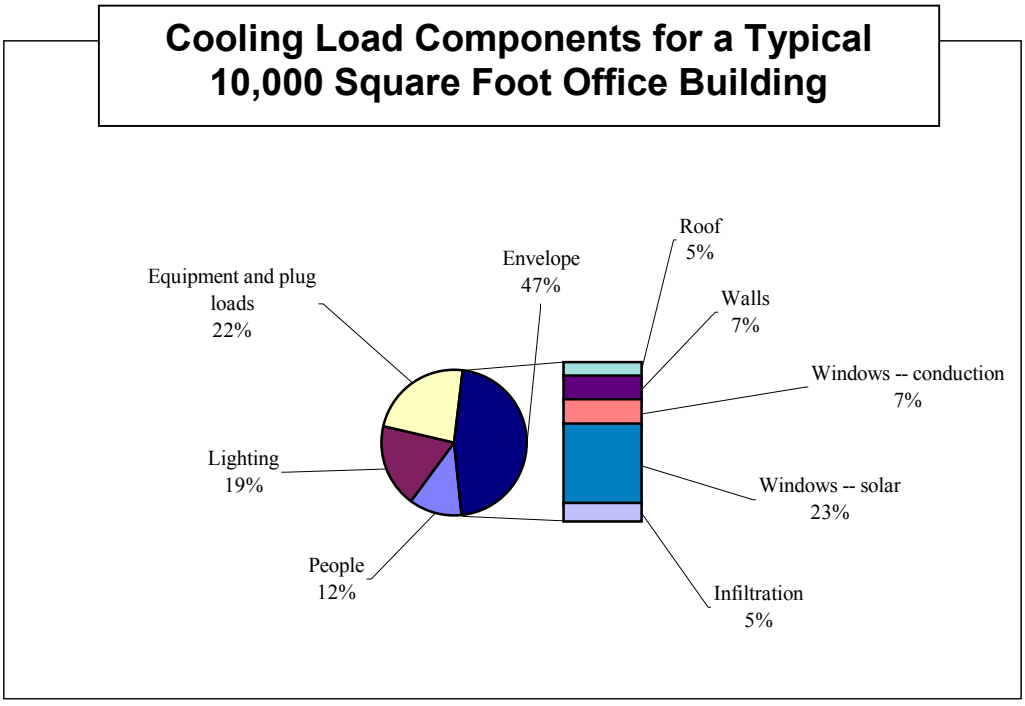
ENERGY Answers for Business

BUILDING ENVELOPE

The envelope of a building is comprised of the surfaces that separate the inside from the outdoors. The design and construction of the envelope of a commercial building can have a significant effect on the building's comfort and energy consumption. If you are building a new facility or doing a major renovation to an existing one, this fact sheet can help you make design decisions that can improve the overall comfort and energy performance of the building envelope.

Sources of Summer Heat Gain

A building's envelope continuously interacts with the outside environment, and its performance has a strong influence on the indoor environment and comfort conditions. The envelope and the air conditioning system are closely interrelated, and proper building design can optimize air conditioning system performance, minimize energy costs and improve comfort. The chart below gives you an idea of how much each component of the building envelope contributes to the overall cooling load for a typical office building. This figure indicates that most summer cooling load is due to solar heat gain through windows, infiltration of outside air, and the internal loads of people, lighting and miscellaneous equipment. Reducing solar heat gain through windows is clearly one of the keys to reducing energy costs in buildings with a large amount of window area such as an office building.



Roof Insulation and Color

Insulation serves to limit the conduction of heat through the building shell. Little of a commercial building's summer cooling is due to conduction of heat through the skin of the building envelope. However, for buildings with a large amount of roof area relative to floor area, such as a single-story retail facility, reducing heat gain through the roof can be an important consideration.

The type of insulation used in roof applications and the cost effectiveness of adding more depends on the type of structure, the building's orientation, the amount of insulation already installed, venting of the space below the roof, and the color of the roof. For flat-roofed structures with rubber membrane roofing, it's common to use a rigid insulation board on the roof deck. For structures with sloped roofs, batts or loose blown-in insulation are more common. Some structures are relatively easy to add additional roof insulation to and others can be more difficult. A building with an attic space can have insulation added at any time, while adding insulation to a building without attic space might not be cost effective unless it can be done at the same time as a roof replacement or other major remodel. The greatest energy savings are typically made when adding insulation to a dark colored, flat, uninsulated roof directly over air-conditioned space. The following table shows the insulating values of common types of roof insulation.

Characteristics of Common Insulation Types

Type	Form	R-value per inch[1]
Polyurethane	Expanding foam	6
Expanded Polystyrene	Rigid board	4 – 5
Polyisocyanurate, faced	Rigid board	7
Fiberglass	Batts or Loose	3.5
Cellulose	Loose or wet blown	3.5
Mineral Wool	Loose	2.5
Rock Wool	Loose	2.5

R-Value is the thermal resistance of a building material. The higher the R-value, the higher the insulating value of the material. **U-Value** is the rate of heat flow through a building element. It is the reciprocal of the R-value and the lower the U-value the higher the insulation value of the material.

Since lighter colors and reflective coatings reflect more of the sun's heat than darker colors, the color of a roof can affect the demand for cooling in buildings. The savings from applying a light colored or reflective roof treatment vary depending on the orientation of the roof, the ventilation of the space below it, and the roof's insulation levels. The greatest savings are expected on a flat roof with no ventilation below it and no insulation. Another method available for flat roofs is to apply a layer of white pebbles. In order to remain effective, a light or reflective roof coating or material needs to be kept clean. If it is allowed to become dark over time due to dirt, dust, and pollutants it's effectiveness will degrade. The effect of different roof insulation levels and color on annual heating and cooling costs is shown in the table below.

Annual Cooling Costs with Different Insulation Levels and Roof Colors For a Single-Story 10,000 Square Foot Building in the Phoenix Area

Insulation Level	Roof Color	Annual Heating and Cooling Cost ($/square foot/year)
No insulation, R-0	Dark	2.26
	Light	2.17
R-19	Dark	1.80
	Light	1.69
R-30	Dark	1.23
	Light	1.11

[1] The values high are typical, however actual values will vary by manufacturer and installation quality.

The following table provides some rules-of-thumb on the cost effectiveness of adding roof insulation to an existing building. For new buildings, APS recommends a minimum R-30 roof insulation. These are general guidelines and it's always a good idea to consult with your architect or builder about the cost-effectiveness of your application.

Cost Effectiveness of Adding Roof Insulation to Existing Buildings in the Phoenix Area[2]

Existing Condition	Is it cost effective to add insulation?
No insulation to R-6	Yes, always
R-7 to R-19	Yes, if attic is accessible or if built-up roof is being replaced
Greater than R-19	Not usually cost effective

Infiltration

When outside air enters a building, it has to be cooled or heated to maintain comfort. The more unconditioned air entering the building, the greater the load on the heating and cooling system and the greater the cost. Air can enter the building in three ways: 1) intentionally via the HVAC system (to provide fresh air), 2) unintentionally through cracks and crevices in the building, 3) unintentionally through doors and windows as they are opened and closed throughout the day. Uncontrolled infiltration may not provide fresh air where needed, and it cannot be turned off when the building is unoccupied. Wind will increase infiltration and tall buildings have a "stack" or "chimney" effect that draws air into the bottom of the building and forces it out the top. HVAC systems that have leaky ducts or do not provide fresh air to replace that exhausted by fans may cause air to infiltrate through building crevices as well. There are several methods to address unwanted infiltration:

1. Caulking and weatherstripping should be in place for doors and windows.
2. For open doorways (such as are often used at loading docks and warehouses), clear vinyl strips can be used to reduce infiltration.
3. HVAC system outside air dampers should seal tightly when closed. Replacement with good quality opposed blade dampers with seals at the blade edges and ends will reduce infiltration.
4. Exhaust hoods should be examined and adjusted to ensure they are exhausting the minimum air necessary to remove contaminants. Baffles can be added to the exhaust ducting or inside the hood to reduce flow.
5. Avoid using building cavities for return air paths. While not well documented in commercial buildings, indications are that using building cavities as return air paths can lead to substantial increases in infiltration rates.

Windows and Window Treatments and Daylighting

Windows play an important role in the comfort, aesthetics and energy efficiency of a building. Our business fact sheet on windows and window treatments provides more detailed information on selecting energy efficient window systems. As a general guide however, Low-E windows provide excellent thermal insulation against weather extremes and can effectively reduce solar heat gain as well. Window tints and reflective films are efficient at reducing solar gain but can also reduce the visual connection with the outdoors. External window screens are excellent solar control devices for single- or two-story facilities, and architectural features such as awnings and overhangs allow year-round solar control without minimizing visual quality.

Other Design Features to Consider

Orientation – The orientation of a building often is determined by siting considerations. However, for those sites where there is a choice, analyzing the effect of orientation on energy and equipment costs can lead to a more energy-efficient building. While it is important to look at each project on an individual basis, as a general guide, long, narrow buildings facing south with their long axis running east/west will have lower peak cooling loads and electricity demand costs, and

[2] Adapted from the Energy Star Small Business Guide for the Phoenix Climate.

may be able to utilize smaller cooling equipment. Conversely, buildings facing east or west with their long axis running north/south will have higher peak cooling loads and electricity demand costs, and may require larger cooling equipment

Landscaping – Well designed landscaping can reduce cooling costs from summer heat gains in building. Trees planted on the east, west and south sides of a one-or two-story building can effectively reduce summer solar heat gains through windows which is one of the major contributors to the cooling load on an air conditioning system. Trees also produce a natural cooling effect in the areas surrounding a building by evaporating water though their leaves. This can help offset the "heat island" effect in urban areas such as Phoenix.

Daylighting -- Daylighting with skylights and other types of architectural glazing features can provide natural lighting creating a pleasant working atmosphere. Daylighting strategies may by particularly effective using skylights in large open areas such as warehouses and manufacturing plants, and in office spaces where the electrical lighting system output can be efficiently varied over a wide range of light levels. In the Arizona desert climate, however, it is important to balance daylighting strategies with good solar heat control in order to keep cooling loads down. See our business fact sheet on Energy-Efficient Lighting for more information on daylighting controls.

For More Information on Energy-efficient Building Technologies

Contact the Web sites of the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), the U.S. Department of Energy's Energy Efficiency and Renewable Energy Network, and the U.S. Environmental Protection Agency's Energy Star Buildings Program.

For general information regarding electric service for your business, call the APS Business Center at 602-371-6767 or 1-800-253-9407. For an on line analysis of your business energy use visit the APS Web site and take the Energy Survey at http://www.aps.com/aps_services/energysurvey/Default_BUSRES.html?type=b