Buildings for the 21st Century

Buildings that are more energy efficient, comfortable, and affordable…that's the goal of DOE's Office of Building Technology, State and Community Programs (BTS). To accelerate the development and wide application of energy efficiency measures, BTS:

- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use
- Provides support and grants to states and communities for deployment of energy-efficient technologies and practices

PASSIVE SOLAR DESIGN

Increase energy efficiency and comfort in homes by incorporating passive solar design features

DESIGN WITH THE SUN IN MIND

Sunlight can provide ample heat, light, and shade and induce summertime ventilation into the well-designed home. Passive solar design can reduce heating and cooling energy bills, increase spatial vitality, and improve comfort. Inherently flexible passive solar design principles typically accrue energy benefits with low maintenance risks over the life of the building.

DESIGN TECHNIQUES

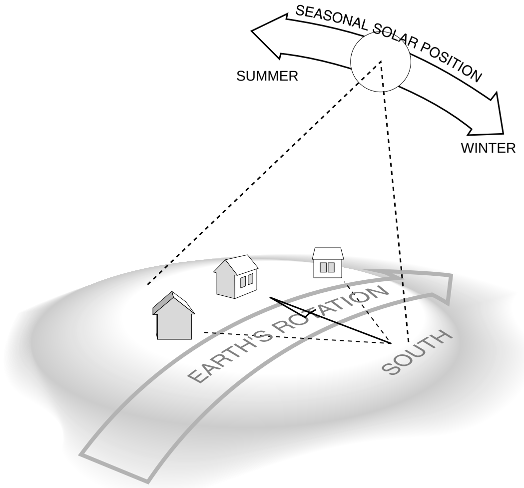
Passive solar design integrates a combination of building features to reduce or even eliminate the need for mechanical cooling and heating and daytime artificial lighting. Designers and builders pay particular attention to the sun to minimize heating and cooling needs. The design does not need to be complex, but it does involve knowledge of solar geometry, window technology, and local climate. Given the proper building site, virtually any type of architecture can integrate passive solar design.

Passive solar heating techniques generally fall into one of three categories: *direct gain*, *indirect gain*, and *isolated gain*. Direct gain is solar radiation that directly penetrates and is stored in the living space. Indirect gain collects, stores, and distributes solar radiation using some thermal storage material (e.g., Trombé wall). Conduction, radiation, or convection then transfers the energy indoors. Isolated gain systems (e.g., sunspace) collect solar radiation in an area that can be selectively closed off or opened to the rest of the house.

Passive solar design is not new. In fact, ancient civilizations used passive solar design. What is new are building materials, methods, and software that can improve the design and integration of passive solar principles into modern residential structures.

SOLAR POSITIONING CONSIDERATIONS

The south side of the home must be oriented to within 30 degrees of due south.



COST

It takes more thought to design with the sun; however, passive solar features such as additional glazing, added thermal mass, larger roof overhangs, or other shading features can pay for themselves. Since passive solar designs require substantially less mechanical heating and cooling capacity, savings can accrue from reduced unit size, installation, operation, and maintenance costs. Passive solar design techniques may therefore have a higher first cost but are often less expensive when the lower annual energy and maintenance costs are factored in over the life of the building.

OFFICE OF BUILDING TECHNOLOGY, STATE AND COMMUNITY PROGRAMS
ENERGY EFFICIENCY AND RENEWABLE ENERGY • U.S. DEPARTMENT OF ENERGY

DIRECT GAIN PASSIVE SOLAR DESIGN TECHNIQUES

Passive solar design strategies vary by building location and regional climate, but the basic techniques remain the same—maximize solar heat gain in winter and minimize it in summer. Specific techniques include:

- Start by using energy-efficient design strategies.
- Orient the house with the long axis running east/west.
- Select, orient, and size glass to optimize winter heat gain and minimize summer heat gain for the specific climate. Consider selecting different glazings for different sides of the house (exposures).
- Size south-facing overhangs to shade windows in summer and allow solar gain in winter.
- Add thermal mass in walls or floors for heat storage.
- Use natural ventilation to reduce or eliminate cooling needs.
- Use daylight to provide natural lighting.

These techniques are described in more detail below.

✓ **Cutting Losses.** A passive solar home should start out well sealed and well insulated. By reducing heat loss and gain, remaining energy loads can be effectively met with passive solar techniques. Approaches that contribute to minimizing heating and cooling loads include using advanced framing guidelines, properly installing insulation, using recommended insulation levels (International Code Council's International Energy Conservation Code, (703) 931-4533, www.intlcode.org or the U.S. Department of Energy's Insulation Fact Sheet, DOE/CE-0180, (800) DOE-EREC, www.ornl.gov/roofs+walls), reducing duct losses, and tightening the building envelope.

✓ **Site Orientation.** The building's southern exposure must be clear of large obstacles (e.g., tall buildings, tall trees) that block the sunlight. Although a true southern exposure is optimal to maximize solar contribution, it is neither mandatory nor always possible. Provided the building faces within 30˚ of due south, south-facing glazing will receive about 90 percent of the optimal winter solar heat gain.

✓ **Window Selection.** Heating with solar energy is easy: just let the sun shine in through the windows. The natural properties of glass let sunlight through but trap long-wave heat radiation, keeping the house warm (the greenhouse effect). The challenge often is to properly size the south-facing glass to balance heat gain and heat loss properties without overheating.

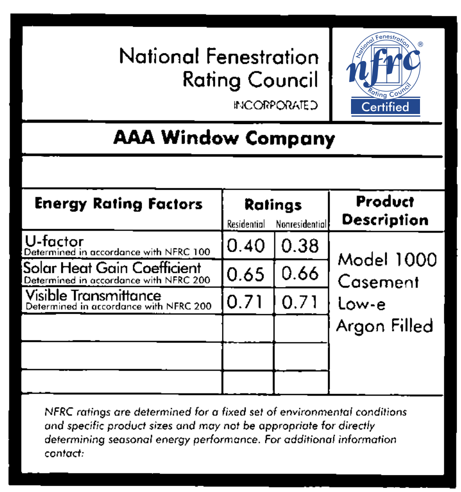
Increasing the glass area can increase building energy loss. New window technologies, including selective coatings, have lessened such concerns by increasing window insulation properties to help keep heat where it is needed.

In heating climates, reduce the window area on north-, east-, and west-facing walls, while still allowing for adequate daylight. Effective south-facing windows require a high Solar Heat Gain Coefficient (SHGC)—usually 0.60 or higher—to maximize heat gain, a low U-factor (0.35 or less) to reduce conductive heat transfer, and a high visible transmittance (VT) for good visible light transfer. SHGC refers to the portion of incident sunlight admitted through a window, and U-factor indicates the heat loss rate for the window assembly.

In cooling climates, particularly effective strategies include preferential use of north-facing windows along with generously shaded south-facing windows. Shading from landscaping, overhangs, shutters, and solar window screens helps lower heat gain on windows that receive full sun.

WINDOW RATINGS

Many windows include a National Fenestration Rating Council sticker that lists U-factors, SHGC, and VT.


National Fenestration Rating Council
INCORPORATED

Certified

AAA Window Company

Energy Rating Factors	Ratings: Residential	Ratings: Nonresidential	Product Description
U-factor (Determined in accordance with NFRC 100)	0.40	0.38	Model 1000 Casement Low-e Argon Filled
Solar Heat Gain Coefficient (Determined in accordance with NFRC 200)	0.65	0.66	
Visible Transmittance (Determined in accordance with NFRC 200)	0.71	0.71	

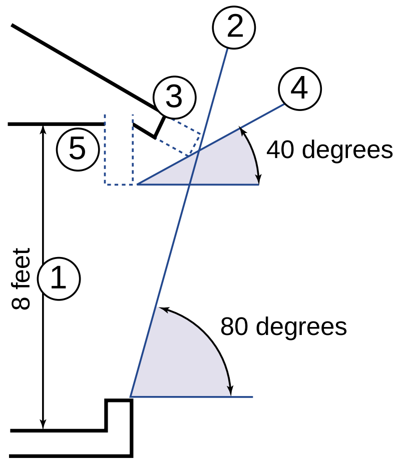
NFRC ratings are determined for a fixed set of environmental conditions and specific product sizes and may not be appropriate for directly determining seasonal energy performance. For additional information contact:

Cost effective windows for cooling climates have a U-factor below 0.4 and a SHGC below 0.55 (a lower SHGC cuts cooling costs).

Wherever possible, climate-specific window property recommendations from the Efficient Windows Collaborative should be followed.

- ✓ **Suntempering.** In cold climates, a strategy termed “suntempering” orients most of the home’s glazing toward the south—a glazing area of up to 7 percent of the building floor area. Additional south-facing glazing may be included if more thermal mass is built in. Such a shift in window location is a great strategy for cold climates and costs nothing beyond good planning. Many passive solar homes are merely suntempered.

SIZE SOUTH FACING OVERHANGS TO PROPERLY SHADE WINDOWS



OVERHANG SIZING RULES:

1. Draw the wall to be shaded to scale.
2. Draw the summer sun angle upward from the bottom of the glazing.
3. Draw the overhang until it intersects the summer sun angle line.
4. Draw the line at the winter sun angle from the bottom edge of the overhang to the wall.
5. Use a solid wall above the line where the winter sun hits. The portion of the wall below that line should be glazed.

- ✓ **Shading.** The summer sun rises higher overhead than the winter sun. Properly sized window overhangs or awnings are an effective option to optimize southerly solar heat gain and shading. They shade windows from the summer sun and, in the winter when the sun is lower in the sky, permit sunlight to pass through the window to warm the interior. Landscaping helps shade south-, east-, or west-facing windows from summer heat gain. Mature deciduous trees permit most winter sunlight (60 percent or more) to pass through while providing dappled shade throughout summer.

- ✓ **Heat Storage.** *Thermal mass*, or materials used to store heat, is an integral part of most passive solar design. Materials such as concrete, masonry, wallboard, and even water absorb heat during sunlit days and slowly release it as temperatures drop. This dampens the effects of outside air temperature changes and moderates indoor temperatures. Although even overcast skies provide solar heating, long periods of little sunshine often require a back-up heat source. Optimum mass-to-glass ratios, depending on climate, may be used to prevent over-heating and minimize energy consumption (*The Sun’s Joules*, http://solstice.crest.org/renewables/SJ/passive-solar/136.html). Avoid coverings such as carpet that inhibit thermal mass absorption and transfer.

- ✓ **Natural Cooling.** Apt use of outdoor air often can cool a home without need for mechanical cooling, especially when effective shading, insulation, window selection, and other means already reduce the cooling load. In many climates, opening windows at night to flush the house with cooler outdoor air and then closing windows and shades by day can greatly reduce the need for supplemental cooling. Cross-ventilation techniques capture cooling, flow-through breezes. Exhausting naturally rising warmer air through upper-level openings (stack effect; e.g., clerestory windows) or fans (e.g., whole-house fan) encourages lower-level openings to admit cooler, refreshing, replacement air.

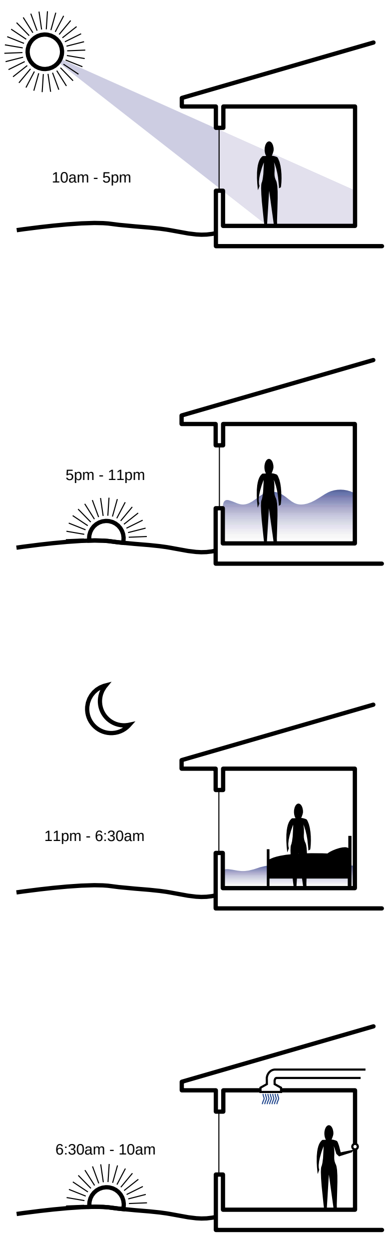
- ✓ **Natural Lighting.** Sometimes called daylighting, natural lighting refers to reliance on sunlight for daytime interior lighting. Glazing characteristics include high-VT glazing on the east, west, and north facades combined with large, south-facing window areas. A daylit room requires, as a general rule, at least 5 percent of the room floor area in glazing. Low-emissivity (low-E) coatings can help minimize glare while offering appropriate improved climatic heat gain or loss characteristics. Sloped or horizontal glass (e.g., skylights) admit light but are often problematic because of unwanted seasonal overheating, radiant heat loss, and assorted other problems.

PASSIVE SOLAR DESIGN

PASSIVE SOLAR DESIGN TOOLS

One of the best ways to design an energy-efficient house featuring passive solar techniques is to use a computer simulation program. Energy-10 is a PC-based design tool that helps identify the best combination of energy-efficient strategies, including daylighting, passive solar heating, and high-efficiency mechanical systems. Another tool to optimize window area and aid window selection is RESFEN. Access these and other passive solar design tools from the DOE's Office of Building Technology, State, and Community Program's website.

THERMAL MASS IN THE HEATING SEASON



10:00 am to 5:00 pm

Sunlight enters south-facing windows and strikes the thermal mass inside the home. The sunlight is converted to heat energy, which heats both the air and thermal mass materials. On most sunny days, solar heat maintains comfort during the mid-morning to late afternoon periods.

5:00 pm to 11:00 pm

As the sun sets, it stops supplying heat to the home. However, a substantial amount of heat has been stored in the thermal mass. These materials release the heat slowly into the passive solar rooms, keeping them comfortable on most winter evenings. If temperatures fall below the comfort level, supplemental heat is needed.

11:00 pm to 6:30 am

The home owner sets the thermostat back at night, so only minimal back-up heating is needed. Energy-efficient features in the home minimize heat losses to the outside.

6:30 am to 10:00 am

The cool early morning hours are the toughest for passive solar heating systems to provide comfort. The thermal mass has usually given up most of its heat, and the sun has not risen enough to begin heating the home. During this period, the home owner may have to rely on supplemental heat. Energy-efficient features in the home minimize the need for supplemental heating.

For more information, contact:

Energy Efficiency and Renewable Energy Clearinghouse (EREC)
1-800-DOE-3732
www.eren.doe.gov

Or visit the BTS Web site at www.eren.doe.gov/buildings

Or visit the Sustainable Buildings Industry Council Web site at www.sbicouncil.org

Or visit the Efficient Window Collaborative Web site at www.efficientwindows.org

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Factsheets on insulation are available from the Energy Efficiency and Renewable Energy Clearinghouse (EREC) 1-800-DOE-3732 www.eren.doe.gov

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