

PASSIVE SOLAR HEATING DESIGN FOR THE SOUTHEAST

North Carolina **Solar Center**

Passive Solar Heating

In the southeast, there exist many climate zones where heating needs are low to minimal. If designed properly, a passive solar heating system can provide most of a home's heating needs for much of the heating season. Because the sun is the main source of heat, a passive solar home includes four features that distinguish it from a conventionally heated home:

- ◆ A method to collect solar energy;
- ◆ A way of storing that energy;
- ◆ A system to distribute heat to the living spaces; and
- ◆ A means for controlling the heat that reaches living spaces.

A passive solar home should always be built to meet high energy conservation standards for the region in which it is built. Carefully planning and designing a home to balance the glass and thermal mass storage areas is crucial in the southeast. Otherwise, the house may overheat, underheat, or have undesirable temperature swings.

Passive Solar Benefits

Good passive solar homes are not difficult to design or expensive to build. However, they do require the use of basic, common-sense methods of working with the climate rather than against it. When building a passive solar home that responds well to the climate in which it is built, count on it being:

- ◆ **Attractive & Healthy** – full of light and well connected to the outdoors, providing a healthy space for people;
- ◆ **Comfortable** – warm in the winter and cool in the summer;
- ◆ **Durable** – often built from locally available, long-lasting, low-maintenance materials;
- ◆ **Economical** – homeowners receive a positive cash flow or excellent return on their investment; and
- ◆ **Environmentally Responsible** – passive solar homes make efficient use of energy resources.

Passive Solar Questionnaire

Passive solar concepts are not difficult to apply, but require consideration from the early stages of design to be cost effective and perform well. These questions are presented as a preliminary planning tool.

Is this a good site for a passive solar home?

- ◆ Is the site clear of potential sun blockers on the south side, such as evergreen trees or buildings which would interfere with solar energy collection?
- ◆ Are there thick evergreens to the west to provide summer shading and block winter wind?
- ◆ Are there deciduous trees to the north and east that will shade the ground surrounding the house in summer yet allow the sun to warm it in the winter?
- ◆ Are there wind blocks for the prevailing winter winds? In the southeast, winter winds dominate from the southwest; however, local microclimates can create a large variation in wind speed and direction.

- ◆ Does the south side offer a pleasing view?
- ◆ Will adjacent property be developed in such a way that it will block the sun in the future?

The southern orientation of a house can vary by up to 30° from true south without significantly harming its heating season performance; however, because *such a large variance could seriously reduce the house's cooling performance*, it is recommended that the house's orientation should not vary by more than 15° either to the east or west of true south.

Is the House Plan Designed for Passive Solar?

- ◆ Is the house plan custom or can a standard plan be adapted to implement passive solar strategies?
- ◆ Extensive modifications, to an existing plan, including changes to the shape of the house or changing a large number of windows may be necessary.
- ◆ Is the chosen home plan designed for a hot humid or mixed humid climate? Insulation, heating requirements, and the design of south-facing overhangs for summer shading will vary throughout the southeast.
- ◆ As with any home buying or building project, expect to spend preliminary time looking at passive solar homes, comparing features, reading about solar, and talking with those who have solar design or building experience.

Are Experts Available?

- ◆ Does the project include experienced passive solar designers and builders? It takes real expertise to design a home that is livable, attractive, and performs well. Using a contractor who has built a passive solar and/or energy efficient home before can cost more but save time and increase quality, thus reducing operation and maintenance costs.
- ◆ Is education available locally or regionally? For the homeowner who wants to act as designer and/or builder, check with a lending agency first to determine requirements. Check local/state codes and ordinances.

Passive Solar Heating Expectations

- ◆ Passive solar heating systems can contribute 30 to 70 percent of home's heating demands, depending upon the design. The North Carolina NCSU Solar Demonstration-House, located in a mixed humid climate, creates about 70 percent of its heat using passive solar heating strategies.
- ◆ Different designs require varying degrees of interaction—from seasonal shading which needs to be added or removed twice a year, to movable insulation which needs to be adjusted twice daily. Choose a design that requires a level of interaction that is appropriate.
- ◆ Check with the Database of State Incentives for Renewable Energy (www.dsire.usa.org) for details concerning federal, state and local energy efficiency incentives. Many incentives may not be called passive solar but encourage techniques that are supportive of passive solar design strategies.

Energy Conservation First!

The passive solar home should be built with maximum attention to energy conservation details, including insulation, air sealing and energy efficient appliances. If a structure isn't energy-efficient to begin with, proper passive solar design will require the addition of energy efficiency strategies to create a comfortable environment and to avoid adding a good deal of supplemental heat.

Any well-insulated and weatherized house needs proper ventilation and fresh air to reduce problems from indoor air pollution and help control humidity inside the house. Humidity in the home is a critical indoor air quality issue for most of the southeast. Bathrooms and kitchens should have outside vented exhaust systems. See the NC Solar Center fact sheet *Build a High Performance House, Earn Tax Credits* for extensive additional information on this topic.

Window technology has improved greatly in recent years; recommendations include:

- ◆**North windows:** Use windows with a glass area of 5-8 percent of the floor area. This provides additional, low glare light with little heat gain, helping replace the use of electrical lighting.
- ◆**East windows:** Eastern and western windows generally don't add much to winter net heat gain, and will add to overheating problems in the summer. Use windows with a glass area of 0-4 percent of the floor area, depending on climate and building exposure.
- ◆**West windows:** Use windows with a glass area of 0-3 percent of the floor area, depending on climate and building exposure.

Passive Solar Design Checklist

This checklist is intended to provide the owner, designer and builder with a simple checklist of the basic requirements of a passive solar design. Although the focus of this checklist is on passive solar heating, some elements of passive solar cooling design are incorporated in order to prevent overheating in the southeast and because some passive design elements are common to both heating and cooling strategies. References to other, more complete resources are included at the end of the factsheet.

1. Proper Home Orientation

The longest wall of the home should face within 15 degrees of true south to receive plenty of winter solar heat gain and adequate summer shade. At 30 degrees east or west of south, winter heat gain is reduced by 15 percent from the optimum. Also, minimizing east and west facing walls and windows reduces excessive summer heat gain. For an existing home, it is possible to implement a reasonable passive solar heating strategy if the home faces within 20 degrees of true south.

Consider vegetation and other surrounding structures; *deciduous tree branches may allow enough sunlight in on the east and north side of the home but will block the collection of sun on the south side.* Consider the slope of the land; a north facing slope may shade a home during the winter, while a south facing slope may expose a home to desired winter heat gain.

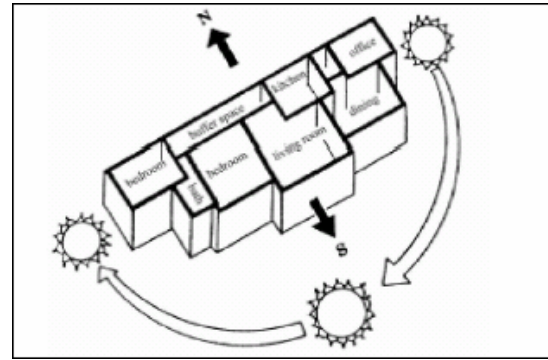


Figure 1. Longest wall should face south. Expose south facing rooms as appropriate for more or less sun exposure based on the use of the room.

2. Size south-facing windows and thermal mass appropriately.

Passive solar designs should include only vertical glass. Sloped glazing, which is any glass installed at a slope of 15 degrees or more from vertical, can cause serious overheating.

◆**Suntempered** homes with no internal solar thermal mass should have south facing windows with a glass area of between 5 and 7 percent of the floor area.

◆**Direct gain systems** can have south-facing window glass area which is 7-12 percent of the floor area. Every 1 square foot of south-facing glass over the 7 percent suntempering allowance must be accompanied by 6 square feet of 4-inch-thick horizontal masonry that directly receives sunlight and/or 40 square feet of 4-inch-thick horizontal masonry that does not directly receive sunlight and/or proportionately sized vertical masonry surfaces (thickness dependent on placement).

◆**Sunspaces** require a dedicated passive solar room and, in the southeast, are more expensive to create and should always be designed by a professional due to the potential for overheating. Sunspace design is not described in this fact sheet.

3. Match the solar heating system to the room use

Passive solar homes take advantage of winter solar gain by locating windows mainly on the south side of the house. A logical design is to have the home laid out as a rectangle, with the long axis running east-west, so that the long side of the house faces south (see *Figure 1*).

Rooms should be arranged inside the house to take advantage of the sun's path and match solar gain to the time of the day the room is used. For example, kitchens and dining rooms are natural choices for the east or southeastern portion of the plan. The rooms benefit from early morning sun but are protected by the rest of the house from the afternoon sun.

What are the heating, lighting, and privacy needs of a bedroom before and after sunset? A bedroom may benefit from being placed on the north or northeast corner. A living room, often needs daytime and early evening heat, has a higher lighting requirement, and might benefit from a direct gain passive solar

heating strategy when it is placed on the south side of a home.

Where comfort is not as critical, rooms can be placed on the west sides of the house. Areas which aren't consistently occupied, such as utility rooms, closets, hallways, stairs, and even the garage are good choices. They buffer the living space from cold winter winds and the hot, late afternoon sun in the summer.

3. Size overhangs properly (see figure 2)

As a rule of thumb to prevent summer gains, the angle " α " between a line "S" from edge of the overhang to the bottom of the window and a vertical line "V" should be approximately equal to the latitude minus 18.5 degrees. To prevent winter shading, the angle " β " between a line "W" from the edge of the overhang to the top of the window and a vertical line should be approximately equal to the latitude plus 18.5 degrees. An overhang designed with this formula will provide shade all summer and full sun in the coldest part of the winter (Figures 1 and 2). For more detailed calculations, use computer simulation software.

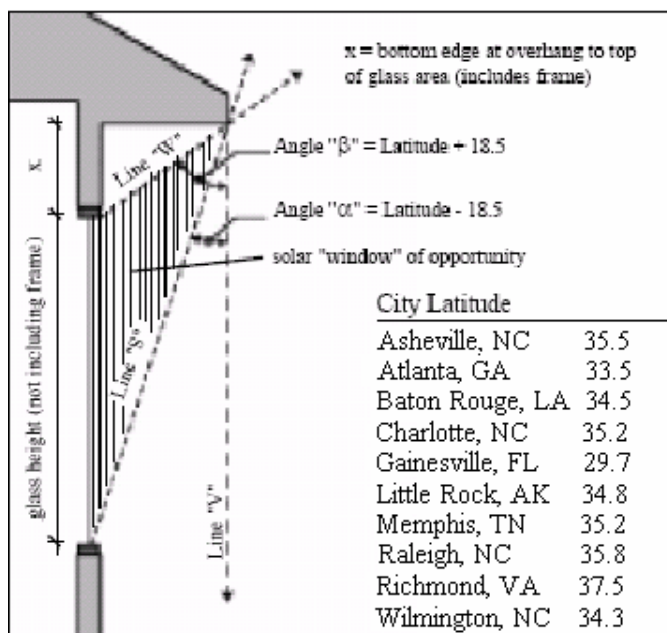


Figure 2. Diagram for sizing overhang

5. Choose & locate materials appropriately

Lightweight materials should be lighter in color; lighter colors absorb less energy (sunlight) and are more reflective. Light colored, lightweight materials "bounce" the sun to more massive materials as long as they are in a room with lots of sun. On the other hand, heavy materials absorb light energy and transform it into heat energy. This is known as *thermal mass*. If the material has insufficient thermal storage capacity, the material may heat quickly and release excess heat into the air, causing overheating.

Masonry walls, an example of thermal mass, can be any color in a direct gain system, but the best choice are colors in the middle range of the absorptivity scale to diffuse the solar energy over all the storage mass in the room. (The absorptivity range of

concrete masonry falls in this range without paints or special treatment being necessary).

Colors for dense thermal mass materials such as brick and concrete, need to be somewhat darker than lighter weight materials; however, if the thermal mass is too dark, surfaces exposed to the direct rays of the sun will soon reach high temperatures. This can lead to overheating of the room's air.

It is wise to plan in advance to match the system to room use. For direct gain systems, performance is fairly insensitive to the locations of thermal mass in a room. It is relatively the same whether the mass is located on the floor or on the east, west, or north walls. Comfort is improved if the mass is distributed evenly in the room because the increased surface area reduces localized hot or cold spots. Also, vertical mass surfaces not in direct sunlight can reduce temperature swings by absorbing excess heat in the air.

It is important to put some mass in direct sun, but rarely is it possible to expose all the required thermal mass because of furniture and floor coverings. Furniture should not cover all of the thermal mass area. Rugs and wall tapestries can also reduce the effect of thermal mass.

6. Retain & Distribute heat

Winter night heat loss and summer heat gain from all windows can be reduced by the use of *movable insulation*, either inside or outside the house. For south facing windows, R-9 moveable insulation (provided by exterior-mounted panels, interior draperies, shutters, or pop-in panels) over windows provides an increase of approximately 20 to 30% in annual heating performance over passive solar heating systems without moveable insulation. This strategy works best when it is motorized and installed on the exterior, however many passive heating and cooling systems do not utilize this strategy due to the increased owner interaction necessary to achieve reasonable benefit.

Another owner occupant device is the ceiling fan. This is a much more common fixture in southeastern US homes and can be used both to distribute heat radiated from thermal mass in the winter and to cool occupants by 2-5 degrees in the summer. Other minor distribution elements can include transfer ducts between rooms which allow the free flow of air. For more information on these systems, see the NC Solar Center fact sheet *Build a High Performance House, Earn Tax Credits*.

Once these preliminary design issues are addressed, it is time to consider the finer details of a direct gain system.

DIRECT GAIN HEATING SYSTEMS

The passive solar system is part of the house itself. It doesn't require external power, and there are no or few moving parts to break down. Standard building materials can be used. Sometimes active and passive components are combined to improve distribution of the heat. The active parts are usually small fans, blowers, or dampers.

Sunt tempered design is the basis of not only passive solar heating systems but typical energy efficient designs. These systems are quite simple because they have a good amount of glass to provide light and warm a room during daylight hours, but not enough to collect extra light energy to provide heat after

the sunset. Therefore, these systems do not need thermal mass, unlike direct gain passive solar heating systems which require thermal mass to function properly

In a *direct gain passive solar heating* system, sunlight enters the house through large areas of south-facing glass, known as *collectors*. The sunlight heats the floor and walls directly; in the floor and sometimes the walls, *thermal mass* is appropriately distributed. When the inside air temperature is lower than that of the thermal mass, heat energy from the thermal mass is released (radiated) into the surrounding room's air. When air distribution throughout the home is even, the air temperature throughout the house can rise (in winter) or fall (in summer) due to this intelligent use of the natural properties of energy and materials.

The amount of south-facing glass and thermal storage mass should be balanced. If the windows collect more heat than the floor or walls can absorb, overheating occurs. Since the direct gain system is part of the living space, this can be uncomfortable for those living in the house. Shading is necessary to reduce heat gain in the summer. Overhangs, awnings, trellises, louvers, and movable insulation are some choices. Most designers recommend exterior shading rather than interior shading because exterior screens and other devices stop heat before it gets into the house.

With the direct gain system, the thermal mass may be thinner and more widely distributed in the living space but should not be less than 2" thick. This allows an even distribution of heat throughout the room or rooms. Clerestory windows are sometimes used to increase the amount of sunlight hitting the back area of walls or floors. They can help improve the performance of the direct gain system. Skylights should be used sparingly as they tend to create overheating problems in the summer and lose heat in the winter. If skylights are used, it is important to install them so that they directly heat properly sized thermal mass.

Advantages of the Direct Gain System:

- ◆ It is comparatively low in cost to build, since no special room has to be added. The floor, walls, or even an inside wall fireplace can serve as the storage mass.
- ◆ It provides direct heating. There is no need to transfer energy from one area to another.
- ◆ South-facing windows provide natural daylight and views.
- ◆ The number and size of south-facing windows can be adjusted to match the space you have for thermal mass. Clerestory windows can direct sunlight on the back parts of floors or walls used as thermal mass.

Disadvantages of the Direct Gain System:

- ◆ Overheating occurs if the windows and thermal mass are not properly sized and located.
- ◆ Large amounts of south-facing glass can cause problems with glare and privacy if not well designed
- ◆ The thermal mass used for heat storage should not be covered by carpet or blocked by furnishings. Furnishings and fabrics exposed to ultraviolet radiation from the sun can degrade or change color.

REFERENCES

The following publications provide further information on passive solar energy. This list is not exhaustive; inclusion does not imply endorsement by the North Carolina Solar Center, nor does omission of similar materials imply criticism.

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Solar Control and Shading Devices; and Design with Climate. Aladar Olgyay, Victor Olgyay, www.amazon.com, 1976.

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Sunbook, 2nd. ed., Energy Division, NC Department of Commerce, Raleigh, NC 1999. (Available from the NC Solar Center website)

NATIONAL AND STATE RESOURCES

American Solar Energy Society
Boulder, CO
(303) 443-3130
www.ases.org

US DOE-Energy Efficiency and Renewable Energy
Merrifield, VA
www.eere.energy.gov
Florida Solar Energy Center
University of Central Florida
Cocoa, FL
(407) 638-1000
www.fsec.ucf.edu

National Renewable Energy Laboratory (NREL)
Golden, CO
(303) 275-3000
www.nrel.gov

North Carolina Solar Center
Raleigh, NC
(919) 515-3480
www.ncsc.ncsu.edu

Sustainable Building Industries Council
Washington, D.C.
(202) 628-7400
www.sbicouncil.org

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