NORTH CAROLINA
SOLAR CENTER

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Passive Solar Retrofit

For North Carolina Homes

Passive solar retrofit is the adding of solar features to an existing house. A retrofit can lower heating bills, but usually will not provide as much heat as a passive solar system designed into a new house. The type of retrofit, the condition of your house, and the cost of the project should all be considered before you invest in a solar retrofit.

In North Carolina, common passive retrofits include:

- **windows** & **thermal mass storage** for direct gain,
- a **thermosiphoning air panel (TAP)** for direct gain,
- a **Trombé** wall for indirect gain, and
- a **sunspace** or **greenhouse** for isolated gain.

Before you begin a passive solar retrofit, you should make sure that your house is energy-efficient, that it has a good southern exposure, and that the retrofit will be appropriate (in cost and function) for your house. You may also want to review passive solar principles described in the Solar Center's *"Passive Solar Options for North Carolina Homes"* fact sheet.

First Improve Energy Efficiency

It doesn't make sense to retrofit a home that is not energy-efficient. Energy conservation measures should come first. They usually cost less and give a higher return per dollar spent than solar retrofits.

An energy audit or house diagnostic, offered by some private companies, can tell you where your house needs to be improved. Generally, your house should be well-caulked, weatherstripped and insulated. Caulking should be done around doors, windows, openings through the roof, walls or foundation, and along the foundation sill. Windows should be insulated by exterior or interior storms. Movable insulation for night time winter use will help reduce heat loss through windows. Additional insulation in the attic, walls and basement or crawl-space may be needed, even if your house already has some insulation. ***Only*** when your house has reached a high level of energy-efficiency should you consider a solar addition.

Is a Solar Retrofit Right for Your Home?

A sketch and floor plan of your house will help determine if you can add a solar retrofit. On your floor plan, note the placement of rooms, windows, exterior doors, load-bearing walls and heating and air return vents. You'll want to note exterior dimensions initially (Figure 1). As you plan your project, you may also need interior dimensions of the room or rooms that are included in the retrofit. Make a sketch or rough drawing of the south wall and roof (Figure 1). These drawings will help you determine solar access and appropriate retrofit options.

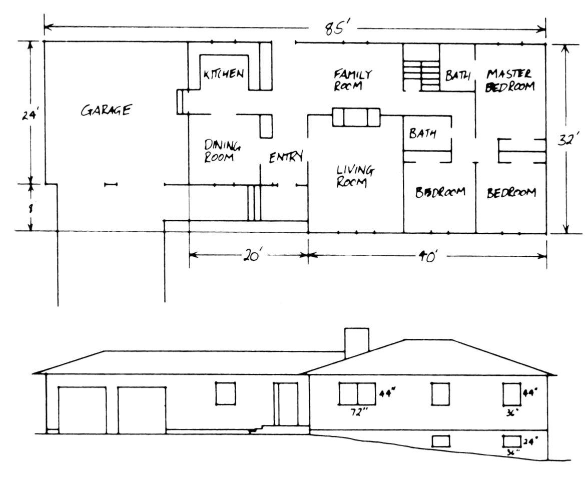

Figure 1. Sketch the floor plan of your house, noting dimensions, window locations and the south facing wall.

Consider Solar Access

A good southern exposure is needed to get the most benefit from your passive solar retrofit. Determine how close the south-facing wall of your house is to true south or solar south. True south is the location of the sun at solar noon. To find true south, you must first know solar noon. Check for the times of sunrise and sunset on a given day. Solar noon will be the time that is exactly halfway between sunrise and sunset.

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Thereafter, drive a stake vertically into the ground in front of your south-facing wall. At solar noon the stake will cast a short shadow that points to true north. Measure (with compass or protractor) the angle from this shadow line to the wall to get the solar orientation. For the best results, the wall should be within 15° east or 15° west of true south. If your south-facing wall is oriented to within 30° of true south, a solar retrofit may still be feasible.

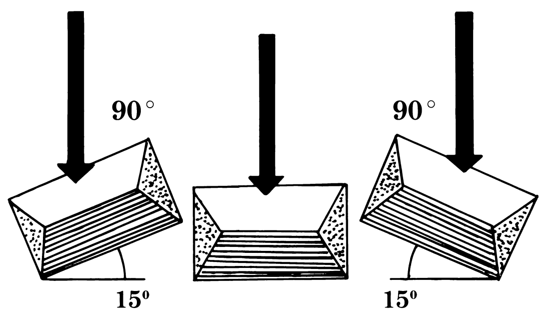

Figure 2. The south-facing wall can vary up to 15° either east or west of true south and still be effective for solar collection.

In addition to good orientation, the south-facing wall should get direct sunlight during the winter. The southern exposure should not be shaded by other buildings, trees or overhangs, from about 9 a.m. to 3 p.m., October through April. Even deciduous trees, which provide desirable summer shading, can reduce solar gain in the winter. Bare branches and trunks can shade up to 50 percent of sunlight. This may reduce the solar gain so much that the system won't perform as expected.

The following table may help you estimate if the south-facing wall will have good access to the winter sun. The table is figured using the shortest day of the year and the day with the lowest sun angles, December 2.

Direction	Shadow Length
SE	3.2 x Height
SSE	1.8 x Height
S	1.7 x Height
SSW	1.8 x Height
SW	3.2 x Height

Table 1. Relationship of orientation to shadow length. Shadow length = shade factor (based on North Carolina latitude) times object height (H).

You can use this table to determine how much shading will occur along the south wall. Pick a reference point somewhere toward the lower center of the south wall area you plan to retrofit. This point represents your solar collector area, which should be unshaded for most of the day. Note objects in front of the south wall and their approximate height. Stand facing the reference point and look at the object to determine the direction on the chart to use. To find the shadow length for a particular object, select the appropriate direction on the chart.

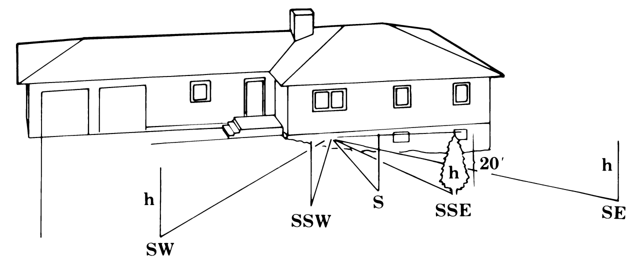

Figure 3. Solar access can be evaluated by the amount of shading on the south wall. For example, a 20 foot evergreen to the south-southeast of the reference point needs to be 36 feet or further from the south wall to avoid shading it.

For example, the tree in Figure 3 is south-southeast of your reference point. Multiply the shade factor times the height of the object. In this example, the shade factor for an object SSE is 1.8, which is multiplied times the tree height to give the shadow length. Once you get the shadow length, you should be able to determine if the shadow will cover the reference point. You want to be sure that trees, buildings and other objects don't cast shadows that shade the reference point (Figure 3). The glass area that will serve to collect the sun's rays should not be shaded more than one hour of the time between 9 a.m. and 3 p.m.

If you find the area you plan to retrofit is not within 30° east or west of true south, or if it is shaded for more than 10 percent of the collection time, a passive solar retrofit will not be practical or economical.

Instead, make your home as energy-efficient as possible by adding insulation, controlling air leakage, and reducing heat loss through windows by extra glazing and movable insulation.

Which Option is Best?

Once you've determined that your house has potential for a retrofit, how do you decide which option is best suited to your house and your lifestyle? There are relatively simple solar retrofits, like the thermosiphoning air panel (TAP), and there are more complex projects, like adding a greenhouse. The greenhouse or sunspace will probably provide more heat, but usually costs more to build. While a thermosiphoning air panel may be an inexpensive retrofit, you may not be pleased with how it looks when installed. Appearance, the cost of the project, and the difficulty of the retrofit should all be considered.

A passive solar retrofit, like any passive solar system, collects solar energy through south-facing windows. Some of the energy is stored in thermal storage mass, such as concrete, brick, stone or even water in closed containers, for nighttime heating. Some of the solar energy also can provide immediate heat for living spaces. The heat is distributed by natural air currents, through vents and openings or sometimes by the use of small fans.

DIRECT GAIN

In a direct gain retrofit, solar energy passes directly into the living space through south-facing windows (Figure 4). The floors and/or walls provide storage for night time heating. This can be an efficient and economical project. The direct gain retrofit usually performs efficiently at the lowest cost. It is most suited to the house with a fairly open floor plan, such as one with a combined living, dining and family room areas.

Figure 4. A direct gain system may be the easiest and least expensive passive solar retrofit. Extra mass is not needed if south windows are less than 7 percent of the floor area.

Direct gain may mean adding both window area on the south and supplemental storage mass. If you cannot add large amounts of mass to the floor or walls, you can still have a moderately-sized direct gain system. If south-facing window area is kept to less than 7% of the floor area, extra storage mass should not be necessary. For every square foot of window area exceeding that 7%, provide extra thermal storage mass equivalent to 6 square feet of 4"-6" thick concrete or masonry. The storage mass on walls or floors generally must not be covered by carpet or materials that interfere with storage.

When you plan your direct gain retrofit, you should also plan for movable night time insulation such as insulated draperies with tight edge seals, thermal shades, insulated panels or insulated shutters. Since the thermal storage mass is spread out along the walls/floor, it can lose heat rapidly to the outside on winter nights if windows aren't well-insulated. You will also need to consider summer shading.

The existing roof overhang may not be enough to keep your living areas from overheating. You may need to add solar screens, louvered shading panels, awnings or other seasonal shading.

A variation of the direct gain system which is relatively low-cost and requires no extra storage mass is the thermosiphoning air panel (TAP) (Figure 5). The TAP consists of one or more window-like panels that attach directly to the exterior south wall. It can be used in areas where, for reasons of privacy or interior function, additional south-facing windows are impractical. The wall area to be used must be free of plumbing, wiring or structural members because vents must be installed through the wall.

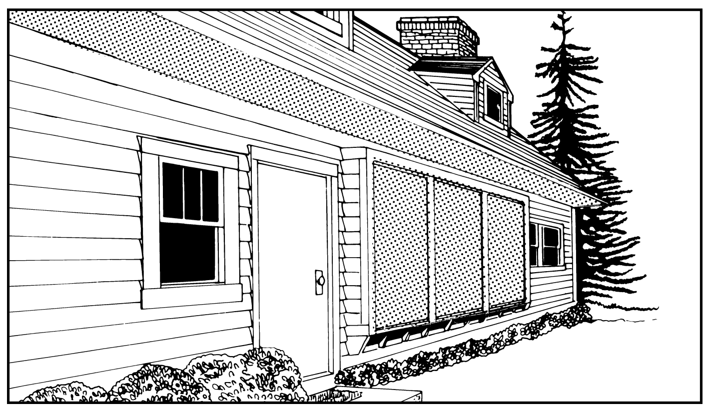

Figure 5. A thermosiphoning air panel (TAP) can be used when it is impractical to add windows to a south wall. Air that is heated in the collector panel circulates to the living space through vent openings.

The TAP is similar to an active solar collector panel mounted vertically on the wall. It consists of glazing, mounted in front of an absorber plate, with an air channel between the two. Vent openings at the top and bottom of the panel allow for air to circulate from the house, to be heated in the TAP, and return as warm air into the living space. Dampers are used to prevent reverse cycling of air at night, and to prevent warm air from entering during summer months.

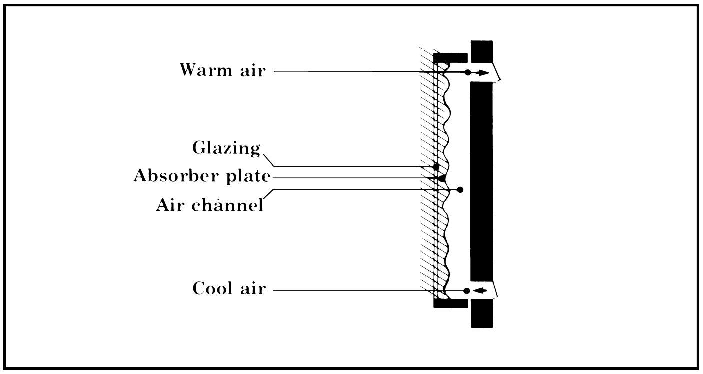

Figure 6. To prevent reverse cycling of air flow at night, and to keep heated air out in the summer, the TAP should have dampers.

Since air circulation distributes heat to the living space, there may be a problem with temperature distribution. The upper portion of the space may get too warm, while the floor stays too cool. Small fans can be added to improve air movement, but they require power to operate and can reduce the savings. Summer shading is needed with the TAP.

Thermosiphoning air panels can be purchased already constructed, or made from common building materials. You may be able to make and install your own TAP.

TROMBÉ (THERMAL STORAGE) WALL

A second passive retrofit option is the Trombé wall (Figure 7). Here a thermal storage mass wall is placed a few inches behind the south-facing glass. The mass heats up slowly during the day as sunlight strikes it, and it gives off heat to the living space at night. Trombé walls may be vented to let some warmed air pass directly to the living space in the daytime, and also used to store heat for night time use.

The Trombé wall will usually cost more than a direct gain retrofit, and may not perform as efficiently. It may be a better retrofit situation than direct gain if your house has a closed plan (many separate rooms, rather than open living space). It is also good for rooms like bedrooms, dens and family rooms that are used mainly at night. If privacy is a major concern, and traditional floor and wall coverings are important, then a Trombé wall may be a good option for your house. (NOTE: The inside-facing side of the Trombé wall should not be covered or blocked by furniture).

The Trombé wall releases heat fairly even to the house during the evening. Room depths should be kept to 15-20 feet behind the Trombé wall for maximum effectiveness. The Trombé wall itself needs to be 8-12 inches thick of solid masonry or concrete, depending on its size and materials used. Water walls weigh less and take up less space, but maintenance may be more of a problem.

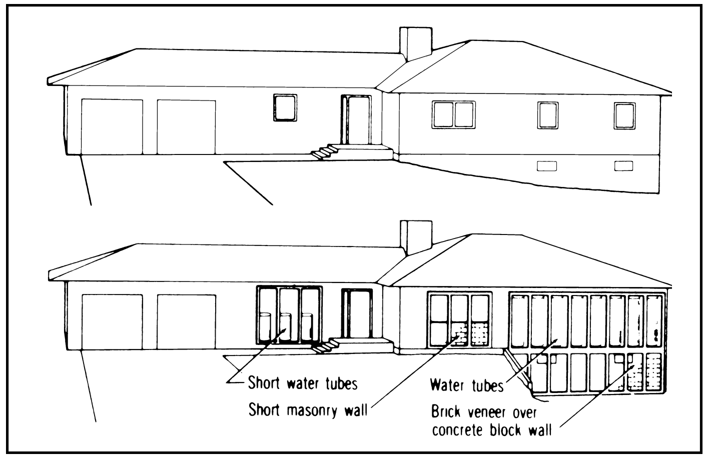

Figure 7. A Trombe wall uses mass placed very close to the south-facing glass. It may cost more and perform less efficiently than a direct gain retrofit.

Although the Trombé wall gains more heat in the day than it loses at night, exterior night time insulation improves its performance in winter. Plan for summertime shading, as with other solar retrofits.

SUNSPACE OR GREENHOUSE

A third retrofit option is the passive solar sunspace or attached greenhouse (Figure 8). The sunspace uses south-facing glass in a separate room that is attached along one or more exterior walls of the house. Massive floors and rear or side walls can be used for heat storage. Water containers may provide additional heat storage. Opening or closing doors and windows between the sunspace and house lets you control the amount of heat into the living space.

The sunspace is generally the most expensive passive solar retrofit to build, but allows you to close off or isolate the solar system from the rest of your house during periods of extreme heat or cold. This control feature improves the comfort and efficiency of the sunspace.

Figure 8. The sunspace or attached greenhouse is usually the most expensive passive solar retrofit, but it can provide the most supplemental heat. You should be able to close off the sunspace from the rest of the house.

Thermal mass is important to the proper operation of a sunspace. Three or four square feet of mass area per square foot of vertical glass is recommended to provide a comfortable living environment with moderate temperature swings. With appropriate thermal mass, the sunspace can serve as an effective heat source and a delightful living area as well.

Storage mass should not be blocked by excessive pieces of furniture or covered by carpeting, limiting its use as living space. If it is to be used as a greenhouse, it may require design modifications to meet the requirements of plants. Plants will also affect sunspace efficiency. You can build a sunspace to serve as primary living space, or as a greenhouse, or to provide maximum supplementary heat, but probably not to serve more than one major use year-round.

The sunspace can be added to houses with south-facing living areas, such as family rooms, dining rooms, and living rooms. If the sunspace cannot be closed off from these rooms, it should be designed more as a direct gain system and sized accordingly. There are many moderate-to-high-cost greenhouse kits available today. Some of these can be owner- built, and some require commercial installation. If there is a porch on the south side of your house, it may be possible to convert it to a sunspace.

When the sunspace can be closed off from the living room, winter night time movable insulation is not as critical. Of course, such insulation will help improve the overall efficiency of your sunspace. Do plan for shading and ventilation. To avoid overheating, use only vertical glass in the sunspace. Sloping glass adds to overheating problems, may develop leaks, and is more difficult to shade.

Final Considerations

Your solar retrofit project can provide supplementary heat, but the costs shouldn't exceed the benefits. Determine which retrofit option is best-suited to your house and your way of living. Before you start on any project:

1. Evaluate solar retrofit projects in your community and talk to those who have built them. Review appropriate solar references.
2. Be sure your house is already energy-efficient.
3. Talk to builders, architects, and engineers about which project (TAP, sunspace, etc.) is best suited for your house. Have them review your plans, or draw plans, for your retrofit.
4. If you are planning to do the retrofit yourself, make certain that the project will meet local codes and ordinances.
5. Make certain that your mortgage and homeowner's insurance will allow modifications.
6. Don't forget that movable insulation for night time winter use will improve the efficiency of your system. Also, plan for summer shading, with an overhang, louvered panels, awnings, screening or natural vegetation.
7. Check requirements for available state tax credits before you build. There are restrictions about items that qualify for North Carolina's solar tax credit, which is 40% of the cost of a passive, active or photovoltaic (solar electric) system, up to a maximum credit of $1,500.

REFERENCES

The following publications provide further information on solar retrofits. 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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North Carolina offers a personal tax credit of 40 percent of the construction, equipment and/or installation costs for solar energy systems, including passive solar, active solar and photovoltaics. The maximum credit per system is $1,500, available for only one system per year. Any excess credit can be carried over to the next year for up to five years.

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