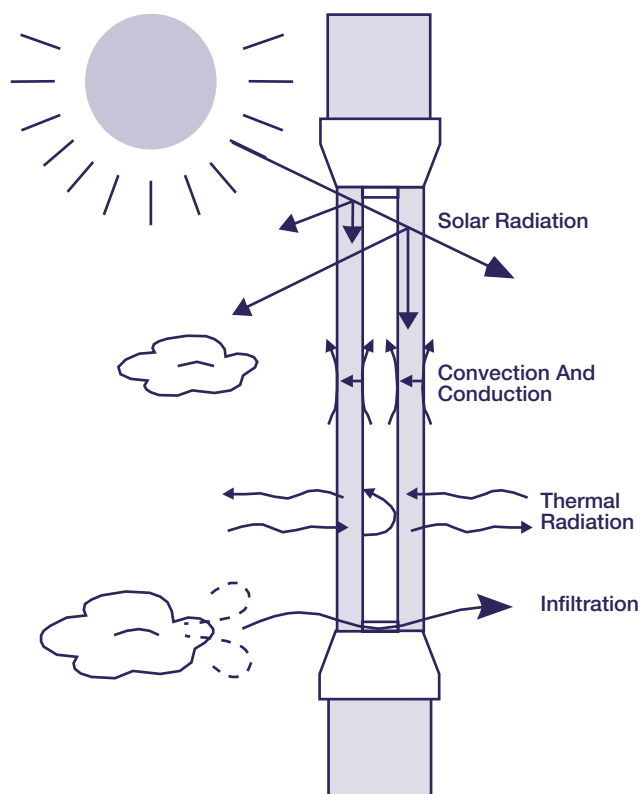
### *Infiltration*

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.





**Figure 3: Window Heat Flow**



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, doorjamb, 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 (natural convection, most commonly 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.



*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.

## **Supplemental Load Reduction Opportunities**

As the heat flow diagram (Figure 1) illustrates, load reductions made in this stage can significantly and positively affect equipment modifications that will be made in the remaining stages.

Fan System Upgrades addresses fan systems, which can usually be right-sized to a smaller capacity or operated more efficiently as a result of load reductions.

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### **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.

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Heating and Cooling System Upgrades address equipment that also can be right-sized, usually to a smaller capacity, and/or operated more efficiently as a result of load reductions.

Upgrades that effect load reductions have the potential for both future energy savings and lower first costs in Fan Systems and HVAC Systems. A analysis done on supplemental load reductions will pay back more than once.





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### Distribution System Benefits

Distribution system motor size may be reduced with smaller cooling loads. The first cost on a fan motor, for example, would be \$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)

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### **Load Reduction Strategy: ENERGY STAR Labeled 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 labeled office equipment. Virtually all office equipment manufacturers offer a wide range of ENERGY STAR labeled 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 cost the same as comparable non- labeled equipment. However, the savings are greater for labeled equipment, as shown in Table 2. The estimated savings below are per unit and can be multiplied to estimate savings for an office with hundreds of energy-efficient products.

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**Table 2: ENERGY STAR Labeled Office Equipment Savings**

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

**Source:** Lawrence Berkeley Laboratories.

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ENERGY STAR labeled equipment produce less heat by powering down when not in use. This reduces cooling load, and energy costs of air-conditioning 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 (including ENERGY STAR labeled 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 labeled 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, or retailer if the model meets the ENERGY STAR specifications.

For 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, control devices are available for non-ENERGY STAR labeled computers, monitors, and printers. These external hardware units are designed to reduce the energy consumption of older equipment by turning them off when not in use. To request a list of control device manufacturers and their products, call the ENERGY STAR hotline at 1-888-STAR YES.

**Ensure Proper Equipment Setup** – Confirm 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 through regular training and other internal materials, that ENERGY STAR is an organizational policy. 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 Labeled Office Equipment**

<i>Equipment</i>	<i>ENERGY STAR Specifications</i>
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 5–105 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.
Printers	Automatically power down to 15–45 watts, depending on print speed.
Scanners in use.	Automatically power down to 12 watts or less when not

#### *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 labeled 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** – As of January 1998, ENERGY STAR labeled monitors automatically enter two successive low-power modes of 15 watts and 8 watts. In addition to reducing wasted energy, ENERGY STAR labeled 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 labeled 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 US 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 5 to 105 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 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<sub>2</sub> Sensors and Time Clocks*

Because occupants are most often the primary source of CO<sub>2</sub> in buildings, CO<sub>2</sub> is sometimes used as a surrogate for determining levels of occupant-related contaminants. Accordingly, there is some interest in using CO<sub>2</sub> sensors to control outdoor air ventilation. When CO<sub>2</sub> levels are low, outdoor air ventilation rates are reduced to save energy, and, when CO<sub>2</sub> levels are high, outdoor air rates are increased to reduce occupant-related contaminants. Because demand-controlled ventilation using CO<sub>2</sub> 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<sub>2</sub> monitoring can be significant, the risk of causing occupant discomfort is also significant. Thus, ENERGY STAR recommends obtaining outside expertise to implement this load reduction strategy.

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 set-point, 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**

<i>Climate</i>	<i>Savings (%)</i>
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 ENERGY STAR Approach, 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 6.3.1).

#### **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).

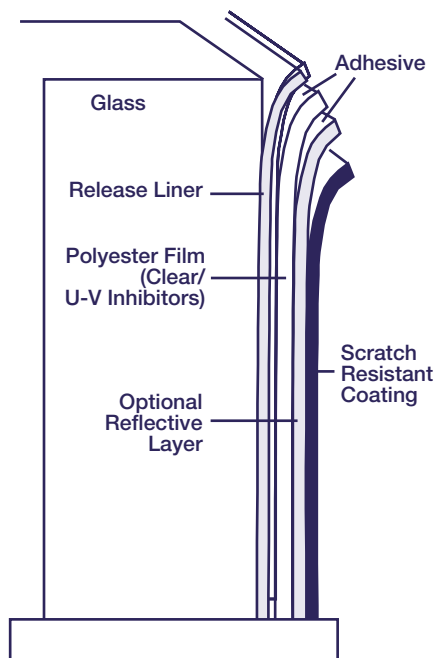
Window films are thin layers of polyester, metallic coatings, and adhesives that save energy by limiting both the amount of solar radiation passing through the windows and the amount of internal heat escaping through windows. They can be applied directly to the interior surfaces of all types of glass 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.

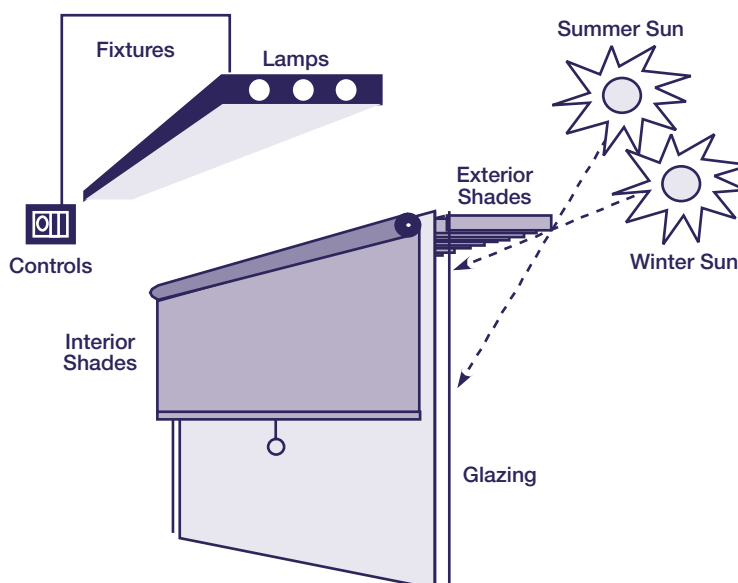
#### *Low emissivity coatings*

**Low-emissivity (low-e)** coatings provide better insulation, while letting in as much solar heat gain as possible. These coatings are now typically offered on many window systems.

#### *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.

**Figure 5: Shading Strategies**







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 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 single 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.

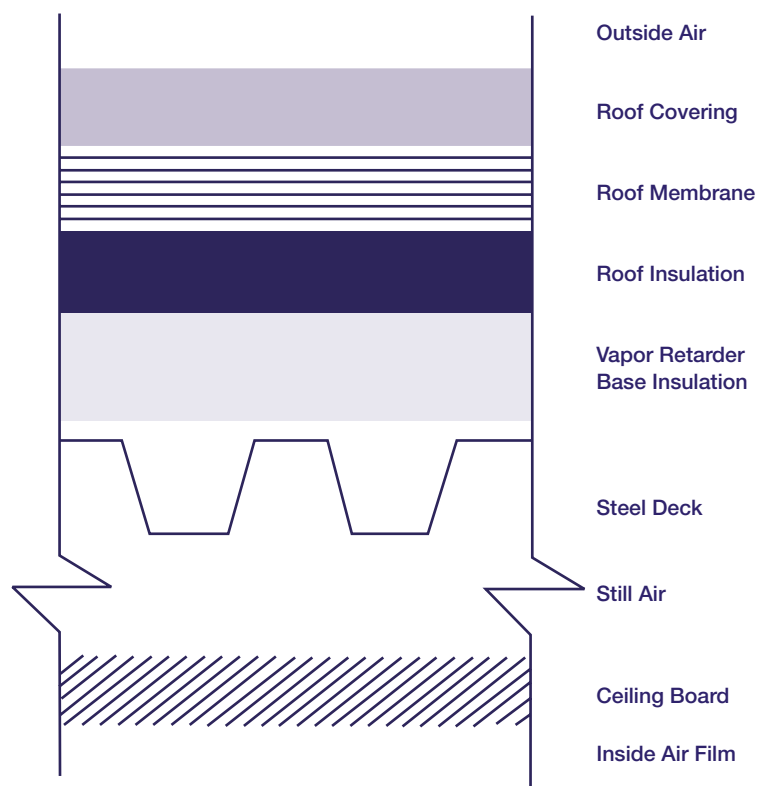
In buildings undergoing roof replacement, it is always a good idea to incorporate roof insulation as part of the renovation. Rigid board insulation, typically two inches thick, can be applied to the exterior surface of the roof prior to the application of the new roof covering. This technique works well 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.

**Figure 6: Roofing Layers**



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.

### **Load Reduction Strategy: ENERGY STAR Labeled Roof Products**

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. As with insulation, an effective means of reducing the heat transfer rate through the roof is to minimize the amount of heat conducted through the roof. ENERGY STAR labeled roof products use reflectivity to lower the roof surface temperature by up to 100 °F, thereby decreasing the amount of heat transferred into a building's interior.

Benefits of ENERGY STAR labeled roof products include:

- Downsized A/C equipment. A reflective roof can reduce peak cooling demand by 15%. The home or building owner may be able to purchase a smaller, less-expensive cooling system.
- Extended roof life. Roofs undergo significant expansion and contraction as they heat and cool throughout the day. Heat absorbed by the roof can also accelerate degradation by ultraviolet rays and water. A reflective roof can reduce the amount of thermal shock that occurs on the roof surface and make the roof last longer.
- Reduced Heat Island Effect. Roofs made of non-reflective products cause the temperature of the air passing over them to rise, resulting in an increase in the overall temperature of the area, also known as a "heat island effect." The elevated temperature leads to increased building and vehicle air conditioning demand, increased levels of smog, and the associated increased incidence of heat- and smog-related health problems.

Energy savings from installing ENERGY STAR labeled roof products will depend on the geographic location and climate where it is installed, existing insulation levels in the building, the type of roof it replaces, the type of roof installed, and how well it is kept clean and maintained. In general, cooling energy savings can be as high as 50%. Additionally, a reflective roof can reduce peak cooling demand by 10 to 15%. As a result, building owners may be able to purchase smaller, less expensive HVAC systems.





## 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:

- **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.
  - Gas filled windows, using argon or krypton gas, minimizes the convection currents within the space, conduction through the gas is reduced, and the overall transfer of heat between the inside and outside is reduced.

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 dew point 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-efficiency 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

Other Load Reductions identifies numerous opportunities for further reducing your loads and allowing the installation of smaller, lower first-cost equipment in fan and HVAC Systems. To recap, here are your best savings opportunities:

- Ventilation Upgrades
  - Control ventilation rates to minimum requirements
  - Install air-side cooling economizer cycle
  - Install energy recovery technologies
- Equipment Upgrades
  - Use ENERGY STAR labeled 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 fan and HVAC systems.
- If possible, delay the installation of HVAC equipment until all loads can be reduced and the impacts on HVAC systems can be measured directly.

## Appendix: History Of Ventilation Requirements

Building codes require minimum ventilation rates. Code requirements have changed significantly over the years in response to the impact of outside air quantities on energy consumption, occupant comfort and health.

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. ASHRAE Ventilation Standard 62-1989 required at least 15 cfm of



outside air per person (and more for many types of spaces) and a maximum CO<sub>2</sub> concentration of 1,000 ppm.

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. The new standard defines acceptable air quality as “air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities . . .” Since the 1989 publication of the Standard, several cognizant authorities have determined that tobacco smoke is harmful to human health. These authorities include, among others, the U.S. Environmental Protection Agency, World Health Organization, American Medical Association, American Lung Association, National Institutes of Occupational Safety and Health Administration, and the Office of the U.S. Surgeon General, while smoking lounges still require 60 cfm of outside air per occupant.

The current ASHRAE Ventilation Standard 62-1999 requires at least 15 cfm of outside air per person (and more for many types of spaces) and modifies the criteria for maximum CO<sub>2</sub> concentration to 700 ppm above the outdoor air concentration. In addition, language has been added more clearly describing the CO<sub>2</sub> concentrations as a useful indicator of the concentration of human bioeffluents. Finally, Standard 62-1999 removes references that the ventilation rates (in Table 2 of the Standard) will accommodate a moderate amount of smoking. Please see Standard 62-1999 for further details regarding smoking and ventilation. (Table 1 summarizes the history of ventilation requirements.)

**Table 1: Historical Outside Air Requirements**

<i>Outside air per person</i>	<i>cfm</i>
Industry Standard 1973	15–25
ASHRAE Standard 62-1981	> 5
ASHRAE Standard 62-1989	> 15
ASHRAE Standard 62-1999	>15

With the increased use of chemical-based products, building materials, and furnishings that contribute to indoor pollution, health and comfort complaints, ASHRAE has concurrently tried to address contaminants not produced by occupants in its ventilation requirements. The current Standard 62-1999 allows the user to establish ventilation requirements based on a separate procedure that analyzes specific contaminants.