NORTH CAROLINA
SOLAR CENTER

SOLAR CENTER INFORMATION

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# Passive Solar Options

## For North Carolina Homes

If you're planning to build or buy a new home, you may be considering passive solar design. A passive solar home has four features that distinguish it from a conventionally heated one.

Since the sun is the primary source of heat, a passive solar design includes:

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

The passive solar home should always be built to high energy conservation standards. Also, it must be carefully planned and designed to balance the glass area and the storage mass. Otherwise, the house may overheat, underheat, or have undesirable temperature swings. Without proper planning, your passive solar home could end up using more energy than it collects.

Before you buy or build a passive solar home, you need to ask some questions.

### Do you have a good site for a solar home?

- Is your site clear of potential sunblockers 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 winter windblock?
- 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 winter?
- Are there windblocks for the prevailing southwest winter winds? This can be done by low evergreens, or taller evergreens located at such a distance to the southwest that they do not block the prime winter collection zone to the south.
- Does the south side offer a pleasing view? Most of your window area will face this direction.
- Will adjacent property be developed in such a way that it will block the sun at a later time?

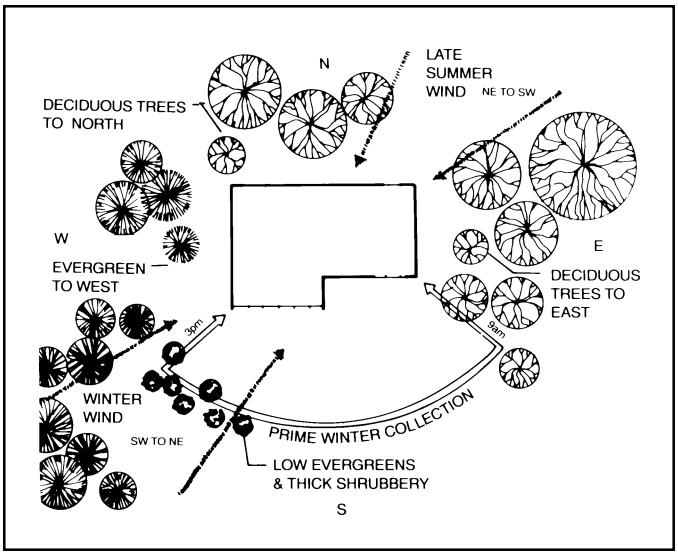


**Figure 1. The ideal site offers summer shading, winter windblock, and a clear solar collection zone to the south.**

### Which house plan will you use?

- Is your plan designed for solar, or do you want to adapt a standard plan?
- Extensive modifications, such as changing the shape of the house, adding a second story, or changing a large number of windows may make your home more expensive to build. These changes may also make it harder to balance the solar elements.
- If you've picked a passive solar house plan, is it designed for North Carolina? Insulation, heating requirements, and the amount of south-facing overhang for summer shading will vary throughout the United States. Try to start with a plan suited to North Carolina's geography and climate.
- Are you willing 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?

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### Do you have expert help?

- Do you have an architect or qualified designer to draw a solar plan? It takes real expertise to design a home that is livable, attractive, and performs well.
- If you plan to design your own home, will you be able to balance the solar elements? If you're drawing your own plan, check with your local lending agency first to determine their requirements. You will also want to check local codes and ordinances.
- Do you know of a builder or contractor with experience building passive solar homes? This could affect construction time, costs, and even how well the system performs.

### What do you expect from the solar system?

- Do you have realistic expectations for the solar home you have chosen? Passive solar systems can contribute 30 to 70 percent of home heating demands, depending upon the design. The North Carolina State University Solar Demonstration House gets about 70 percent of its heat from its passive solar systems.

### Will your lifestyle accommodate a passive solar home?

- How willing are you to adapt your family's lifestyle to get the most performance from your passive solar home? 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 or more daily. Choose a design that requires a level of interaction that you will be comfortable with the entire time you plan to live in the house.

### What about tax credits?

- Are you aware that North Carolina offers a 35 percent tax credit (up to a maximum credit of $3500) for residential passive or active solar energy heating systems? For commercial buildings, there is also a 35 percent tax credit available (up to a maximum credit of $250,000). Check with the North Carolina Department of Revenue or the North Carolina Solar Center for details on eligibility requirements.

## ACTIVE VS. PASSIVE SOLAR

Active solar systems usually collect the sun's energy with large panels through which air or a liquid are pumped. Solar energy heats the air or liquid, which is pumped into a storage area and then recirculated to the panels.

The stored heat is recovered by a heat exchanger and distributed to areas in the house by a mechanical system.

In recent years, active systems have most frequently been used for the heating of domestic water. They can also be used in new construction or for retrofit applications when they are added to an existing house for space or water heating. Solar water heating systems, which require regular maintenance, are eligible for a 35% tax credit up to a maximum of $1400 for residences and $250,000 for business and industry.

Passive solar systems have collector, storage, and distribution elements, but they don't use a mechanical system of panels, pumps, and heat exchangers. Southfacing windows collect solar energy. The floors and walls can be used to store the heat. Distribution into the living space occurs naturally by radiation, convection, and conduction.

The passive solar system is part of the house itself. It doesn't require external power, and there are no 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 result is a hybrid system. The active parts are usually small fans, blowers, or dampers.

## PASSIVE SOLAR SYSTEMS

All passive solar homes have these common elements:

- **Collection—**To collect solar energy, double-glazed windows are used on the south-facing side of the house.
- **Storage—**After the sun's energy has been collected, some heat is immediately used in the living spaces and some is stored for later use. The storage, called thermal mass, is usually built into the floors and/or interior walls. Mass is characterized by its ability to absorb heat, store it, and release it slowly as the temperature inside the house falls. Concrete, stone, brick, and water can be used as mass.
- **Distribution—**Heat stored in floors and walls is slowly released by radiation, convection and conduction. In a hybrid system, fans, vents, and blowers may be used to distribute the heat.

There are several types of passive solar systems that can be used in North Carolina homes. The most common are direct gain, indirect gain, and isolated gain.

## DIRECT GAIN

Direct gain is the simplest approach and usually the most economical to build. With this system, sunlight enters the house through large areas of south-facing glass. It heats the floor and walls directly.

Energy from the mass in floors and walls is released to the living space when the inside air temperature is lower than that of the mass.

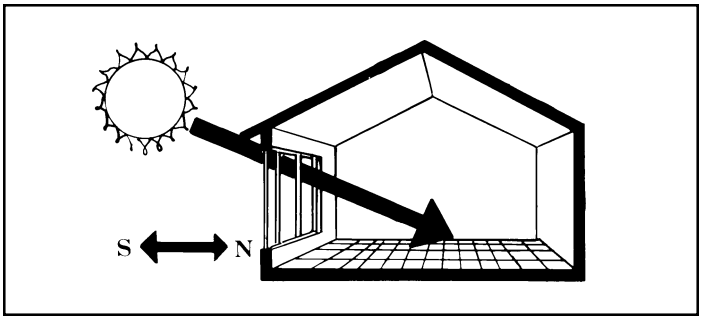


**Figure 2. Direct gain solar system.**

Clerestory windows and skylights 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, however, tend to create overheating problems in the summer and may leak if improperly installed.

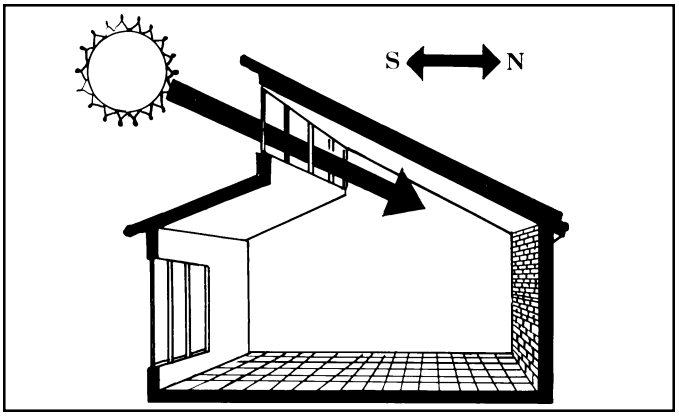


**Figure 3. Clerestory windows in a direct gain system let sunlight strike the thermal mass on the back wall.**

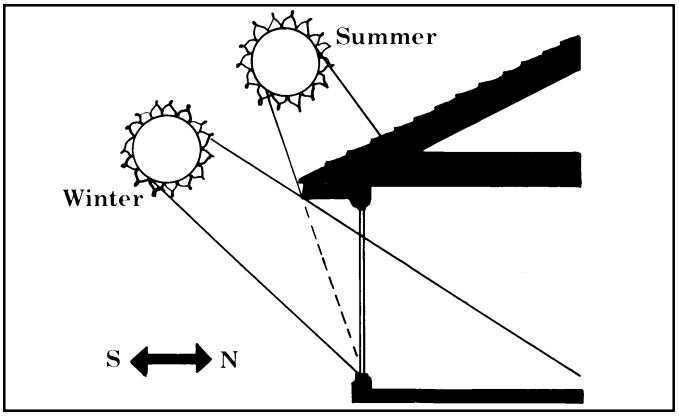


**Figure 4. The overhang lets in the winter sun while shading southfacing glass in the summer.**

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 needed to reduce heat gain in the summer. Overhangs, awnings, trellises, louvers, solar screens, 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 storage mass may be thinner and more widely distributed in the living space than with other passive systems. This allows an even distribution of heat throughout the room or rooms, but requires some thought about how the living space will be used. Don't cover the thermal storage mass with carpet or other materials that will reduce its storage capacity. Select and arrange furnishings carefully so they don't interfere with solar collection, storage, and distribution.

## 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. The solar elements are incorporated into the living space.
- It provides direct heating. There is no need to transfer energy from one area to another.
- South-facing windows provide natural daylight and outdoor views.
- The number and size of south-facing windows can be adjusted to match the space you have for thermal mass. Clerestory windows can let sunlight fall directly on the back parts of floors or walls used as thermal mass.

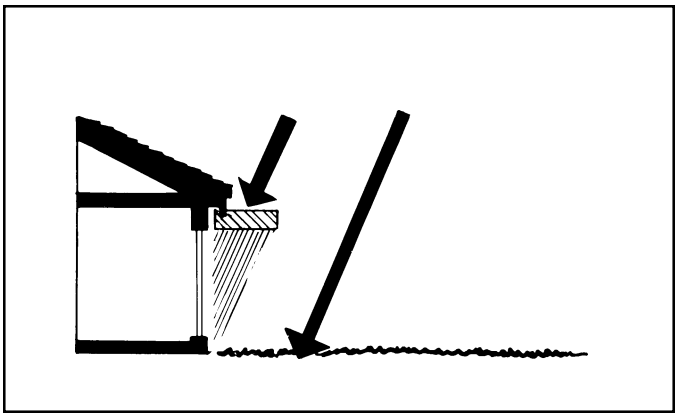

**Figure 5. Louvered panels can provide shading if the overhang is insufficient.**

## Disadvantages of the Direct Gain System:

- It can overheat if the windows and thermal mass are not balanced.
- Large amounts of south-facing glass can cause problems with glare and privacy.
- 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.
- South-facing windows need summer shading and a night-time insulative covering in winter. Nighttime insulation can be provided by exterior-mounted panels, interior draperies, shutters, pop-in panels, or other insulating window treatments.

Window insulation is especially important for direct gain systems. The thermal storage is usually not as thick as with other systems, and heat will be lost quickly through uncovered windows.

## INDIRECT GAIN

In this passive solar system, the storage mass is between the south glass and the living space.

Indirect gain systems use a thermal wall to store collected heat. Usual choices are a masonry Trombe wall or a water wall of tubes or barrels placed several inches behind the window.

The concrete block or brick Trombe wall is usually 8 to 12 inches thick. In comparison, direct gain mass is usually just 4 to 6 inches thick but is spread out over a larger area.

During the day, sunlight passes through the south-facing glass and is absorbed by the mass. The mass heats up slowly and then releases heat to the living spaces 6 to 8 hours later. The time lag as the mass warms and then gives off heat keeps temperatures in the living space fairly uniform. It also means that the heating of the living area occurs in the late afternoon and evening, when it is most needed.

The Trombe wall can be vented or unvented. The vented wall allows heated air to circulate directly to the living space. Stored heat in the thermal mass is also radiated later to the

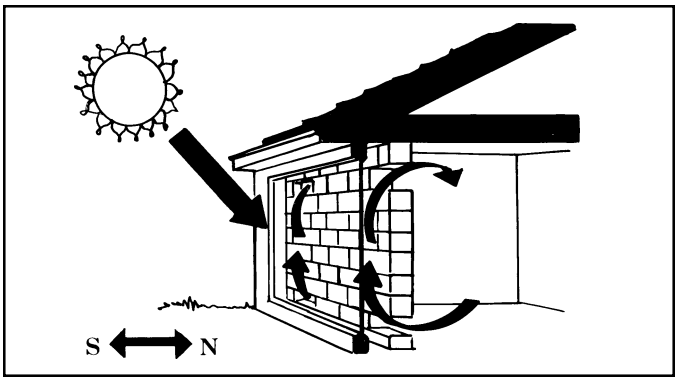


**Figure 6. Trombe wall vents circulate heated air to the living space in the daytime. The vents are closed at night to prevent reverse cycling of heated air.**

living space. A vented Trombe wall requires nighttime closing of wall vents. Otherwise, heated air would cycle back to the front of the Trombe wall from the living space and be lost to the cooler temperatures outside. Because of the difficulty in assuring the proper opening and closing of vents, venting of Trombe walls has been used less frequently in recent years.

As with all passive solar designs, the Trombe wall should be shaded on the outside during the summer and insulated at night during the winter. Although research shows that a Trombe wall gains more heat during the day than it loses during the night, moveable insulation over the Trombe wall will improve its efficiency. In most cases, this means installing insulated panels or shutters on the outside. Of course, these insulating panels are effective only if used regularly.

### Advantages of an Indirect Gain System:

- The storage mass is located closer to the glass or collection area, which allows for efficient collection of solar energy.
- The thickness and heat storage capacity of the thermal mass lets it heat up slowly and distribute the heat to the living space when it is most needed. Extreme temperature variations in the living area are reduced.
- The floor and wall space of the living area can be used more flexibly since the storage mass is moved next to the south-facing glass. This frees up interior floor space and also doesn't expose furnishings to direct sunlight.

### Disadvantages of an Indirect Gain System:

- The south-facing view and natural daylight is lost. Some Trombe walls have been designed with a window set into the wall to compensate for this. If properly designed, an inset window should not interfere with the efficiency of the system.
- Vented Trombe walls must be closed at night to prevent reverse cycling of heated air. The inside of the south-facing glass in a vented Trombe wall will also need to be cleaned from time to time, so access to the glass needs to be considered.
- The Trombe wall may take up too much wall space in a smaller home.
- Furniture and objects placed against or on the Trombe wall affect its efficiency in heating the living space.
- Because the Trombe wall heats only the room it is connected to, the cost of labor and materials in its construction may be high relative to the contribution it makes to the overall heating needs of the house.
- In the summer or on winter days without sunshine, the Trombe wall acts as a very poorly insulated wall. Exterior moveable insulation would improve its effect on comfort and energy use.

## ISOLATED GAIN

You may have heard of this system called an "attached sunspace" or "attached greenhouse." This system is usually designed so that the collector and storage elements can be closed off from the rest of the house during periods of extreme heat or cold.

Typically, the sunspace is a separate room on the south side of the house with a large glass area and thermal storage mass. The sunspace can project out from the house, or the house can wrap around the sunspace, partially enclosing it (Figure 8).

A U-shaped wrap-around design is used in the NCSU Solar House. It reduces heat loss from the sunspace area and allows more storage mass to be located in the sunspace. Heat from the sunspace can be distributed into the house through all three side walls.

If the sunspace is to serve as the primary heating system, you will probably want a design that is thermally isolated from the living area. This means that the sunspace can be closed off from the rest of the house by shutting the doors and windows that connect the two areas.

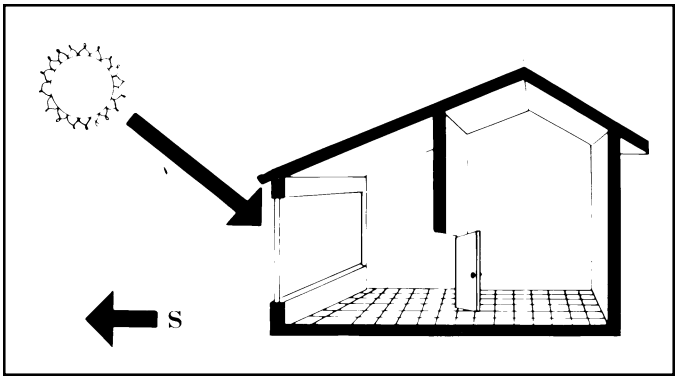


**Figure 7. An isolated gain system, or sunspace, can be closed off from the rest of the house.**

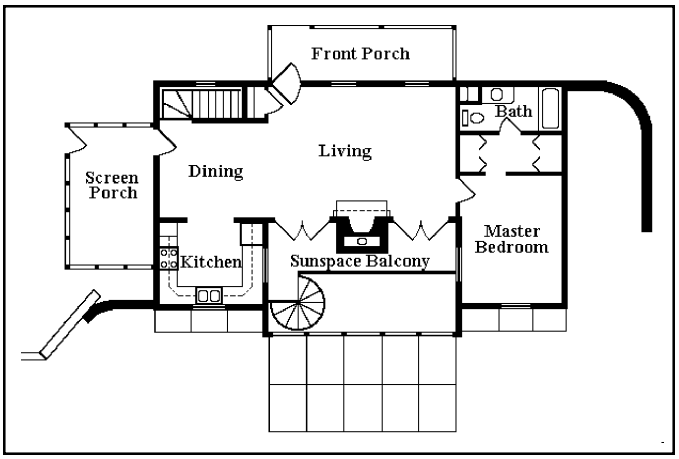


**Figure 8. The NCSU Solar House has a sunspace enclosed on three sides. Windows and doors can let heat into or keep heat out of the living spaces.**

The isolated gain design of the sunspace provides a buffer wall between the house and the sunspace. This reduces temperature fluctuations inside the house. The buffer wall can serve as heat storage mass absorbing and giving off heat like a Trombe wall. The floor is also ideal for heat storage, provided it isn't covered by an insulative material like carpet or by large pieces of furniture.

Because of the large glass area, the sunspace must be protected from summer overheating. The NCSU Solar House uses a combination of permanent roof overhangs and seasonal, drop-in louvers to shade its two-story sunspace. Awning windows at the base of the sunspace provide ventilation and help reduce summer heat gain.

With North Carolina's long, hot summers, many solar designers recommend the use of only vertical glass in sunspaces. Sloped glass can add to the potential for overheating and may be more difficult to cover with movable insulation or to shade. It may also leak.

When the sunspace is designed with sufficient mass, it can provide thermal performance better than that of Trombe walls and direct gain. It can also become one of the most popular areas of the house.

### Advantages of the Sunspace, or Isolated Gain, System:

- It can be physically separated from the living space. This means that temperature fluctuations within the sunspace do not adversely affect the comfort of the living area.
- Doors and windows between the sunspace and the rest of the house allow control of the heat transfer between these areas. The sunspace can be closed off when equipment is used to heat or cool the rest of the house.
- Due to their energy savings, attractiveness, and the appeal of having a warm sunny room on a cold winter day, sunspaces increase the resale value of a home.

### Disadvantages of the Sunspace, or Isolated Gain, System:

- Heavy furnishings and rugs must be avoided to prevent shading of the thermal storage mass.
- Shading and venting are important to avoid summertime overheating.

## ROOM LAYOUT

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.

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. The family room, living room, and bedrooms lend themselves to a south or southwestern location, where they will be warmed by the afternoon sun for evening use.

Where comfort is not as critical, rooms can be placed on the west and north 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.

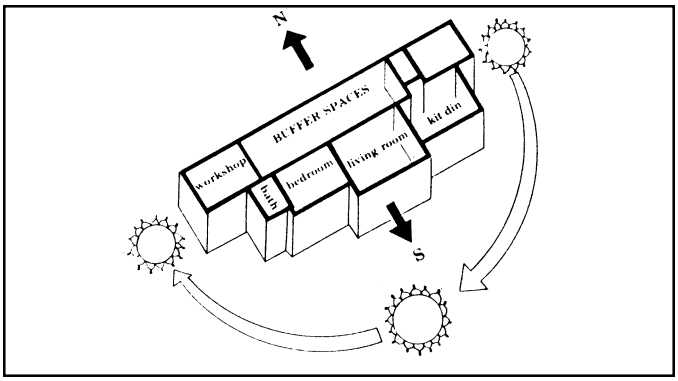


**Figure 9. The floor plan should be designed so that living spaces are compatible with the sun's path.**

## ACCESS TO THE SUN

In planning or buying any new house, especially a passive solar house, proper orientation to the sun and access to its solar energy are important. Placing the house on the northernmost part of the lot will help with winter solar gain and reduce winter shading from buildings and trees on lots to the south.

If it is not possible to locate the south-facing wall directly south on the site, a passive solar system can still be effective. The southern orientation of the house could vary by up to $30^0$ from true south without significantly harming its heating season performance, but 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 $15^0$ either to the east or west of true south.

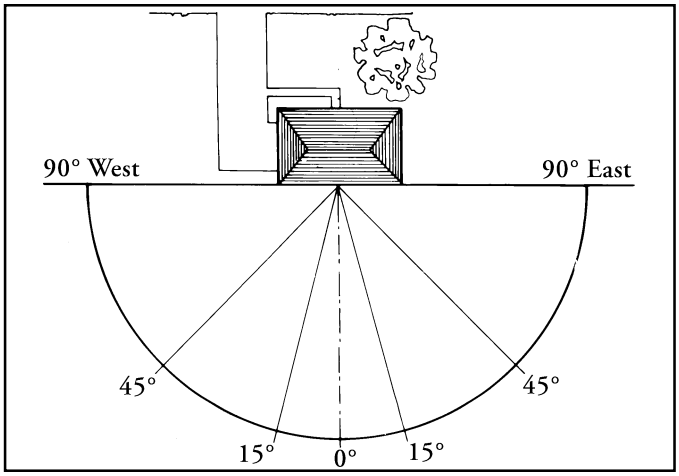


**Figure 10. Your house can be angled as much as $15^0$ east or west of true south and still be energy efficient.**

## ENERGY CONSERVATION

The passive solar home should be built with maximum attention to energy conservation details, including insulation. Windows and doors should meet recommended air infiltration standards. Infiltration or air leakage can also be reduced by careful caulking and weatherstripping. If the structure isn't energy-efficient to begin with, you will still have to add a good deal of supplemental heat.

Windows on the north side should be few in number and small in size, to reduce heat loss from this exposure. Eastern and western windows generally don't add much to winter net heat gain, and will add to overheating problems in the summer. Winter night heat loss from all windows can be reduced by the use of movable insulation, either inside or outside the house.

Any well-insulated and weatherized house needs good ventilation to reduce problems from indoor air pollution and help control humidity inside the house. Natural ventilation should be used in attic, basement, or crawl space areas. Bathrooms and kitchens should have outside vented exhaust systems. Sunspaces can be vented with windows or by mechanical ventilation. A large number of indoor plants inside the sunspace may increase its humidity levels, so good ventilation is important.

## SEE PASSIVE SOLAR AT WORK

The NCSU Solar House, which houses the North Carolina Solar Center, was built in 1981 and has been monitored for many years. It's heating bills for the *entire winter* average less than $70.You can obtain information about its performance or see it for yourself by visiting the Center. The House is located on the N.C. State University campus in Raleigh adjacent to the McKimmon Center for Continuing Education on the corner of Western Boulevard and Gorman Street. It is open free of charge to the public on weekdays from 9:00 - 5:00 and Sundays from 1:00 - 5:00, except on holiday weekends.

**Figure 11. North Carolina State University Solar House**

# 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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## For More Information

The North Carolina Solar Center has a reference library, as well as other free factsheets and information on solar energy, energy efficiency, and related subjects. For more information on these topics or to learn more about the resources available at the Solar Center, call the Solar Center's toll-free hotline at 1-800-33-NC SUN or (919) 515-3480, or visit our website at www.ncsc.ncsu.edu.


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# Take advantage of the state tax credit for solar energy!

North Carolina recently revised and updated its renewable energy tax credits, effective January 1, 2000.

For residential applications, homeowners may now take a 35 percent tax credit for all renewable energy sources, up to a maximum credit of $3,500 for passive and active space heating systems, $1,400 for solar water heating systems, and $10,500 for photovoltaic and other renewable energy applications (e.g. wind, microhydro, and biomass systems). For commercial and industrial applications, the tax credit is also 35 percent, with a maximum credit of $250,000. For further information on these tax credits, contact the North Carolina Solar Center at 1-800-33-NC SUN.


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