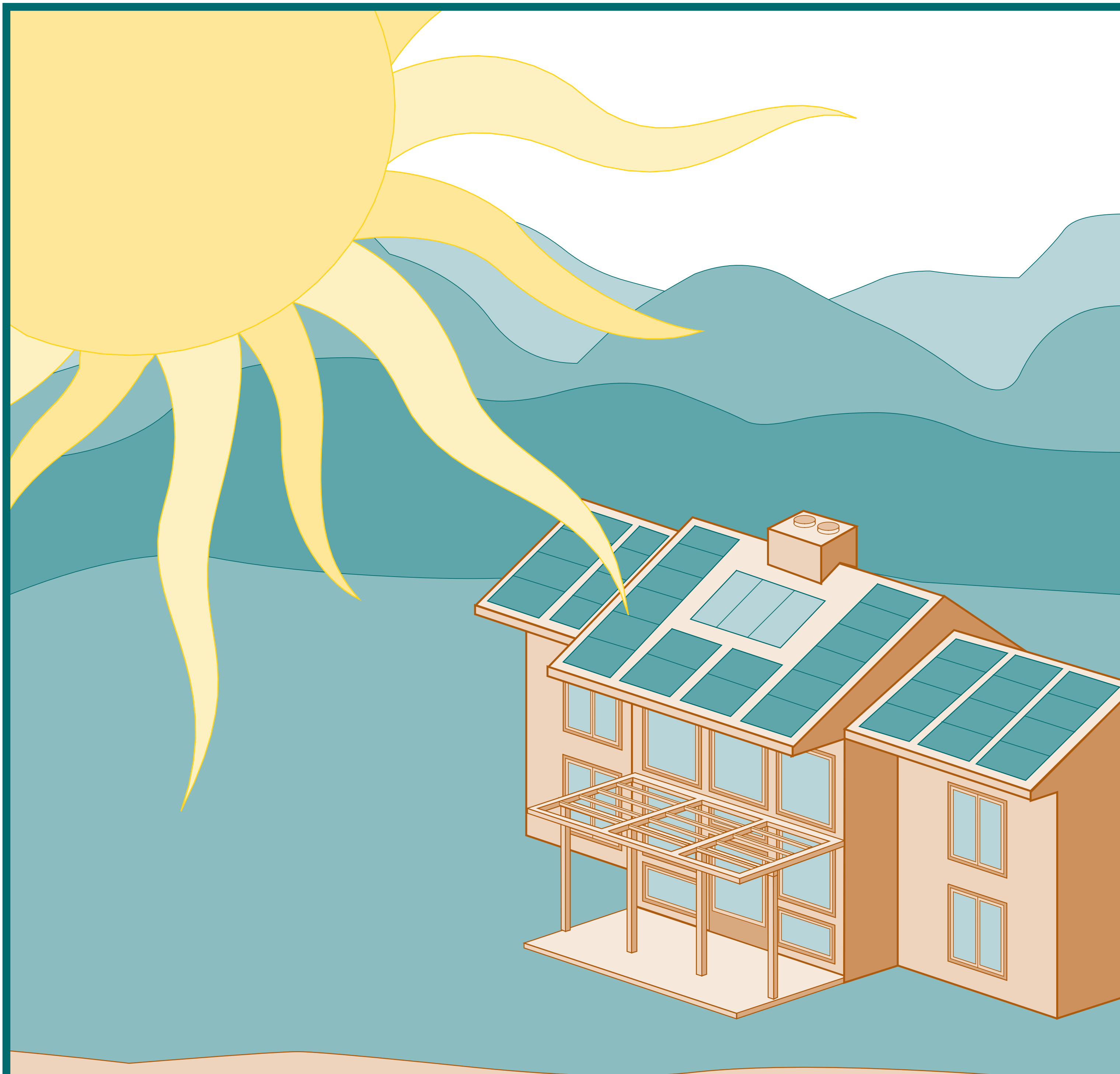

A Guide to Solar Energy in North Carolina

SUNBOOK

Energy Division, North Carolina Department of Commerce

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Revised in 1999 by the N.C. Solar Center with funding provided by the Energy Division, N.C. Department of Commerce.

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Introduction

Does A Switch To Solar Energy Make Sense?
Yes! The technology is available today
—and it is getting better and better

As prices go up for electricity, oil, natural gas or propane, we tighten our belts just a little bit more. In North Carolina, the cost of heating and cooling a home in recent years has risen faster than any other basic commodity. Some families are getting monthly utility bills that are higher than their mortgage payments.

Yet other North Carolinians are paying as little as $50 to heat their homes for an entire winter. How do they do it?

To be sure, they have cut their utility bills with a combination of good conservation measures and habits. However, most of their savings have come about because they have started using solar energy in their homes.

Solar energy is in North Carolina to stay. As of 1996, thousands of homes in the state are heated by the sun and more than 25,000 additional homes rely on solar energy to provide most of their hot water throughout the year.

North Carolina has a generous solar tax credit for businesses, homeowners, and industry. North Carolina also has available a large and growing network of solar energy dealers and installers and several equipment manufacturers. You can look in almost any telephone book and find a company that designs, sells or maintains solar energy systems. However, you may find it difficult knowing which is best for your needs. Even knowing what questions to ask is not easy.

Sunbook will help you determine your home's solar potential and what type of system best suits your needs, lifestyle and pocketbook. There is also a chapter on consumer protection. Finally, there's a bibliography and listing of organizations involved in solar research and education. We hope it all helps you gain a better understanding of solar energy and its potential in your home.

CHAPTER 1

HOW MUCH SUN IS ENOUGH FOR HEATING?

See If Your House Gets Enough Direct Sun

It is difficult to find anyone today who doesn't think that solar energy is a good idea. But whether or not solar energy is a wise investment for you depends on several factors. For instance, there are only a few low-cost solar devices that are worth investigating if you live in rental housing. If you own your home, your house must be relatively energy efficient before any solar system will perform up to its potential. Insulation, caulking and weatherstripping will save more money than a solar system and usually costs less.

You also need a relatively open view of the sky to the south of your home, at least during the winter months. The drawing on this page shows the path of the sun on December 21, the shortest day of the year, and June 21, the longest day of the year. During the short winter days, we get only nine to eleven hours of sunlight in North Carolina. The sun rises slightly to the south of east, climbs to between 32 degrees and 45 degrees above the horizon and sets to the south of west. In summer, the sun is up 12 to 14 hours and is almost directly overhead.

To get an accurate picture of the available sunlight at any particular location, use a sun chart such as the one shown on this page. Sun charts show the sun's path at different times of the day and year for a given latitude. When the chart is printed on clear plastic and mounted on a viewing stand—usually consisting of a wide-angle lens, a compass and a level—a homeowner can observe the sky from the point where the solar system is to be located and determine if neighboring trees or buildings will block the sun. While you can construct your own viewfinder, you may want to talk to a local solar equipment dealer about checking your home's solar potential.

To take good advantage of solar power, you need access to direct sunlight in the area above the altitude sun angle for December 21 and at a maximum, 60 degrees both east and west of true south. This corresponds roughly to having an unobstructed view of the sun between 9 a.m. and 3 p.m. from late September to late March. Remember, these are ideal conditions. A partially obstructed view still can provide a great deal of solar heat.

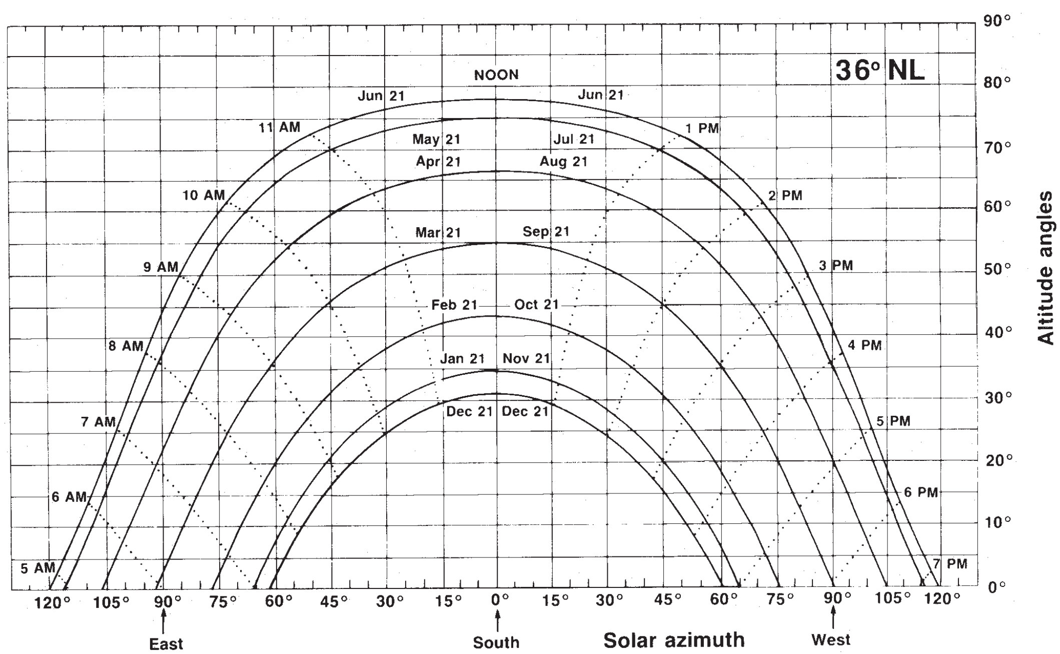

Fig. 1: A sun chart for 36 degrees north latitude.

CHAPTER 2

COLLECTING THE SUN'S HEAT

The Key: Storing Heat Your System Collects

The term "solar system" refers to a combination of items working together to provide space heat or hot water. To work, solar systems need a means of collecting solar heat, a means of controlling and distributing heat and, in most cases, a means of storing heat.

The collection of solar energy is made possible by what is known as the "greenhouse effect." You have experienced firsthand the greenhouse effect when you got into your car on a hot summer day with the windows rolled up. The sunlight that passed through the window glass was converted into heat after striking the inside of the car. Heat—thermal radiation—cannot easily escape, so air temperatures in the car rise, eventually going far above outdoor temperatures.

ACTIVE SOLAR SYSTEMS

Solar collectors are designed to take advantage of the greenhouse effect. The flat-plate collector, used for most solar space and water heating applications, is essentially an insulated metal box with a glass or plastic cover. A black metal absorber plate with tubes or channels for the passage of the heat transfer medium is located within the box (Figure 4).

The heat transfer medium is nothing more than hot air or a hot liquid that transfers solar energy from a collector to a heat storage unit and then to the home's living quarters. When tilted at the proper angle in relation to the sun, sunlight will pass through the glass cover, strike the absorber plate and be converted to heat. The collector, insulated on the bottom and sides, prevents most of the heat from escaping.

Typically, a collector will be mounted on the roof of a building, where it will get the most exposure to sunlight. This type of design is referred to as an "active" solar system (Figure 2). It is called active because it requires electrically powered pumps or fans to operate. In fact, active

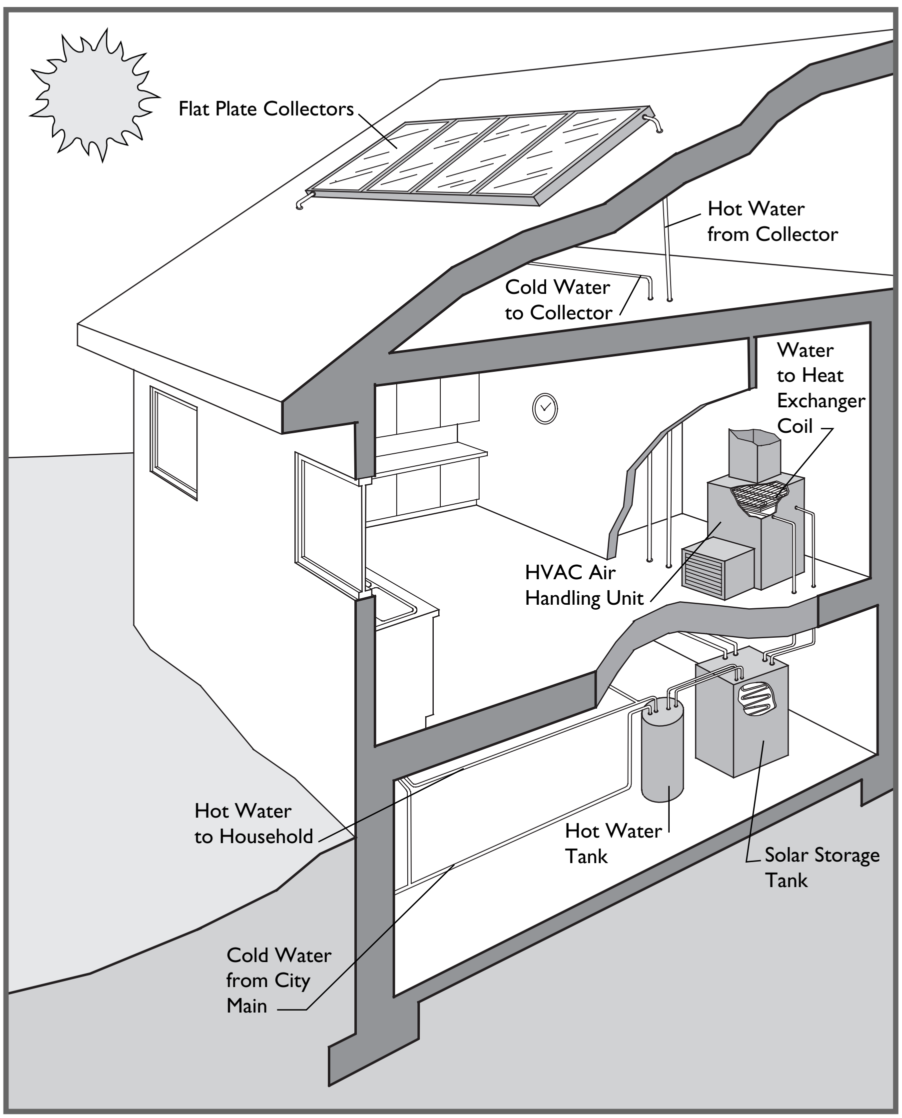

Fig. 2: Cut-away drawing of an active solar heated house.

systems may be thought of as solar appliances because of their similarity to conventional heating and hot water systems.

Usually, your household will need the most heat when the sun is down at night and temperatures are colder. You will need the least heat during the day when sunshine is abundant. A system that stores solar heat for later use will thus be able to provide more of your home's heating needs than one without storage. In an active solar system that uses air as the transfer medium, heat usually is stored in an insulated rock bin or an air-cored masonry wall in the house. Liquid solar systems usually rely on a water tank for heat storage.

Passive Solar Systems

A different approach to solar collection, storage and distribution can be seen in "passive" solar systems (Figure 3). Rather than collecting solar energy through roof-mounted panels, passive systems allow sunlight to enter the building directly through south-facing windows or skylights. The interior walls and floors act as absorbers, converting sunlight to heat. Walls and floors also function as storage, provided they have sufficient mass. Heat is contained in the structure by insulating around the outside of the ceilings, walls and floors. Within the building, heat is distributed primarily by natural convection and radiation, rather than by mechanical means.

There are many ways to design solar energy systems, not all of which can be easily classified as strictly active or passive. For example, some homes rely on south-facing glass to collect solar energy but use fans and ductwork to distribute the heat. These designs are often known as hybrids. In any case, each type of solar system can be desirable, depending on your particular situation. The following chapters will describe these systems in greater detail and illustrate their appropriate use.

Fig. 3: The NCSU Solar House with direct gain, trombe walls, sunspace, active solar water heating system and photovoltaic electrical system.

CHAPTER 3

THE SUN AND A LITTLE ENGINEERING HELP
Mechanical Power Makes
"Active" Solar Systems More Efficient

Active solar systems basically are appliances consisting of solar collectors, a mechanically powered distribution system and a heat storage unit. Active solar systems can be used to condition household air or to heat water. In North Carolina, we mostly use active solar systems to heat our hot water.

SOLAR WATER HEATING SYSTEMS

Did you know that the average person uses between 15 and 20 gallons of hot water a day? At 8 cents to 13 cents per kilowatt hour for electricity, an average family of four spends between $400 and $500 a year to heat water. That figure probably will continue to rise each year as the cost for energy rises. You can cut your hot water costs by half with a properly sized solar water heater.

There already are more than 25,000 solar water heaters installed on North Carolina homes and the number is growing daily. Dealers and installers of solar water heating systems can be found in almost every large city, as well as in many small towns. The N.C. Solar Center also offers a referral service free of charge to the public.

There are four basic types of solar water heating systems sold in the state, although other designs may be available. These systems share three similarities: flat-plate collectors to gather solar heat, one or two tanks to store hot water, and associated plumbing with or without pumps to circulate the heat transfer fluid from the tank to the collectors and back again.

The crucial difference in these systems lies in their freeze protection methods. In a "draindown system" (Figure 5), potable water from the home's hot water tank is pumped directly through the solar collectors, where it is heated by the sun and returned to the tank. Freeze protection is provided by valves that automatically open and drain the system when sensors detect freezing temperatures. The water usually is dumped down a sewer drain. The valves close when the danger of freezing has passed and fresh water is reintroduced to the system. Solar collectors and piping in a draindown system must be pitched so water will drain automatically, even in a power failure.

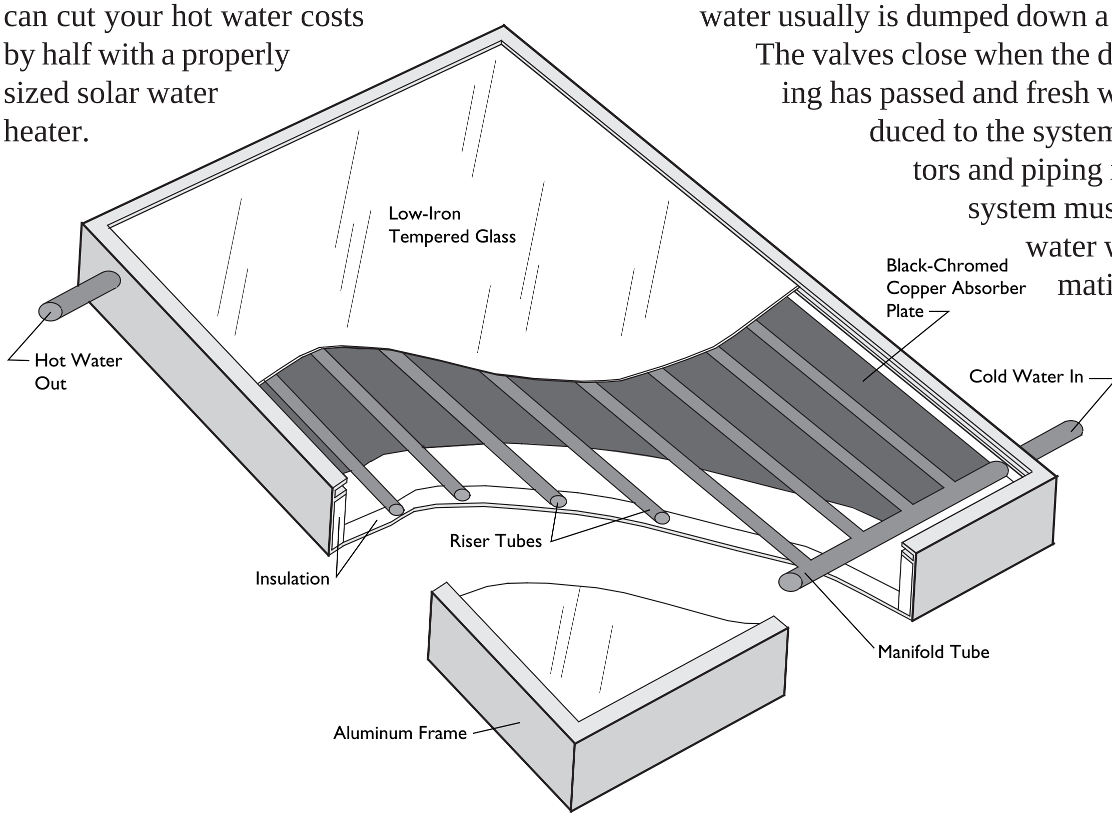

Fig. 4: Cut-away drawing of a typical solar collector.

Draindown systems are classified as "open loop" because they are tied directly into the domestic water supply. You should test the hardness of your water before installing an open loop system. Mineral deposits or acidity can ruin the collectors.

The second general type is a "drainback" system (Figure 6), so called because fluid in the collector loop drains back into a solar storage tank whenever the pump shuts off. A drainback system does not circulate household water up to the collectors. Instead it uses a separate plumbing line filled with distilled water or some other fluid to gather the sun's heat. The heat is transferred to the household water supply by means of a heat exchanger—a coil of copper pipe that runs into and out of the water tank. A drainback system operates

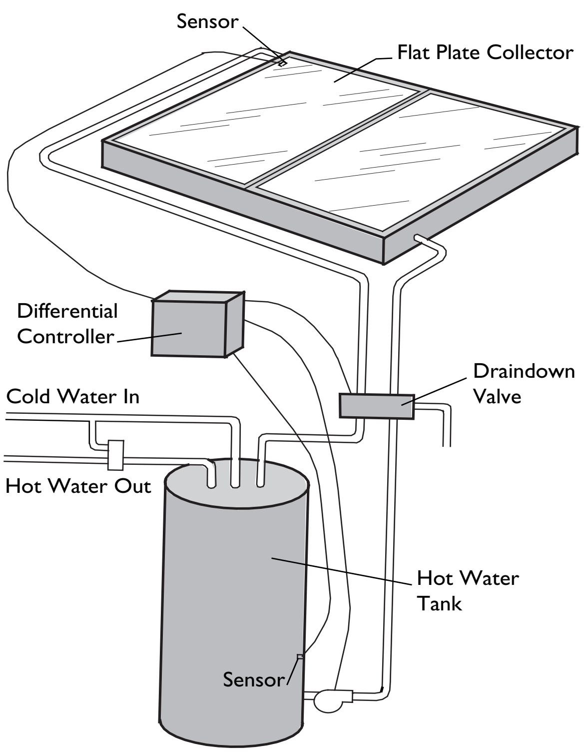

Fig. 5: Draindown solar water heating system.

strictly on gravity—whenever the temperature is near freezing, the pump shuts off and the transfer fluid drains back into the solar storage tank. A drainback system lacks some of the controls of a draindown system and does not have to be pressurized. However, it does have pitched collectors and piping like the draindown system to allow the transfer fluid

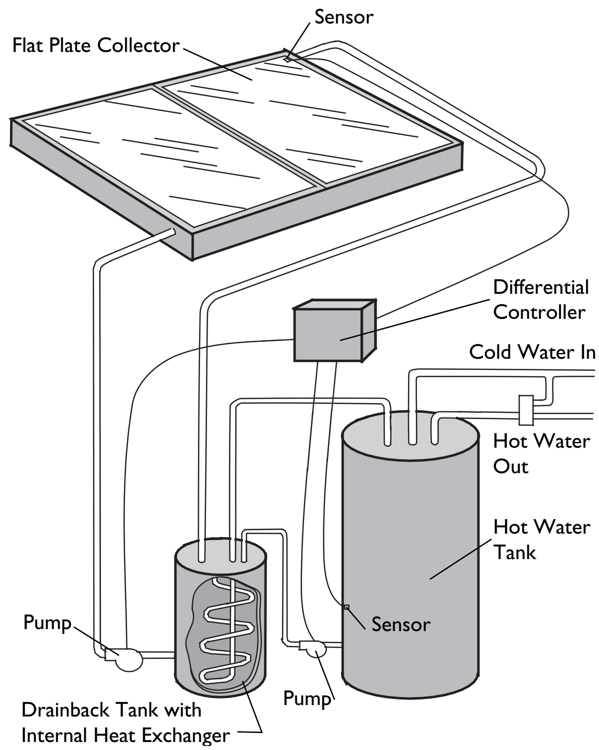

Fig. 6: Drainback solar water heating system.

to drain back into the tank. Drainback systems are classified as "closed loop" because the heat transfer fluid is contained in a separate plumbing line rather than being tied into the domestic water supply.

A closed loop system using an antifreeze solution represents the third basic type of solar water heater available (Figure 7). The use of antifreeze allows the system to operate continuously throughout the winter months. Because they are toxic, antifreeze solutions must be separated from household water by a double-walled heat exchanger.

There are several antifreeze solutions used as transfer fluids in solar water heating systems. Two of the most popular are a propylene glycol/water mixture and silicone oils. Propylene glycol is far less expensive than silicone oil and is more widely used. However, the propylene glycol mixture can become acidic when constantly exposed to high temperatures and should be checked and replaced every few years to avoid corrosion. Silicone oils are noncorrosive, but they have a very low surface tension. This means they can seep through the smallest cracks.

The Collector Panel

A crucial feature in all solar water heating systems is the collector panel. The collector will be exposed to the harshest elements of nature and must be made of strong, well-assembled materials if it is to last for 20 years as claimed by most manufacturers. A good

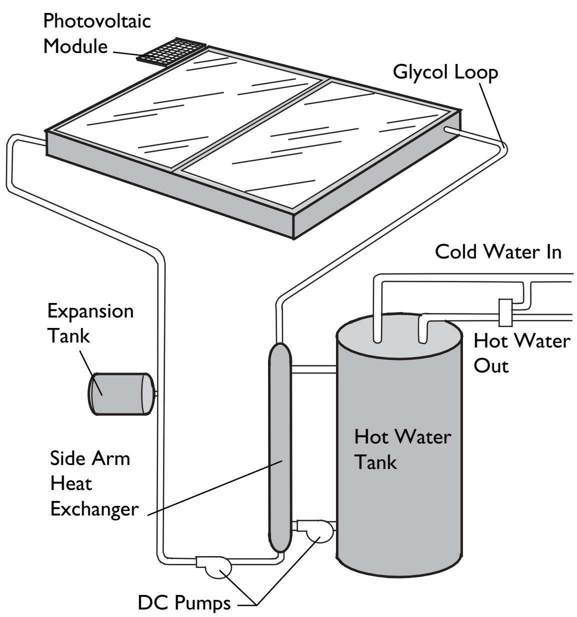

Fig. 7: Pressurized glycol solar water system.

quality collector generally has a metal frame, a single pane glass cover (double glazing is unnecessary in most Southern areas), and a copper absorber plate and tube assembly through which the heat transfer fluid is circulated. The collector should be well insulated on both the back and the sides (Figure 4).

As with other solar systems, the best orientation for a solar water heating collector is due south—three to seven degrees west of magnetic south depending on where you are in the state. However, solar water heating collectors can face up to 30 degrees east or west of south without a significant deterioration of performance.

Traditional wisdom has held that the proper tilt for solar water heating collectors is equal to the latitude of the location where the system is being installed. However, keep in mind that hot water consumption is often greater and incoming water temperatures are lower during the winter months. You will find that a steeper angle (latitude plus 10 degrees) is often recommended in Southern climates because it enables the collection of more of the sun's heat throughout the year. The optimum tilt for solar water heating collectors in our region is around 45 degrees. Collectors that tilt as much as 15 degrees off the optimum slope still will perform relatively well on an annual basis. This variation makes it possible to mount the panels flush with the roof for aesthetic reasons.

We still have not mentioned the fourth type, the "passive" solar water heating system designs—"thermosiphoning" and "batch." These are available commercially and are also popular among do-it-yourselfers. Both are classified as passive solar water heating systems as they do not require pumps to operate.

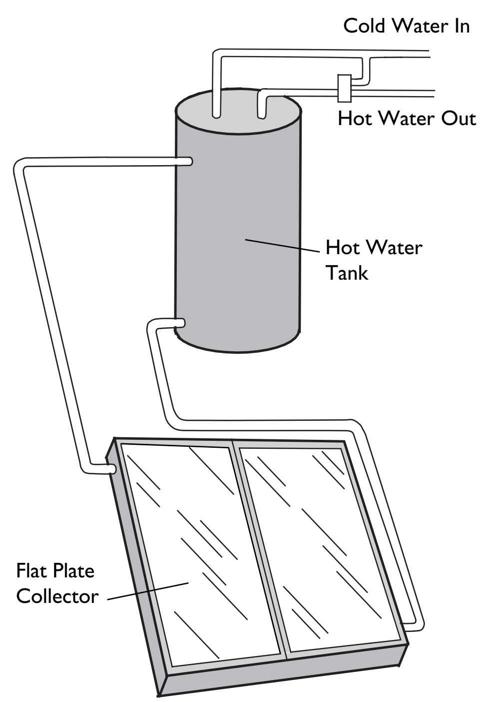

Fig. 8: Thermosiphoning solar water system.

A basic law of thermodynamics says that when a fluid—such as air—is heated, it becomes less dense and is then easily displaced by the relatively denser cold fluid. This is called thermosiphoning or convection.

In a thermosiphoning solar water heater (Figure 8), the storage tank is located at least two feet above the collectors so the cooler liquid from the bottom of the tank will naturally drop down into the collector and be heated. Warmer transfer fluid heated in the collectors will rise up to the tank. The cycle continues as long as the sun is shining.

Thermosiphoning solar water heaters are popular in non-freezing climates where domestic water can be circulated directly through the collectors. In freezing climates, an antifreeze solution contained in a separate loop is normally used. The main advantages of a thermosiphoning solar water heater is that it requires no mechanical energy to operate. The biggest disadvantage is that it heats only about one-fifth the volume of water that a pumped system does. Also, a thermosiphoning system can be hard to install because the water tank must be installed above the collectors.

According to the results of a comparative study by New Shelter magazine, the most cost effective of all solar water heating systems is the “batch” or “breadbox” water heater (Figure 9). In a batch heater, the water storage tank also functions as the collector. The tanks are used as collectors by putting one or two water tanks, painted black, in a well-insulated box or other enclosure. The south wall of the box is made of clear glass or plastic and tilted at the proper angle so the sun shines directly on the tank and heats the “batch” of water. Freeze protection can be provided by adding an insulated cover to the enclosure, giving the system the appearance of a giant breadbox—hence, the name “breadbox solar water heater.” However, some homeowners find that the effort required to open and close the insulated cover during the winter is tiresome. Also, it is usually the pipes leading to and from the insulated enclosure that freeze. Thus, it may make more sense to drain the collector during the winter in climates like North Carolina. Even with the system shut down for several months, the breadbox heater can save considerable electricity that otherwise would be required to heat water. Materials for a breadbox water heater usually run no more than $500.

Commercial batch collectors are also available. You usually will find them assembled, with instructions for interconnection to the house water supply. A plumber or a homeowner with plumbing experience can complete the installation. These already assembled collectors use better materials than similar materials available at home supply stores. Materials include low-iron insulating glass, selective surface coated tanks and a parabolic reflector. Commercial batch collector systems also may offer warranties, such as guaranteed protection from freezing by virtue of their increased thermal performance. Costs for commercial batch collectors will range from two to four times the cost of homeowner-built systems (Figure 10).

Active Solar Space Heating

Much of what you have just read about solar hot water systems can be applied to active space heating systems. The main differences between the two systems are size, complexity of installation and initial cost.

Where size and initial cost are concerned, consider the collector area needed for an

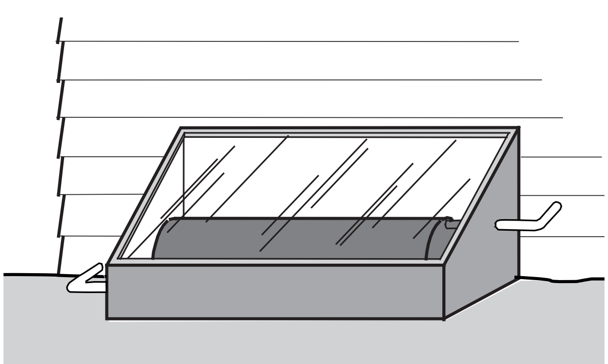

Fig. 9: Breadbox batch solar water heater.

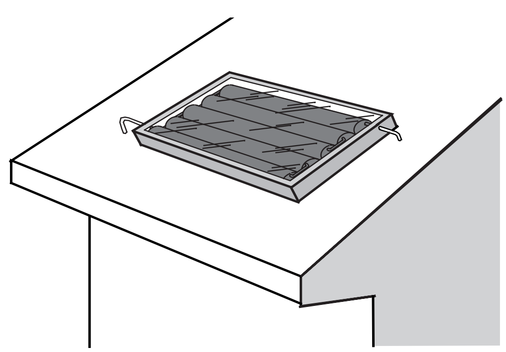

Fig. 10: Integral collector storage system.

active solar system. Collector size will depend on your heating needs and how much of these needs you expect solar energy to provide. Because of costs involved, most active solar space heating systems are sized to provide 75 percent or less of a home's space heating needs. The rest is supplied by a conventional backup heating system or a wood stove. An active solar system sized to provide 50 percent to 75 percent of the space heating and hot water needs of a well-insulated, 1,500-sq. ft. home in the Piedmont area is likely to run between $8,000 to $10,000 (Figure 11).

Active solar space heating systems circulate either air or liquid through collectors to gather heat. Regardless of the heat transfer medium, most solar space heating systems store heat for later use at night or during overcast days. Systems that circulate air for heat transfer commonly use either a large rock bin, or air-cored floor or masonry wall for heat storage. With the help of fans, hot air is pulled out of the collectors, into a duct system and through the heat storage unit before returning to the collectors. By sundown, the system has stored enough heat to account for much of your heating requirements during the night.

Systems that use a liquid transfer medium usually store solar heat in a large tank of water. The transfer fluid absorbs heat in the collectors and then flows through a heat exchanger inside the storage tank. When the house needs heat, the water in the storage tank is pumped directly through baseboard heating coils, a heat coil in a radiant floor slab or through another heat exchanger in the warm air duct of the home's space heating system. You can also meet your hot water needs by using solar-heated water in the storage tank.

Another form of thermal storage uses phase-change materials. Phase-change materials include eutectic—or glauber—salts and paraffin wax that actually change from a solid to a liquid between 70 degrees to 85 degrees, absorbing heat in the process. When the temperature drops, heat is given off as the liquid returns to its solid form. Phase-change materials store two to five times more heat per unit volume than water or rock, but they are more expensive and difficult to find for sale.

Connecting an active space heating system with a conventional forced air heating system is simple. However, matching solar to a hydronic heating system can be tricky. Baseboard hydronic systems usually are designed to use water heated from 160 degrees to 180 degrees. Flat-plate solar collectors produce water heated to 140 degrees or less. If you have a hydronic heating systems, consult a reputable solar dealer to see if interconnection makes sense for you.

A number of designs have evolved using solar collectors to preheat air or water for heat pumps. Low-cost, low-performance collectors can be used in these applications as heat pumps cannot tolerate high temperatures. The cost effectiveness and performance of these systems have been highly variable, so commercial availability currently is limited. However, as research progresses, the future is bright for solar-assisted heat pumps.

Fig. 11: Active solar space heating system.

CHAPTER 4

PASSIVE SOLAR DESIGN
Nature and Common Sense
—Add Up To Savings

Before the introduction of modern heating and air conditioning, Americans relied heavily on sun, shade and natural air movement for heating and cooling. Reliance on the natural elements was reflected in the building materials, orientation and design of their houses.

In the Southwest, for example, Native Americans typically built their homes under the overhang of a south-facing cliff where they were bathed in sunlight in winter yet fully shaded in summer (Figure 12). Walls were made of thick adobe or stone that absorbed the heat of the winter sun and released it into the dwelling at night. Protected by the overhang in summer, the thick walls kept inside temperatures cool.

In the Deep South, cooling was the major problem. People responded by developing passive design features such as wraparound porches to shade windows, cupolas and tall ceilings to allow hot air to rise above head level, and "dogtrot" floor plans that allowed for effective cross ventilation.

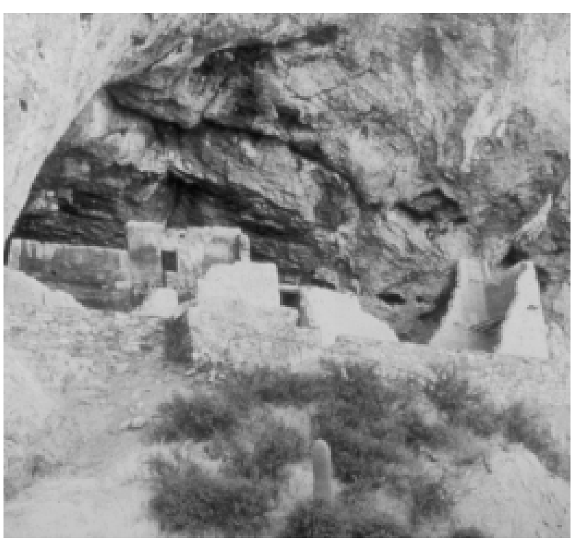

Fig. 12: Adobe pueblo under cliff overhang.

Today the reliance on proper orientation is the trademark of the passive solar home. So is the use of special building materials and designs for heating and cooling. As the cost of conventional fuels increases and people become more aware of their natural and built environments, passive design is rising in popularity in North Carolina. Passive energy systems can be incorporated into both new and existing homes. The same technologies that are used for passive heating are also used for passive cooling. However, the difficulty of renovating an existing home makes passive better suited to new construction. The following sections cover a variety of passive solar energy systems that can be designed easily into new homes, either alone or in combination. Passive retrofit ideas for existing homes will be discussed in Chapter 6.

ORIENTATION, LANDSCAPING AND WINDOW LAYOUT

Builders of any new home, regardless of heating system, should follow basic passive design principles in orientation, landscaping and window layout. The added cost, if any, will be small, but the energy savings can be substantial.

Ideally, one of the long sides of the building should face due south to expose as much of the roof and southern wall as possible to the winter sun. Moderate deviations off true south are acceptable and advantageous in some instances. For example, if you are seldom home during the day, orient the home slightly west of south to allow more sunlight in during the afternoon. The opposite orientation would be best for an office building that needs to start gathering solar heat in the early morning hours.

Regardless of your heating needs, deviations of more than 30 degrees should be avoided if at all possible. At a 30 degree deviation, the percentage of solar heat will drop by about 10 percent from that of true south. Over 30 degrees of deviation will result in a sharp drop in the available solar heat.

Large deciduous trees can be excellent for maintaining an energy efficient home. Deciduous trees shade the house in the summer and expose it to the sun when they drop their leaves in the fall. If you have deciduous trees on your lot, locate your house where it will be shaded in summer but open to sunlight in winter. The southeast and southwest corners of the house are prime locations for trees.

Once you have decided how to locate the building on the lot, you can begin designing the structure. Locate most of the windows on the south side of the house where they will pick up winter sunlight. The windows on other sides of the house, particularly the west side, should be kept to a minimum. Windows facing west pick up virtually no direct sunlight in winter, but can cause severe overheating problems in the summer when the afternoon sun lingers in the western sky. Windows should not be totally eliminated on any side of the house since they are needed for providing cross ventilation, balanced light and a means of emergency escape.

With a house designed along these basic principles of "sun tempering," you can get as much as 30 percent of the winter heating load from solar energy. Further design changes that add thermal mass and solar windows can increase the share of heating provided by the sun up to 80 percent and at the same time help reduce the cost of air conditioning.

Direct Gain Systems: Efficient Passive Designs

Direct gain systems allow sunlight into a home's living area through large sections of glass facing south (Figure 13). Direct gain can be the most cost effective of all passive designs because the heat produced by sunlight hitting the walls, floors and other objects does not have to be transferred to another part of the house.

However, the surface area of south-facing windows and the capacity of your storage area should be balanced. If the windows collect more heat than the floor or walls can absorb, overheating occurs. Be sure you have at least five square feet of four-inch-thick mass for every square foot of glass and you will have enough capacity for storing the sun's heat for use later at night.

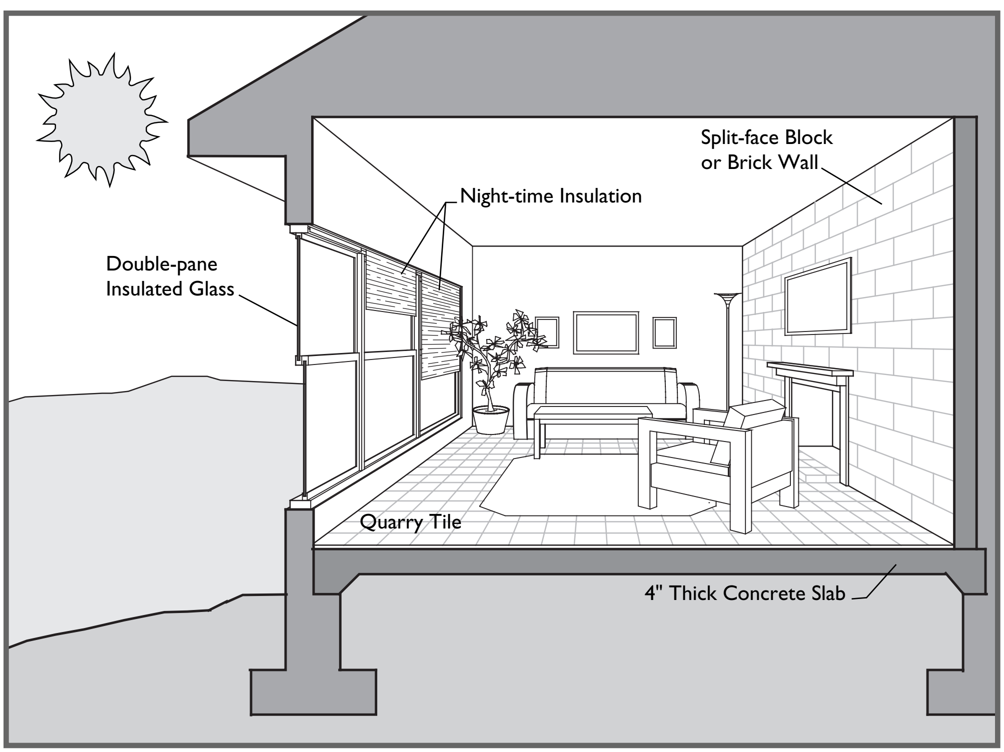

Fig. 13: Cut-away drawing of a direct gain passive solar house.

Building materials used in conventional home interiors—for example, wood and sheetrock—retain some heat. But their heat-storing capacity is limited. Masonry and water are much better at storing heat. Masonry, of course, can be used in interior walls and floors of buildings. Water and phase-change materials are normally contained in tubes arranged along the back wall of the living space or along the inside of the window. Storage materials should be put where they receive direct sunlight during the day. Materials out of direct sunlight save only one-fourth as much heat as materials hit by the sun directly.

When the sun begins to set and inside temperatures drop, the heat absorbed by these materials will radiate back into the room, moving as heat always does from a warmer to a cooler space. Properly designed thermal storage materials should keep inside temperatures from fluctuating by no more than 13 degrees over a 24-hour period.

While storage materials help maintain comfortable air temperatures in most of the house, an uninsulated glass wall loses a lot of heat at night and will make one side of the house markedly cooler than the rest. You can greatly reduce this problem by covering the windows at night with accordion insulating blinds or insulated drapes. Other approaches you can take to reduce nighttime heat loss are exterior or interior insulated shutters or quilted roman shades.

With direct gain systems, the thermal storage mass tends to 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. Do not cover the thermal storage area with carpet or other materials that reduce storage capacity. Select and arrange furnishings carefully so they do not interfere with solar collection, storage and distribution. Another thought to keep in mind—sunlight fades different types of materials.

Indirect Gain Systems

Some problems of direct gain systems often can be solved by using indirect methods of solar heating. As the name implies, indirect gain systems do not admit sunlight directly into the living area. Instead, south-facing glass is placed in front of a massive wall that absorbs, stores and transfers heat into the house.

One of the most commonly used indirect gain systems is the Trombé wall (Figure 14), named after its inventor, French scientist Felix Trombé. A Trombé wall usually is built of solid masonry—concrete, solid block or brick—and painted black or covered with a selective coating on the outside to absorb and transfer much of the heat to the living quarters. A sheet of glass or plastic covers the outside of the wall to trap additional heat.

Heat is distributed from the Trombé wall to the house in two ways. During the day, air trapped between the wall and the glass gathers heat and enters the room through vents at the top. Cool household air is drawn between the wall and glass through floor-level vents, where

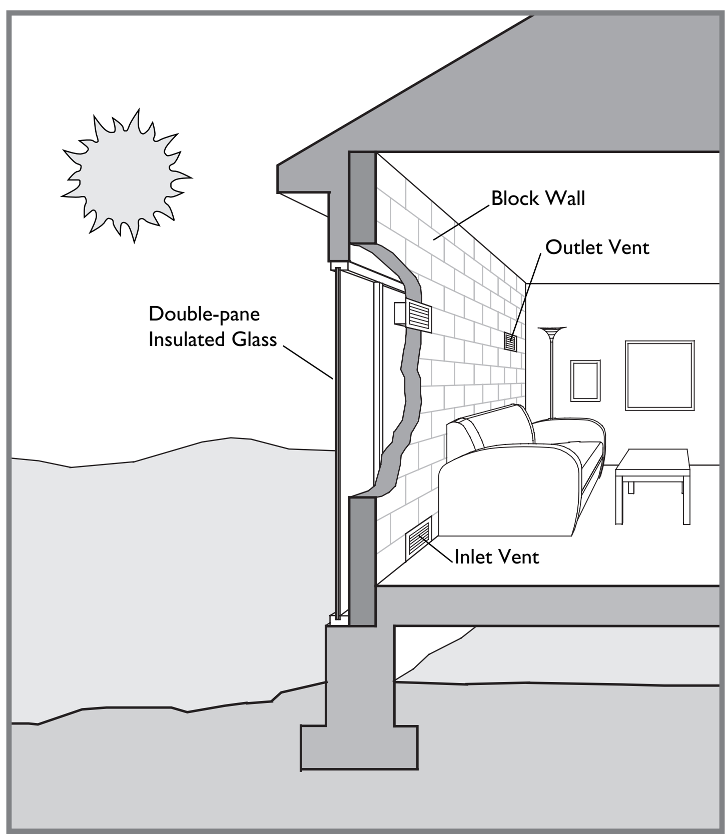

Fig. 14: Indirect passive solar Trombé wall.

the cycle repeats itself as long as sunlight strikes the wall. Heat also is gradually conducted through the Trombé wall and reaches the living area near the end of the day. In a 12-inch wall, heat travels from between the wall and glass to the living area in about eight hours.

The cycle plays nicely to your advantage. Sunlight striking a living room Trombé wall between 10 a.m. and 3 p.m. is released inside as heat between 6 p.m. and 11 p.m. In a bedroom, you probably would prefer a 16-inch wall with an 11-hour heat-release cycle.

To prevent nighttime heat loss, you must close the vents along the Trombé wall after sunset—usually by hand. Solar designers have found many of us often forget about the vents, wasting the heat that is stored along the wall. You can avoid the problem by building the Trombé wall without vents as long as the air space between the glass and masonry is vented or shaded in the summer. If daytime heat is needed in the adjacent room, windows incorporated into the wall will help heat the room. An added benefit of a sealed Trombé wall is that household dust cannot get into the space between the wall and glass. Moveable insulation or double glazing also is advisable for Trombé walls.

Water As Thermal Storage

As mentioned, water also functions well as a thermal storage material. Some passive solar designs substitute water-filled containers for the masonry wall. Water stores twice as much heat as an equal volume of concrete or brick. Water's heat storing capacity allows the storage mass to be concentrated in a smaller area. Water responds more quickly to temperature fluctuations, which means that it will heat up earlier in the day but also cool off quicker at night. Thus the glass in front of water walls must be covered with insulation at night to prevent excessive heat loss.

Isolated Gain Systems

Unlike direct and indirect gain systems, isolated gain passive designs capture solar radiation in an area thermally separated from the living space. Isolated gain systems allow for the collection and storage components to function somewhat independently of the house itself, while heat can be drawn from them as needed. The sunspace or solarium is the most common type of isolated gain system (Figure 15). In Chapter 6, the attached greenhouse is discussed as an effective, low-cost option for existing homes. However, the sunspace has much greater flexibility in terms of design and performance when incorporated into plans for a new home.

Isolated gain systems, such as the sunspace, collect solar radiation directly through a south-facing wall of glass. Heat then is transferred into the house as needed through vents, doors or windows. In some sunspace designs, the back wall is made of solid masonry to store and transfer heat for use during nighttime hours. In this respect, the sunspace is simply an expanded Trombé wall system. Instead of the glass being a few inches in front of the wall, it is several yards away.

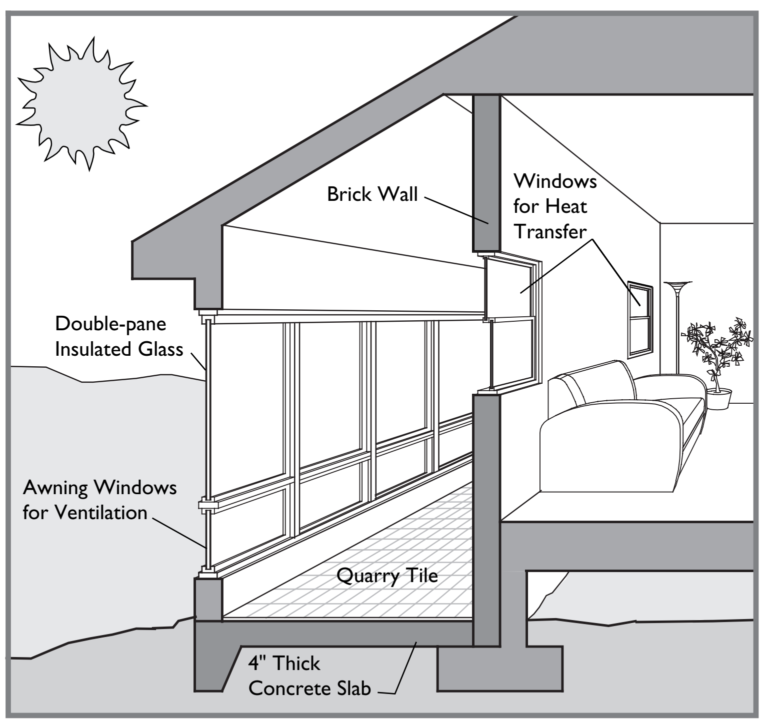

Fig. 15: Isolated passive solar attached greenhouse.

There are several other options that can improve the efficiency of a sunspace in new home construction. The sunspace can be designed into the house so the south glass wall is flush with the rest of the structure, eliminating heat loss through the sides of the sunspace. On the other hand, temperatures inside isolated sunspaces fluctuate more than in the rest of the house since no heating or cooling is provided. In this sense, sunspaces are considered semi-conditioned.

Thermal Envelope House

One variation in passive solar design is the "thermal envelope" or double shell house. The thermal envelope design combines the accepted idea of a south-facing greenhouse for solar collection with the novel concept of a continuous double wall around the roof, floor and north side of the house. During the winter, sunlight warms the air in the greenhouse and causes it to rise. Vents at the top of the greenhouse allow heated air into the cavity between the double-walled roof. The air travels to the back of the roof, down the north wall as it cools, under the house and back into the greenhouse again in a continuous convective loop. Theoretically, this action creates a buffer zone of moderately warm air surrounding the house on four of its six sides, cutting heat loss to a minimum. Excess heat from the greenhouse also flows directly into the living area through open doors or windows.

Promoters of the thermal envelope design claim they will provide 100 percent of the home's space heating needs. Test studies by the Brookhaven National Laboratory done some time ago indicated that thermal envelope homes are highly energy efficient, but some backup heat is usually required to maintain comfortable temperatures through the winter.

There are a number of other potential problems with some of these designs. The air cavities between wood stud walls may increase the risk of fire hazard. The double wall design is more expensive than a single wall design with extra insulation. Finally, if the cavity under the house is not properly sealed, it may introduce unacceptable levels of moisture into the house. Successful thermal envelope houses are being built, but there are other ways of taking advantage of convection loops inside the home for distributing heat.

Hybrid Solar Systems

The best solar system for a new home in terms of cost, comfort and convenience may well be a combination of both active and passive design, known as a "hybrid solar system." A combination may be as simple as adding a fan and ductwork to move hot air from a solarium to other parts of the house, or it could involve the use of a number of separate systems. For example, daytime heat could be provided passively by south-facing windows while an active system is relied upon to heat the house at night. An active system used only for night-time heating can be smaller and less expensive than a system designed to provide all the home's space heating needs.

Earth-Sheltered Homes

Some advocates of solar heating believe the marriage of passive solar and earth-sheltering can result in the ideal home from an energy efficiency standpoint. An earth-sheltered home is either built partially underground or banked—bermed—with earth on one or more sides (Figure 16). Earth sheltering offers two main advantages. One, cold air is not as likely to leak inside. Also, the walls of the home are not exposed to the same temperature extremes as conventional dwellings.

The deeper into the earth a house is built, the more stable the temperature. At two feet deep in Raleigh, temperatures will vary from 47 degrees in February to around 77 degrees in August. At 10 feet deep, temperatures run from 56 degrees in February to 68 degrees in August. While ground temperatures are more moderate than corresponding air temperatures, insulation still is required to prevent excessive heat loss and potential moisture problems from condensation on cold masonry.

Whether earth-sheltered construction is possible depends on site conditions and whether financing is available for this form of housing. Earth-sheltered construction also depends on the familiarity of local contractors and code officials with underground building practices and whether this type of construction is available in your area.

The ideal location for an underground home is on a south-facing slope. The north, east and west walls can be set into the hillside while the south wall is left exposed for passive solar heating. Most underground houses are constructed of 8-inch to 12-inch reinforced concrete walls, which serve as excellent storage for solar radiation collected through south-facing glass. There is no reason why a well-insulated underground home with a southern exposure cannot be 90 percent self-sufficient in heating and cooling.

Proper drainage and waterproofing also are important in earth-sheltered construction, so avoid low-lying sites. All surfaces exposed to the earth will require special waterproofing. Construction should be done correctly the first time to avoid costly expenses that might be required later to repair leaks.

Fig. 16: Earth-bermed passive solar house.

CHAPTER 5

PASSIVE COOLING TECHNIQUES

Tips To Reduce Use Of Air Conditioning

In North Carolina, your air conditioning bill can run higher than your winter heating costs. But you can get summer relief from high energy bills with passive cooling techniques. These techniques will not render your air conditioning unit obsolete. You would still have humidity problems without it. However, solar cooling can reduce significantly the amount of air conditioning you need.

In the hot, humid summers of the Southeast, passive cooling involves a twofold approach. First, direct sunlight must be kept out of your home as much as possible. South-facing windows and mass walls can be shaded with extended roof overhangs (Figure 17) or other forms of shading. The length of the overhang should equal roughly one-fourth the distance from the bottom of the window to the bottom of the overhang to shade the window in the middle of summer.

Because we have so many warm days in late fall and early spring, it is impossible to design a fixed overhang that ensures a comfortable indoor temperature throughout the year. Many homeowners prefer adjustable awnings for windows facing south (Figure 18). A trellis with vines or grapes is an attractive and very effect method for shading but does require maintenance. Interior blinds help reduce heat buildup but are not as effective as shading that stops the sun before it hits the window glass.

Windows facing east and west cannot be protected as easily from the rising and setting sun. These windows are best protected by deciduous trees or solar window screens and films. If you have skylights, greenhouse roof glazing or other horizontal glass hit by the sun to worry about, you can still use sunscreens, vegetation or reflective shutters to cut down heat buildup. However, protecting skylights from the sun is obviously more difficult than shading your windows. If you're building a new home, you must decide before construction begins whether skylights are worth the extra expense in a passive cooling design. There are new solar light tubes on the market that can provide natural light without the excessive heat build up.

Another approach to passive cooling includes design features that promote air circulation through natural convection. Vents or windows built into the lowest and highest parts of your house will release hot air trapped near the ceiling while letting in cooler air. The greater the temperature difference between the air at the top and bottom, the better your circulation will be. Clerestory windows or cupolas are often used in solar houses to provide high ventilation areas. Providing at least two windows on separate walls in a room will greatly improve cross ventilation.

Fig. 17: Fixed overhang.

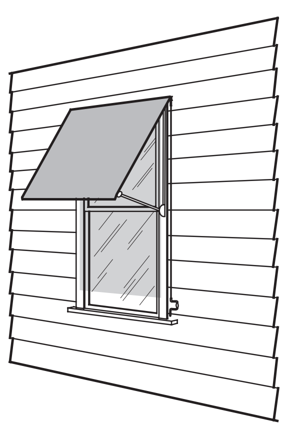

Fig. 18: Retractable awning.

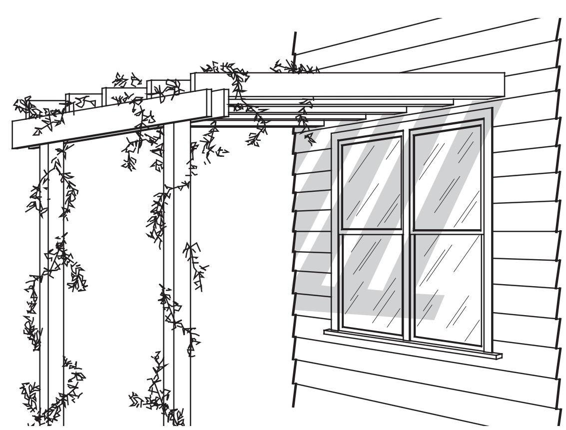

Fig. 19: Trellis with vines.

CHAPTER 6

LOW-COST SOLAR HEATERS

A Small Investment Can Get You Started In The Right Direction

You may decide that you do not want to build a new solar home or buy a complete solar heating system for your current home or apartment. Instead, you may want to build or buy a number of solar heating devices that heat individual rooms during the day. "Dayheaters" usually do not store heat for nighttime use, but they save energy and cost considerably less than solar systems with storage.

WINDOW BOX COLLECTOR

The most inexpensive type of dayheater probably is the "window box collector." The window box collector is a rectangular box with a black absorber plate and airflow channels above and below the plate. The box is sealed with glass or plastic on its sun-facing side and insulated on all other sides. Insulation also is placed on the back side of the absorber plate to prevent condensation and heat loss from the top channel (Figure 20).

The window box heater operates on the thermosiphoning principle mentioned earlier. When the box is positioned at the proper angle in a south-facing window, sunlight will heat the air in the top channel above the absorber plate and cause it to flow upward into the house. As the warm air flows out of the top vent, cooler air will be drawn into the lower channel and heated. The process continues as long as the sun shines.

Because window box collectors are inexpensive, portable and easy to build, they are popular with renters. However, they cut off sunlight from a portion of the windows. The close proximity of the inlet and outlet vents also means the air going out of the box may be drawn back into the lower channel. At best, a window box heater can be expected to help warm an average-sized room during the middle part of a sunny day.

THERMOSIPHONING AIR PANEL

A thermosiphoning air panel—called a TAP—is another low-cost solar collector that heats air by natural convection. TAP collectors are mounted against the outside wall of a house and are similar in function to a Trombe wall. A TAP basically consists of a sheet of glass mounted in a wooden frame with an air space and a corrugated aluminum sheet behind it. The aluminum absorber plate is painted black to soak up sunlight better and convert it to heat. Behind the absorber plate is another air space, where warm air rises and enters the room through a vent near the top. As warm air leaves the collector, cool air is drawn in behind it through a vent near the floor.

Several construction features make the thermosiphoning air panel far more effective than a window box collector. Because the air in the TAP travels behind the absorber plate rather than in front, less heat will be lost through the glass cover. Having the inlet and outlet vents at opposite ends also leads to better air flow than in a window box unit.

The TAP holds one other advantage. Unlike the window box, it does not close off an existing window. Nevertheless, keep in

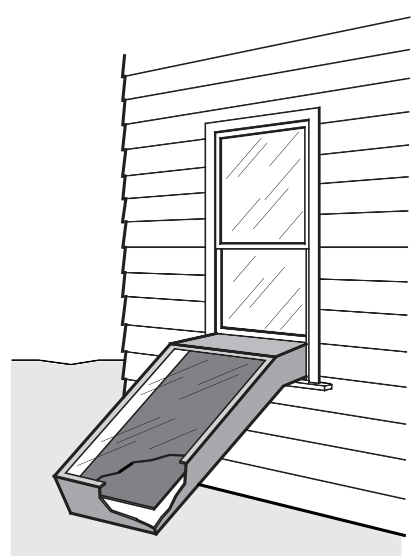

Fig. 20: Window box solar collector.

mind that a TAP requires cutting two vents into the wall. Cutting vents into the wall may not be possible if you live in rental housing.

Thermosiphoning air panels can be bought ready made or can be built from materials available at most building supply houses. The materials can be purchased for a reasonable price.

Active Solar Wall Collector

You can improve the heat output of a solar collector like a TAP by installing a blower or increasing collector size. A thermostatically controlled blower alone can increase hot air circulation by 20 percent. The small cost of electricity will be offset by the increased heating capacity. If you install a blower, use a series of baffles to force air through a serpentine pattern through the collector (Figure 21). The twisting path of the air will increase the amount of heat taken off the back of the heated absorber plate.

You also can increase the output of a solar air collector by increasing its size. A wall collector can be built almost any size or shape as long as you have the space for it. Warehouses, farm buildings and other structures

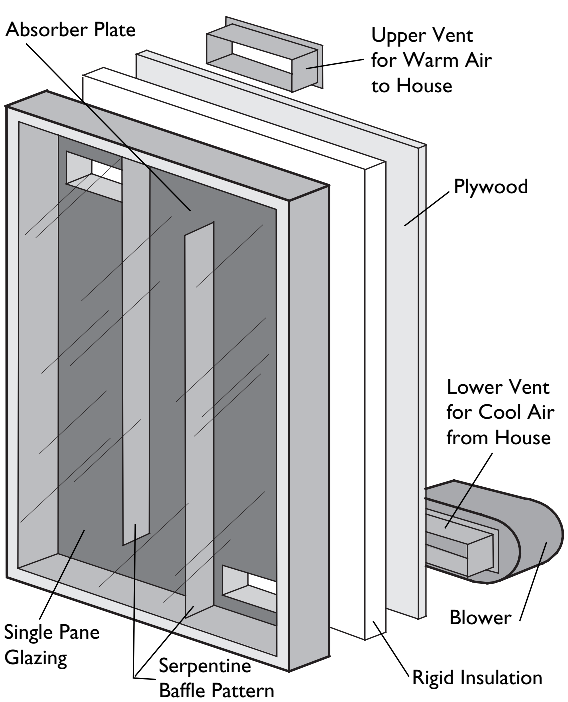

Fig. 21: Active solar wall panel collector.


Fig. 22: Affordable passive solar home.

with long, unbroken wall areas are excellent for large wall collectors. On a sunny day, an 8 foot by 8 foot collector will heat a 600 square foot area with about 60,000 BTUs.

Regardless of whether you build an active or thermosiphoning collector, make provisions to shade or vent it in the summer; otherwise, temperatures easily can rise to 150 degrees. Such high temperatures can warp and damage the collector within a year.

Additional Windows

Adding windows to the south side of the house can be one of the most cost effective ways to add solar heat to your home (Figure 22). Windows are very effective because sunlight can enter the house directly to add to your warmth and comfort. A window offers little control but it is effective.

Make sure that the windows you add have at least double-pane, insulated glass. Low emissivity glass, which has a thin metallic film that blocks heat loss, is beneficial if you don't have insulated shutters or curtains that seal tight against the window frame.

As mentioned in Chapter 4, windows that exceed 7 percent of the floor space should be accompanied by some kind of thermal storage.

Attached Sunspace

The “attached sunspace” is a very popular solar addition. The exact design may vary, but a sunspace serves as additional living space while collecting the sun’s energy. A “greenhouse” also will collect solar heat while serv-

Fig. 23: Retrofitted attached solar greenhouse.

ing as an excellent place for growing plants and vegetables (Figure 23).

You should weigh carefully whether you want a greenhouse or sunspace instead of some other type of solar collector. If you mostly want a simple, cost effective strategy to cut your heating bill, a south-facing window with night insulation—or a wall collector—will be preferable to a sunspace. On the other hand, if you want extra floor space and a higher percentage of heat provided by the sun, then a sunspace may be ideal. If it is a greenhouse you want, keep in mind that although they can provide some heat to the house, a greenhouse will use the majority of the heat it produces to keep its plants warm at night.

For the best wintertime collection, the south wall of a greenhouse should be totally glazed and tilted about 55 degrees to 60 degrees from horizontal. The tilt is especially important since plants need maximum exposure to the sun in winter. On the other hand, you can build a sunspace with the glass mounted vertically and still get 85 percent of the available solar heat. Vertical mounting has several advantages. It is simple to install and much easier to waterproof than a slanted wall. Also, a vertical wall is easier to shade—an important advantage in reducing heat gain in the summer.

Depending on your home design, building an entirely new structure may not be necessary. A porch or carport on the south side of the house can easily be converted into a sunspace by enclosing the sides with sliding glass door panels or double pane windows. For more information on building a low cost attached sunspace, you can find additional information in factsheets printed by the N.C. Solar Center.

CHAPTER 7

PHOTOVOLTAICS FOR THE HOMEOWNER

Technological Breakthroughs
Bring Solar Cells Home

In the next few years, the potential for using photovoltaic—popularly known as PV—power systems at home will increase dramatically as technological breakthroughs continue on an almost monthly basis. Besides the technological advances, prices keep dropping as production methods improve and commercial applications increase. Already, there are hundreds of homes in North Carolina that use photovoltaic systems as their principal source of electricity.

Photovoltaic systems are usually made up of a photovoltaic array, controls, an inverter and battery storage. The PV array contains the individual solar cells. Storage typically is provided by a deep-cycle, 12-volt, lead-acid battery. The heart of the PV system is made up of controls and an inverter that converts the direct current solar energy produced by the PV panels or batteries into alternating current electrical power that can be used by conventional homes and appliances. The controls and inverters also are instrumental in how batteries are charged and discharged.

There are two classifications for PV systems—stand-alone systems and utility-interactive systems.

STAND-ALONE PV SYSTEMS

The stand-alone system operates independently of any power line hooked up to your home. There are two types of stand-alone systems. "Direct systems" use electrical power as it is generated but have no storage capacity, whereas "battery storage systems" have the capacity to store electrical power generated by the photovoltaic system. Stored electrical power is then available when the sun is not shining.

The possibilities for stand-alone PV systems are extensive. Current uses of stand-alone systems are anything from water pumps and navigational signals to electrification of remote homes and area lighting. PV systems require no fuel other than the sun and have low maintenance costs. For developing countries, photovoltaics are an ideal source of power and over 200,000 homes already get their electricity through small PV systems.

In North Carolina, PV systems are available commercially for path lighting, fans, active solar water heating system pumps, electric fences, highway construction signs and call boxes.

UTILITY-INTERACTIVE SYSTEMS

Utility-interactive systems are connected to the power line that the local power company has running into your house. A typical utility-interactive system may have PV solar modules on the roof, like the Solar House at North Carolina State University. Because photovoltaic systems convert power the PV panels produce into alternating current, it is possible to sell your utility company any surplus power you might generate. However, any returns probably would be very modest. Since North Carolina does not currently have a "net metering" law that requires the utility company to buy electricity you produce at the same rate they sell, your utility company will buy your surplus electricity only at wholesale prices. You should not expect to make much money from wholesale prices.

If the market continues as it has, large PV systems will be built and owned by electric utilities and large corporations. As a result, homeowners will benefit as system costs drop and use becomes more widespread. Between 1970 and 1995, the cost of PV modules fell from $100 to $5 per peak watt. Prices are expected to continue to drop in the future to a more affordable $1 to $3 per peak watt.

CHAPTER 8

CONSUMER TIPS

* With a resurgence of demand for solar energy systems, new companies are often entering the solar marketplace. Most companies offer high quality products and use dealers and contractors who provide good service and installation. But not all. Some companies deal in shoddy products, hire fast-talking sales staff and allow systems to be installed by untrained contractors. Just as you would with any major purchase, be alert to these possibilities from the moment you contact a sales person to the day the solar system is installed and working.

* One way to ensure that you get a good solar system is to deal with a local firm that has been doing business in your area for a number of years. The fact that a company is new does not make its service or products inferior. However, there are operators who will take advantage of your enthusiasm for solar energy.

* To locate dealers of active solar systems, check the telephone yellow pages under "Solar Energy Equipment." Designers of passive systems can be found under the "Architects" listing. You also can get a list of solar energy equipment dealers and designers in your area from the N.C. Solar Center.

Sponsored by the Energy Division of the N.C. Department of Commerce in cooperation with N.C. State University, the Solar Center offers solar energy programs and resource referrals in North Carolina. You can go to the Solar Center to get free design reviews, fact sheets and other information on solar energy. The Solar Center periodically holds workshops, seminars, conferences, home tours and exhibitions on solar energy technologies. Headquartered at the N.C. State University Solar House, the Center encourages visits to the facility and the use of its library and media center. The Solar Center also maintains a website at http://www.ncsc.ncsu.edu that contains an online resource directory, bibliography and electronic versions of factsheets. Call the Solar Center at 1-800-33-NC SUN or 919-515-3480 or by email at ncsun@ncsu.edu.

* Call at least two or three dealers to get estimates on different solar systems. Never commit to buy a solar system after hearing only one sales pitch. Be skeptical if the dealer tries to force a sale on you immediately. A responsible solar dealer will not want you to regret your decision to purchase a solar system. Always ask the contractor for names of other customers and call them to ask about their experiences with the company. If possible, take a look at their installations—you don't have to be a solar expert to recognize poor workmanship.

Fast, dependable service should be one of the biggest requirements in selecting a contractor. If you are concerned about the reputation of a solar company, call the Consumer Affairs Division of the Attorney General's Office at 919-733-7741. They can inform you of any legal action or complaints against that business.

* Before the contractor gives you an estimate, make sure he performs a detailed analysis of the space heating and hot water needs of your particular household. The estimate is crucial in determining the proper collection area and storage necessary for various percentages of solar space heating or hot water. The contractor should also analyze the effect a less-than-optimum exposure to the sun will have on the system's performance.

* Once the contractor has completed the analysis of your house, ask for a written estimate that includes a breakdown of all labor and material costs. Also ask to see a copy of the system's warranty. Warranties offered by

different solar manufacturers and contractors vary considerably, so compare them carefully.

Basically, there are two types of warranties—full and limited. A full warranty is preferable because it provides the consumer with the most protection. Full warranties guarantee the product in normal use and cover component repairs and replacement at no extra cost to the customer.

A limited warranty provides coverage only for certain parts or services. For example, a limited warranty may not cover the replacement of a pump or fan. If the part has to be ordered, you also may be responsible for the shipping costs. A full warranty should cover such expenses.

If the individual components on your system are from different manufacturers, you should have a warranty from each manufacturer. These warranties should be backed by the seller and the distributor as well as the manufacturer. Regardless of the type of warranty provided, it should be read carefully to determine the actual coverage.

* A written contract covering all aspects of the installation should be provided by your solar dealer. The starting and completion dates should be in the service contract, along with a schedule for payment. Final payment should not be made until the system is fully installed and has operated normally for several days.

* Your solar dealer and any subcontractors doing the installation should certify that they have insurance coverage, including workmen's compensation, property damage and personal liability. You should check with your own insurance company to see if your existing policy will cover potential damages to the system or the house. Make sure the contractor has obtained the necessary building permits and that the system will not violate any local or state building codes. If you need clarification of the building laws, contact the Consumer Affairs Hotline of the N.C. Department of Insurance at 1-800-662-7777.

* Once the system is installed, it should be thoroughly tested by the contractor and, if installed on a new home, checked by the local inspector. Water systems should be pressure tested for leaks. You also may want to have a temperature gauge installed so you can observe its performance from time to time. The checks provide one sure way for you to know the system is working properly.

* Finally, the best way to guarantee that you get your money's worth in the solar marketplace is to know as much about the subject as possible. Hopefully, this booklet has given you a good introduction to the basic types of solar heating, cooling and hot water systems. Additional information can be obtained by contacting the Energy Division or reviewing solar literature available at libraries and bookstores. To assist you in your research, a bibliography follows this chapter. After researching the basics of solar technology, you will be better prepared to ask insightful questions about the particular systems offered by various solar dealers.

RESOURCE ORGANIZATIONS

STATE ORGANIZATIONS

Brick Association of North Carolina

P. O. Box 13290
Greensboro, NC 27415
Phone: (919) 273-5566
Fax: (919) 273-3463

The Brick Association supports the use of passive solar as a viable energy alternative. It encourages the use of passive solar guidelines for builders and architects developed by the Passive Solar Industries Council and National Renewable Energy Laboratory.

Carolinas Concrete Masonry Association

1 Centerview Drive, #112
Greensboro, NC 27407
Phone: (910) 852-2074
Fax: (910) 299-7346

The CCMA supports the implementation of passive solar applications. It distributes passive solar energy conserving house plans that incorporate the use of mass for thermal energy storage.

**Energy Division,
N.C. Department of Commerce**

430 North Salisbury Street
Raleigh, NC 27611
Phone: (919) 733-2230 or
1-800-622-7131 (toll-free in N. C.)
Fax: (919) 733-2953

As North Carolina's state energy office, the Energy Division conducts seminars and workshops, administers federal programs related to energy conservation, renewable resources and emergency planning, and offers free publications on a wide range of energy topics. The Energy Division has projects under way in the residential, commercial, industrial, agricultural, institutional and transportation sectors.

Farmer's Homes Administration

4405 Bland Road
Raleigh, NC 27609
Phone: (919) 790-2720

The FmHA provides financing for home buyers in low to middle income salary ranges, and distributes a passive solar home plan. The plan is available for a nominal charge through the state office listed or your county FmHA office.

Advanced Energy

909 Capability Drive
Raleigh, NC 27606
Phone: (919) 857-9000 or
1-800-869-8001 (toll free in NC)
Fax: (919) 832-2696

Advanced Energy is a private nonprofit corporation established by the N.C. Utilities Commission to reduce electrical demand and peak loads through research, education, demonstration, and commercialization of energy efficiency techniques. Funds are contributed by electric utilities serving North Carolina. Advanced Energy provides consulting, testing and training to utility, residential, commercial and industrial customers.

North Carolina Solar Center

Box 7401
North Carolina State University
Raleigh, NC 27695-7401
Phone: (919) 515-3480 or
1-800-33 NC SUN (toll-free in NC)
Fax: (919) 515-5778

Sponsored by the Energy Division of the North Carolina Department of Commerce, in cooperation with North Carolina State University, the N.C. Solar Center serves as the lead state organization for solar energy programs and resources in North Carolina.

Headquartered at the NCSU Solar House, a demonstration facility that is open daily and Sundays for public tour, the Solar Center conducts workshops for consumers and building professionals, operates a toll-free hot line for solar-related inquires, publishes and distributes solar publications, operates a videotape lending service and reference library, provides design assistance, offers a referral service to a network of 250 professionals, and offers tours and educational materials for teachers and students.

North Carolina Solar Energy Association
850 West Morgan Street
Raleigh, NC 27603
Phone: (919) 832-7601
Fax: (919) 832-3339

The principal nonprofit membership association working to advance the use of solar energy in North Carolina. Publishes "Carolina Sun", a quarterly newsletter/magazine covering solar developments in the state. Holds conferences and workshops periodically on solar topics. Membership open to the public. NCSEA is the state chapter of the American Solar Energy Society.

Research Triangle Institute
P.O. Box 12194
3040 Cornwalis Road
RTP, NC 27709
Phone: (919) 541-6000

An independent contract research institute located in the center of North Carolina's Research Triangle Park. RTI conducts research for and provides technical services to clients in government, industry, and public service. Research projects include photovoltaics, energy economics, biomass and alternative energy.

N.C. Cooperative Extension Service
Box 7602
North Carolina State University
104 Ricks Hall
Raleigh, NC 27695-7602
Phone: (919) 515-2811

The N.C. Cooperative Extension Service provides educational opportunities to the citizens of North Carolina through county extension offices in each of the 100 counties and the Cherokee Indian Reservation. The Cooperative Extension Service employs democratic techniques to involve local citizens in planning and implementing educational programs directed at contemporary issues.

Industrial Extension Service
College of Engineering
Box 7902
North Carolina State University
1600 Research IV
Raleigh, NC 27695-7902
Phone: (919) 515-2358
Fax: (919) 515-6159

The Industrial Extension Service, with a staff of more than 20 professionals, links business, industry, government and the engineering profession with the College of Engineering. The Industrial Extension Service focuses on bringing many of the engineering faculty and laboratories to bear on industrial, economic and societal problems and opportunities.

National Organizations

Alliance to Save Energy
1725 K Street, NW, Suite 509
Washington, DC 20006-1401
Phone: (202) 857-0666
Fax: (202) 331-9588

Alternative Energy Resources Organization
25 S. Ewing, Suite 214
Helena, MT 59601
Phone: (406) 443-7272
Fax: (406) 442-9120

American Biofuels Association
1925 North Lynn Street, Suite 1050
Arlington, VA 22209
Phone: (703) 522-3392
Fax: (703) 522-4193

American Council for An Energy Efficient Economy
1001 Connecticut Avenue, NW, Suite 801
Washington, DC 20002
Phone: (202) 429-8873
Fax: (202) 429-2248

American Hydrogen Association
216 South Clark Avenue, Suite 103
Tempe, AZ 85281
Phone: (602) 921-0433
Fax: (602) 967-6601

American Solar Energy Society, Inc.
2400 Central Avenue
Unit G-1
Boulder, CO 80301
Phone: (303) 443-3130
Fax: (303) 443-3212

American Wind Energy Association
122 C Street, NW, 4th Floor
Washington, DC 20001
Phone: (202) 383-2500
Fax: (202) 383-2505

Center for Maximum Potential Building Systems
8604 F.M. 969
Austin, TX 78724
Phone: (512) 928-4786
Fax: (512) 926-4418

Center for Renewable Energy & Sustainable Technology
1200 18th Street, NW, #900
Washington, DC 20036
Phone: (202) 530-2202
Fax: (202) 887-0497
E-mail: info@crest.org

Center for Resourceful Building Technology
P.O. Box 3866
Missoula, MT 59806
Phone: (406) 549-7678
Fax: (406) 549-4100

Critical Mass Energy Project
Public Citizen
215 Pennsylvania Avenue, SE
Washington, DC 20003
Phone: (202) 546-4996
Fax: (202) 547-7392

Energy Efficient Building Association
1829 Portland Avenue
Minneapolis, MN 55404
Phone: (612) 871-0413
Fax: (612) 871-9441

Electric Power Research Institute
Communications Services Department
P.O. Box 10412
Palo Alto, CA 94303
Phone: (415) 855-2411
Fax: (415) 855-2954

Enersol
55 Middlesex Street, Suite 221
Chelmsford, MA 01863
Phone: (978) 251-1828
Fax: (978) 251-5291

Florida Solar Energy Center
1679 Clearlake Road
Cocoa, FL 32922-5703
Phone: (407) 638-1000
Fax: (407) 638-1010

Healthy House Institute
430 N. Sewell Road
Bloomington, IN 47408
Phone: (812) 332-5073
Fax: (812) 332-5073

International Institute for Energy Conservation
750 First Street, NE, Suite 940
Washington, DC 20002
Phone: (202) 842-3388
Fax: (202) 842-1565
E-Mail: iiec@igc.apc.org

Interstate Renewable Energy Council
P.O. Box 1156
Latham, NY 12110-1156
Phone: (617) 323-7377
Fax: (617) 325-6738

National Association of Home Builders Research Center
400 Prince George's Boulevard
Upper Marlboro, MD 20772
Phone: (301) 249-4000
Toll-free: (800) 638-8556
Fax: (301) 249-0305

National BioEnergy Industries Association
122 C Street, NW, 4th Floor
Washington, DC 20001
Phone: (202) 383-2540
Fax: (202) 383-2540

National Center for Appropriate Technology
P.O. Box 3838
Butte, MT 59702-3838
Phone: (406) 494-4572
Fax: (406) 494-2905

National Energy Foundation
5160 Wiley Post Way, Suite 200
Salt Lake City, UT 84116
Phone: (801) 539-1406
Fax: (801) 328-3381

National Hydropower Association
122 C Street, NW, 4th Floor
Washington, DC 20001
Phone: (202) 383-2530
Fax: (202) 383-2531

Northeast Sustainable Energy Association
23 Ames Street
Greenfield, MA 01301
Phone: (413) 774-6051
Fax: (413) 774-6053

Passive Solar Industries Council
1511 K Street, Suite 600
Washington, DC 20005
Phone: (202) 628-7400
Fax: (202) 393-5043

Renew America
1400 16th Street, NW, Suite 710
Washington, DC 20036
Phone: (202) 232-2252
Fax: (202) 232-2617

Rocky Mountain Institute
1739 Snowmass Creek Road
Snowmass, CO 81654-9199
Phone: (303) 927-3128
Fax: (303) 927-4178

Solar Box Cookers International
1724 11th Street
Sacramento, CA 95814
Phone: (916) 444-6616
Fax: (916) 447-8689
E-mail: sbc@igc.apc.org

Solar Electric Light Fund
1734 20th Street, NW
Washington, DC 20001
Phone: (202) 234-7265
Fax: (202) 328-2555

Solar Energy Industries Association
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Washington, DC 20001
Phone: (202) 383-2600
Fax: (202) 383-2670

Solar Energy International
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Carbondale, CO 81623-0715
Phone: (303) 963-8855
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Solar Energy Research & Education Foundation
122 C Street, NW, 4th Floor
Washington, DC 20001
Phone: (202) 383-2665
Fax: (202) 383-2670

Solar Rating & Certification Corporation
c/o FSEC, 1679 Clearlake Road
Cocoa, FL 32922
Phone: (617) 323-7377
Fax: (617) 325-6738

Southface Energy Institute
241 Pine Street
Atlanta, GA 30308
Phone: (404) 872-3549
Fax: (404) 872-5009

Sun Day Campaign
315 Circle Avenue, #2
Takoma Park, MD 20912
Phone: (301) 270-2258
Fax: (301) 891-2866

Union of Concerned Scientists
26 Church Street
Cambridge, MA 02238
Phone: (617) 547-5552
Fax: (617) 864-9405
E-Mail: ucs@igc.apc.org

U.S. Export Council for Renewable Energy
122 C Street, NW, 4th Floor
Washington, DC 20001
Phone: (202) 383-2550
Fax: (202) 383-2555

World Resources Institute
1709 New York Avenue, NW, Suite 700
Washington, DC 20006
Phone: (202) 638-6300
Fax: (202) 638-0036

Worldwatch Institute
1776 Massachusetts Avenue, NW
Washington, DC 20036
Phone: (202) 452-1999
Fax: (202) 296-7365

Federal Government

U.S. Department of Energy
Alternative Fuels Hotline:
(800) 423-1363
Clean Cities Hotline:
(800) 224-8437
Building Energy Standards Hotline:
(800) 270-2633

Energy Efficiency and Renewable Energy Clearinghouse
U.S. Department of Energy
P.O. Box 3048
Merrifield, VA 22116
Toll-free: (800) 523-2929

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401
Phone: (303) 275-3000
Fax: (303) 275-4053

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (703) 487-4780
Fax: (703) 321-8547

Photovoltaic Design Assistance Center
P.O. Box 5800, Division 6218
Sandia National Laboratories
Albuquerque, NM 87185
Phone: (505) 844-8161
Fax: (505) 844-6541

Solar Thermal Design Assistance Center
P.O. Box 5800
Sandia National Laboratories
Albuquerque, NM 87185
Phone: (505) 844-3077
Fax: (505) 844-7786

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General Solar

Assessment of Solar Energy Technologies. *Dennis A. Andrejko, AIA, editor. Boulder, CO: American Solar Energy Society, 1989.*
Available from N.C. Solar Center for $8.00, this soft cover publication presents each solar technology in depth.

Alternative Energy Sourcebook. *John Schaeffer. Ukiah, CA: Real Goods Trading Corporation, 1992.*
Essentially an expanded catalog, this book has excellent chapters on resource efficient living and renewable energy. Cost is $23 from Real Goods at 1-800-762-7325.

A Builder's Guide to Energy Efficient Homes in North Carolina. *Jeffrey S. Tiller & Dennis B. Creech. Raleigh, N.C.: N.C. Department of Commerce, Energy Division, 1992.*
This book was written by Southface Energy Institute for the Energy Division and is a good manual on energy efficiency for the homeowner and homebuilder. The cost is $7 from the Energy Division at (919) 733-2230.

The Builder's Guide to Solar Construction. *Rick Schwolsky and James I. Williams. New York, NY: McGraw-Hill Book Co., 1982.*
A practical guide to solar home construction for all. Many photographs and drawings illustrate construction techniques.

Design with Nature. *Ian L. McHarg. Garden City, NY: Doubleday & Company, Inc., 1969.*
A well-known book which deals with climatic design and site planning, particularly as it pertains to urban planning and development.

A Golden Thread. *Ken Butti & John Perlin. Palo Alto, CA: Cheshire Books, 1980.*
This is an entertaining and informative book on the history and lore of solar energy.

More Other Homes and Garbage. *Jim Leckie, Gil Masters, Harry Whitehouse, & Lily Young. San Francisco, CA: Sierra Club Books, 1981.*
Very useful for those looking to develop a self-sufficient lifestyle, it covers topics ranging from aquaculture to active solar collectors. $14.95 postpaid, (415) 923-5600.

Resource-Efficient Housing: an Annotated Bibliography and Directory of Helpful Organizations. *Robert Sardinsky. Snowmass, CO: Rocky Mountain Institute, 1991.*
This resource book will guide you to the organization or information you need on a renewable energy topic. Order from Rocky Mountain Institute for $15.

Science Projects in Renewable Energy and Energy Efficiency. *NREL & DOE. Boulder, CO: American Solar Energy Society, 1991.*
A great source for science projects in the classroom or for science fairs. The material is primarily short project outlines with some background information. Excellent bibliography and resource guide. $10 from Solar Center.

Passive Solar

Climatic Design. *Donald Watson, FAIA and Kenneth Labs. New York, NY: McGraw-Hill Book Company, 1983.*
A well written guide to architectural considerations of passive solar design with many useful formulae and indexes.

Designing & Building a Solar House. *Donald Watson. Pownal, VT: Garden Way Publishing, 1985.*
More conceptual than Climatic Design, this book is a complete guide to active and passive solar energy in home design.

Design with Climate: Bioclimatic Approach to Architectural Regionalism. *Victor Olgyay. Princeton, NJ: Princeton University Press, 1963.*
One of the seminal works of passive solar design. An excellent source of information for professionals and the general public.

Energy Conserving Site Design. *E. Gregory McPherson, editor. Washington, DC: American Society of Landscape Architects, 1984.*

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The New Solar Home Book. *Bruce Anderson. Andover, MA: Brick House Publishing Company, 1987.*
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The Passive Solar Energy Book (Expanded Professional Edition). *Edward Mazria. Emmaus, PA: Rodale Press, 1979.*
No longer in print but worth looking for in your local library. This is a very easy to use guide for designing passive solar homes.

Passive Solar Energy: The Homeowner's Guide to Natural Heating and Cooling. *Bruce Anderson and Malcolm Wells. Amherst, NH: Brick House Publishing Company, 1994.*
A well-illustrated and informative how-to book which describes solar principles in simple terms, with a minimum of technical jargon.

Passive Solar Retrofit Handbook. *Thompson, Hancock, White Architects and Planners. Atlanta, GA: Southern Solar Energy Center, 1980. Available from N.C. Solar Center for $8.*

Sun, Wind, and Light: Architectural Design Strategies. *G.Z. Brown. New York, NY: John Wiley and Sons, 1985.*
Written for architects, this book presents solar design concepts for buildings and town planning with many illustrations.

Solar House Plans

Affordable Passive Solar Homes. *Richard L. Crowther, FAIA. Denver, CO: SciTech, 1984.*
Many home designs by a well known solar architect. Large and small, this is a good place to start for the prospective home builder. Available from ASES for $20.

Energy Conserving House Plans. *Carolinas Concrete Masonry Association. Greensboro, NC: CCMA, 1983.*
A copy of this planbook, which includes 18 plans of 1,000-3,000 square feet in size, is available at no charge from CCMA.

Planbook for Low-Cost Energy Efficient Homes. *Southface Energy Institute. Atlanta, GA: 1988.*
This planbook includes five solar and energy efficient low-cost designs, each about 1,000 square feet in size, and has been used by affiliates of Habitat for Humanity in the construction of several of their homes. One copy may be obtained at no cost from SEI.

Solar Homes for North Carolina. *N.C. Department of Commerce, Energy Division. Raleigh, NC, 1984.*
A booklet containing 12 passive solar house plans designed specifically for the North Carolina climate. Available at no cost from the North Carolina Solar Center.

Sun-Inspired Home Plans. *Debbie Rucker, AIA. Greensboro, NC: Energetic Design, Inc., 1991.*
This book includes four sets of designs, each with numerous options for changing size, facade, number of rooms, etc. It also contains an excellent section on energy considerations for those building their own home. To order this planbook, send $12 to: Energetic Design, P.O. Box 4446, Greensboro, NC 27404 (919) 852-9131.

Photovoltaics

A Guide to the Photovoltaic Revolution. *Paul D. Maycock and Edward N. Stirewalt. Emmaus, PA: Rodale Press, 1985.*
An introductory overview of the photovoltaic industry and its impacts on society and the economy.

The New Solar Electric Home. *Joel Davidson & Richard J. Komp. Ann Arbor, MI: Aatec Publications, 1990.*
One of the best overall books on photovoltaics for the homeowner with complete information and many examples. $18.95 postpaid from the N.C. Solar Center.

Practical Photovoltaics: Electricity from Solar Cells. *Richard J. Komp. Ann Arbor, MI: Aatec Publications, 1995.*
A recently-published guide to the practical applications of photovoltaics.

The Solar Electric House: Energy for the Environmentally-Responsive, Energy-Independent House. *Steven Strong with William G. Scheller. Emmaus, PA: Rodale Press, 1993.*
Written by one of the nations most knowledgeable photovoltaic designers, this book is a wealth of practical information. Order from the N.C. Solar Center, $19.95.

The Solar Electric Independent Home. *Paul Jeffrey Fowler. Worthington, MA: Fowler Solar Electric, Inc., 1991.*
A hands-on book with valuable details written for electricians and homeowner, written by a photovoltaic supplier, designer and installer. $17.95 postpaid from the N.C. Solar Center.

Solar Water Heaters

Active Solar Heating Systems Design Manual. *Atlanta, GA: ASHRAE, 1988.*
A technical evaluation of different systems and guide to systems sizing. Available from ASHRAE.

Active Solar Thermal Design Manual. *Theodore D. Swanson, P.E., project manager. Baltimore, MD: Mueller Associates, 1985.*
A very technical manual on solar DHW system sizing and design. Available from ASHRAE.

Design and Installation of Solar Heating and Hot Water Systems. *J.R. Williams. Woburn, MA: Butterworth Publishers, 1983.*

Installation Guidelines for Solar DHW Systems in One & Two Family Dwellings. *HUD-DOE Publication. Philadelphia, PA: Franklin Research Center, 1979.*
Very useful and accessible nuts-and-bolts information on installing Solar DHW. Available from N.C. Solar Center for $10.

Solar Water and Pool Heating Design and Installation Manual, *Florida Solar Energy Center, 1679 Clearlake Road, Cocoa, FL 32922-5703, 1992.*
An installation guide focused towards solar contractors and plumbers, with good diagrams and descriptions of water heating systems and materials.

Solar Water Heater Handbook: A Guide to Residential Solar Water Heaters. *R. Montgomery and J.H. Livingston, editors. New York, NY: John Wiley & Sons, 1986.*

Low-Cost Solar Heating Devices

The Food and Heat Producing Solar Greenhouse. *Rick Fisher and Bill Yanda. Santa Fe, NM: John Muir Publications, 1980.*
Authoritative and friendly with all the how-to's for greenhouses and vegetable growing. $8 from John Muir Publications, (505) 982-4078.

The Homeowner's Complete Handbook for Add-On Solar Greenhouses & Sunspaces. *Andrew M. Shapiro. Emmaus, PA: Rodale Press, 1985.*
An excellent reference for do-it-yourself building. Focused more on actual construction techniques than the Muir book. Contact Rodale Press at 1-800-441-7761 for ordering, $19.95.

Solar Air Collectors - A Design and Construction Guide for Low-Cost Systems. *Alamosa, CA: San Luis Valley Solar Energy Association.*

Solar Retrofit. *Daniel K. Reif. Andover, MA: Brick House Publishing Company, 1981.*
Includes descriptions and plans for retrofitting a direct gain system, solar greenhouse, thermosiphoning air panel, and active solar wall collector. Call (508) 635-9800 for ordering, $11.95.

Solar Wall Collector Plans Review. *Don Malloy and Ambrose Spencer. Brattleboro, VT: Northeast Solar Energy Association, 1987.*
A comprehensive source and evaluation of wall collector plans. Good general information on all styles and materials. Available from NESEA, (413) 774-6051.

Periodicals

Carolina Sun
North Carolina Solar Energy Association
850 W. Morgan St.
Raleigh, NC 27603
(919) 832-7601, Fax: (919) 832-3339
Free with membership in NCSEA. This magazine/ newsletter will keep you up to date on solar and energy information and events.

Energy Design Update
Cutter Information Corporation
37 Broadway
Arlington, MA 02174
1-800-964-5118
$297 per year. $197 discounted price for contractors and educators. A very thorough reporting of national energy news relating to building products and techniques.

Home Energy
2124 Kittredge, Suite 95
Berkeley, CA 94704
(510) 524-5405
$49 for six issues. Geared toward energy professionals and contractors, this magazine is a reliable source for information, issues and construction techniques.

Home Power Magazine
P.O. Box 520
Ashland, OR 97520
$22.50 for six issues. The source for do-it-yourself information on all types of solar energy with an emphasis on electric power. This magazine is informative and enjoyable.

Solar Industry Journal
122 C Street, NW, 4th Floor
Washington, DC 20001
(202) 383-2600
$25/year, free to SEIA members.
A trade journal for U.S. solar equipment manufacturers, installers and institutions, this journal covers current events world-wide.

Solar Today
American Solar Energy Society
2400 Central Avenue, Unit G-1
Boulder, CO 80301
(303) 443-3130
$29/year, free to ASES members. This broad-based current events magazine is an excellent source for information on recent developments in all types of solar energy.

Sun World
International Solar Energy Society
192 Franklin Rd
Birmingham B30 2HE, UK
+44 21 459 4826
$20/ 4 issues. Similar to Solar Today but with an international focus.

Fact Sheets

These fact sheets are provided free of charge by the North Carolina Solar Center. Call toll free: 1-800-33-NC SUN, inside North Carolina, or (919) 515-3480 to request a copy of the following:

Cost of Photovoltaic-Generated Electricity

Decorating Your Passive Solar Home

Energy Education Resources for Teachers and Students

Energy-Saving Landscaping for Your Passive Solar Home

Heating Your Swimming Pool with Solar Energy

Information Resources for Conservation and Renewable Energy

Low-Cost Solar Options for Retrofit and Affordable Housing

Passive and Active Solar Domestic Hot Water Systems

Passive Cooling for Your North Carolina Home

Passive Solar Design Checklist

Passive Solar Options for North Carolina Homes

Passive Solar Retrofit for North Carolina Homes

Photovoltaic Applications

Photovoltaic Power System of the NCSU Solar House

Photovoltaics: Electricity from the Sun

Selecting a Site for Your Passive Solar Home

Siting of Flat Plate Solar Thermal Collectors and Photovoltaic Modules

Solar Energy and You

Solar Energy: An Overview

Sources of Solar Home Plans

Space Heating with Active Solar Energy Systems

Summer Shading and Exterior Insulation for North Carolina Windows

Sunspace Design Basics

Troubleshooting Your Solar DHW System

Tax Credit Guidelines

A Word to the Wise