

Passive and Active Solar Domestic Hot Water Systems

Introduction

Solar hot water heaters can provide households with a large proportion of their hot water needs while cutting back on home energy costs. The amount of hot water that solar energy will provide depends on the type and size of the system, the climate, and the quality of the site in terms of solar access. A back-up heating system for water will be necessary during times when solar radiation is insufficient to meet hot water demands. Solar water heaters come in a variety of shapes, sizes, and capabilities, ranging from small passive heaters to three- or four-panel active systems costing several thousand dollars.

Before you buy a solar domestic hot water system, find out what your potential savings will be. Private firms can audit your home to determine how present energy costs can be reduced and whether a system would be cost-effective. If you decide to install a system, investigate several options before deciding which type is best for your site. A well-made, properly maintained system should last 15 to 20 years or more, which means your decision will have long-lasting results. Before selecting a system, check with licensed state and local plumbing and electrical companies to ensure the system complies with state and local codes. Currently, the state of North Carolina offers a tax credit for solar hot water systems. For details on eligibility requirements, refer to the Solar Center's fact sheet—*Solar Tax Credits for North Carolina*.

Also check with solar professionals - builders, contractors, designers, home heating suppliers - for guidance. Unless you are an experienced plumber, it is recommended that you consult a professional to install your solar water heating system. The Solar Center maintains the Directory of Renewable Energy and Efficiency Professionals which includes a listing of solar hot water installers in North Carolina. Currently, it is available on the Solar Center's website www.ncsc.ncsu.edu under the publications section.

This fact sheet will provide a basic overview of the basic components, types of systems, and installation issues. In 1999, the Solar Center produced a report titled *Evaluation of Pack-*



Figure 1. Homes in a Neighborhood with Active Solar Water Heating Systems.

aged Solar Domestic Hot Water Systems for North Carolina. Request this document from the Solar Center for more detailed information on readily available systems that are appropriate for North Carolina.

Solar Rating and Certification Corporation (SRCC) is an independent third-party certification organization. The SRCC rates both solar collectors and solar systems. These ratings may help you understand the differences between systems, and may also help you determine which system will be most cost-effective for your home. The participation in SRCC certification is voluntary. More detailed information on the SRCC Solar Collector and System Certification Program and a list of manufacturers with SRCC rated systems is available on their website at www.solar-rating.org.

The Florida Solar Energy Center (FSEC) also provides testing of solar collectors. All solar water collector that are manufactured or sold in Florida must be certified by FSEC. For more information on FSEC's testing and certification program, check their website at www.fsec.ucf.edu.

Basic Components

Although the design type of systems can significantly differ, certain components are common to all systems.

Collectors

A diagram of the most common collector type used in domestic water heating, a flat plate collector panel, is shown in Figure 2. The panel is an insulated weatherproof box containing a dark solar absorber plate under one or more transparent covers. The box is usually made of metal such as aluminum. The dark absorber soaks up heat from sunlight that passes through the cover, and then gives the heat up to a heat transfer fluid flowing through tubes under the absorber plates.

Some solar water heating systems use concentrating collectors instead of flat plate collectors. These collectors may be less effective during cloudy weather and are usually more expensive than flat plate systems, they can produce higher temperatures than flat plates. Another type of collector used for domestic water heating is the evacuated tube collector. These collectors consist of an absorber surface inside a tempered glass vacuum tube. The vacuum helps to reduce convective heat losses.

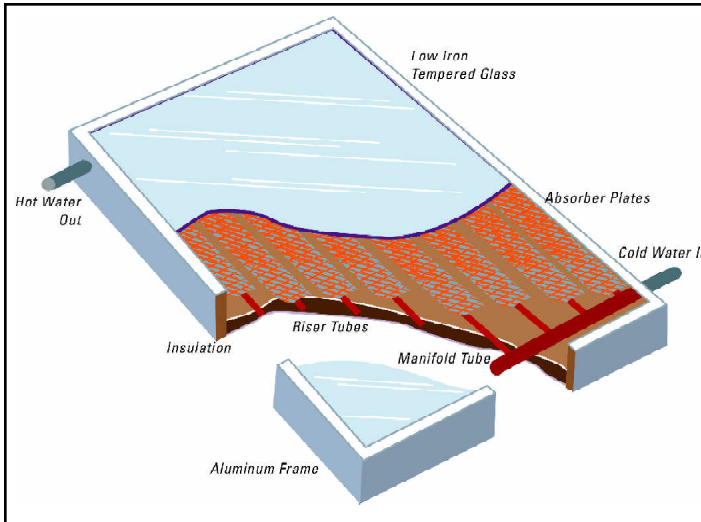


Figure 2. Flat-Plate Solar Collector

Storage Tank

Solar heated water may be stored in a tank that also houses an electric backup heating element (a “one-tank” system), or it may be stored in a separate tank that feeds into the tank of a conventional gas or electric water heater (a “two-tank” system). Whether one or two tanks are used, solar energy preheats the household water. At night and on cloudy days, the conventional backup heater boosts the water to the desired temperature. On sunny days, however, when a typical solar system can raise water to 140°F (the maximum temperature recommended for household water), the backup heater remains off. The solar storage tank is usually large enough to hold at least a day’s supply of hot water.

Common Types of Systems

Systems are classified as either passive or active and direct or indirect. Passive systems rely on natural convection to circulate the water through the collectors. Integral Collector Storage (ICS) and thermosiphon systems are passive systems. Active systems use electrically driven pumps and valves to control the circulation of the heat absorbing liquid. This allows greater flexibility than their passive counterparts since the hot water storage tank does not have to be above or near the collectors. Also, active systems are designed to operate year round without any danger of freezing. The Draindown, Pressurized Glycol, and Drainback are active systems.

All solar water heating systems can be characterized as either direct or indirect, depending on whether household water is heated directly in the collector or via a heat exchanger. In direct systems (Figure 3), the fluid heated in the collectors is potable water, which flows directly to the faucet or washing machine. Direct systems, whether pumped or thermosiphoning, cannot be used in areas with hard or acidic water. Scale deposits would quickly clog the inside of the absorber tubing, and corrosion would impair the entire system. The main direct system types are Integral Collector Storage and Draindown.

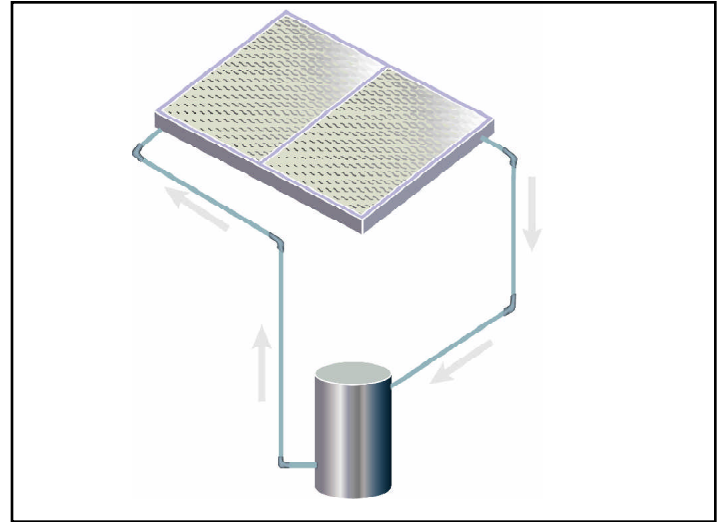


Figure 3. Direct Solar Water Heater

In indirect or closed loop systems (Figure 4), the heat transfer fluid is treated water, a refrigerant, or a non-freezing liquid such as an anti-freeze solution, hydrocarbon oil, or silicone. The heat it draws from the absorber plate is transferred to the potable water through a heat exchanger such as a coil either inside or wrapped around the storage tank. The indirect systems types are Thermosiphon, Drainback, and Pressurized Glycol. The best choice for hard water areas, or for people who do not want to worry about possible freeze damage to their solar array, is an indirect system. If the transfer fluid is toxic, a double walled heat exchanger must be used to ensure that the water supply is not contaminated. Most local codes allow a single walled heat exchanger to be used when the transfer fluid is non-toxic. The single walled heat exchanger is usually placed inside the water heater for maximum transfer efficiency, but a separate unit outside the tank can be used to house the heat

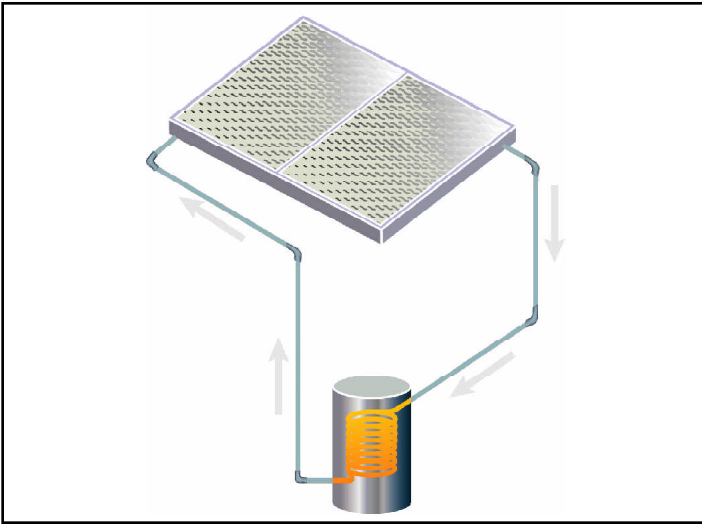


Figure 4. Indirect Solar Water Heater

exchanger. Be sure that it is accessible and well insulated. The type of heat exchanger system can markedly affect the overall efficiency of the solar system since heat exchangers range in efficiency from less than 40 percent to about 90 percent.

While indirect systems are the most flexible for layout and installation, they are generally more expensive to purchase and install. The costs of purchasing and installing most active systems range from \$2500 to \$6000 in northern climates and \$2000 to \$4500 in the Sunbelt.

Protection against freezing is essential for maintaining all solar domestic hot water systems, especially in regions where the temperature frequently drops below 32°F. Freezing can occur at night even at temperatures above 32°F because the collectors radiate heat back out to their environment. The need for freeze protection may dominate the choice of what type of system you install. Passive systems are generally the most susceptible to freezing.

Passive Systems

Integral Collector Storage (ICS)

In an integral collector system, the collector and storage tank are combined. The ICS consist of several metal tanks which have a selective absorber finish and are at least 4" in diameter. The outlet at the top of one tank is connected to the bottom of the inlet of the next tank to create a series. Because the collector is also storage, it has several layers of glazing over the tanks to reduce heat loss. The solar heated water is drawn into an auxiliary heater inside the house as needed. These systems are less expensive and simple, but there is more heat loss at night. For North Carolina, the ICS system does not provide adequate freeze protection.

Thermosiphon Water Heaters

Thermosiphon systems consist of a solar collector panel to absorb solar heat and a separate storage tank, either attached to the top of the collector or placed inside the house. The collector must be mounted at least a foot below the storage tank to permit thermosiphoning, which is the upward movement of heated water by natural convection. When the fluid in the collector is heated, it becomes less dense and rises to the top of the collector and into either a heat exchanger or storage tank.

Although thermosiphon systems can be quite efficient and supply 40 to 60 percent of your hot water, storage problems may inhibit their use. Because the storage tank must be installed above the collector, it is often placed on an upper floor or high in the attic above the roof rafter. In some cases, the roof or flooring may have to be reinforced because water tanks are heavy. Collectors can be placed on the ground if an adequate site is available for them and the storage tank.

In a thermosiphon system, fluid remains in the collector when convection stops (during sunless periods). A direct thermosiphon design is possible. However, if the water freezes, it can expand with enough force to burst the pipes or tanks. Direct thermosiphon collectors generally cannot tolerate freezing and are not recommended for climates where freezing is a problem (as in North Carolina).

Direct Active Systems

Draindown

In a draindown system (Figure 5), water is pumped from the hot water storage tank up to the collectors and back again. It derives its name from the electrically powered draindown valve which is the key to its protection against freezing. When the sun is shining, the valve is activated and the pump circulates water through the pressurized solar loop. When there is not enough solar gain and the outdoor temperature drops to near 32°F (the freezing point), a sensor signals the central controller to deactivate the valve. (In clear, dry areas like Arizona and New Mexico, freezing may occur when the ambient temperature drops to only 40°F because the collectors radiate heat to the clear night sky.) This causes the pressure in the loop to drop, and all the water in the collectors and the exposed plumbing empties out through a special opening into a house drain. When the temperature rises above the freezing point, the draindown valve will activate and the pump will once again circulate the water.

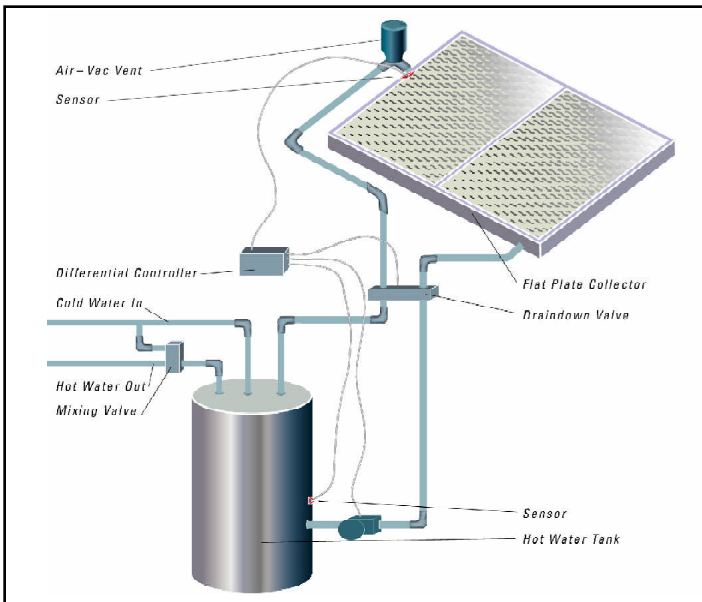


Figure 5. Draindown Solar Water Heating System

Photovoltaic (PV) powered solar domestic hot water systems use PV modules to convert sunlight into direct current (DC) electricity. This electricity powers a DC pump that circulates water through the solar collectors. The PV power is needed only for active systems and can be used for either a direct or indirect system. The pump can only run when there is enough sunlight to pump water through the collectors. These systems are very simple, and tend to be reliable and efficient, providing hot water when other systems have been shut down by power outages. The water heating system at the North Carolina Solar House is a Direct Draindown system powered by a PV module. The system has one 32 square foot flat plate collector and a 50 gallon storage tank.

Indirect Active Systems

Drainback

As in the draindown system, the drainback system (Figure 6) empties its collectors of water to avoid freezing damage when the temperature falls near the freezing point. However, there are several differences which distinguish the drainback system from the draindown system. First, the water from the drainback system is not potable water and empties back into a holding tank where it is saved, whereas in a draindown system the water is potable water and is emptied down the house drain. Another main difference is that the loop between the holding tank and the collectors is not pressurized in the drainback system. Therefore, when the thermostat signals the pump to turn off, the water drains by force of gravity. No electric valves are used which might fail and there is no need for expansion tanks. Distilled water is used for the heat transfer fluid in the collectors.

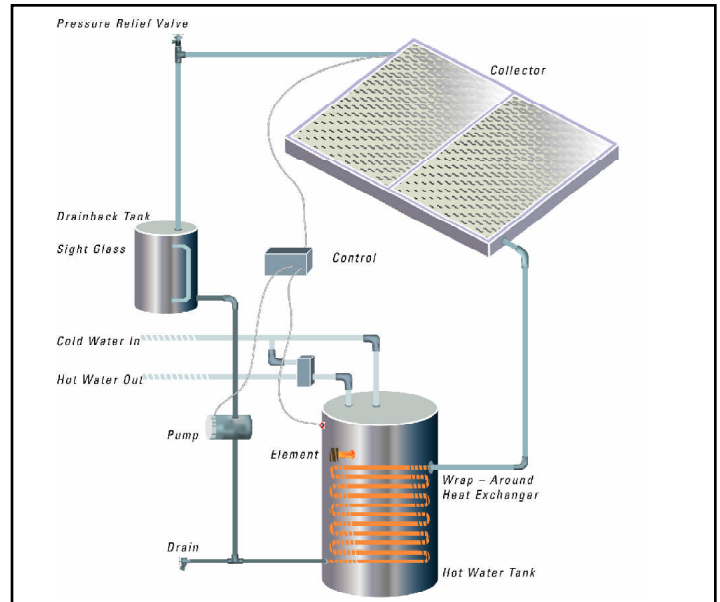


Figure 6. Drainback Solar Water Heating System

Pressurized Glycol

The other indirect active system is the pressurized glycol system shown in Figure 7. The heat transfer fluid either a glycol (usually propylene or ethylene glycol) or other hydrocarbon which provides freeze protection. As mentioned earlier, if the heat transfer fluid is considered toxic, a double walled heat exchanger must be used. If the collector fluid is non-toxic, a single walled heat exchanger can be used. The glycol solution should be inspected regularly, usually annually. Follow the fluid manufacturers' guidelines for the inspecting and refilling collectors. Because these systems are pressurized, fill and drain valves must be incorporated to add or change the collector fluid. Like with draindown system, a PV module can be used to power the pump in a pressurized glycol system.

System Sizing, Siting, and Installation Considerations

Conservation First

Conserving water is an important part of energy conservation. A few simple measures can markedly reduce consumption. Begin by installing low-flow showerheads or flow restrictors in showerheads and faucets. Next, check the thermostat setting on the hot water tank. Many thermostats are set at 140°F. It is possible to set the thermostat at 120°F and still have adequate hot water, particularly if the home does not use a dishwasher. (Dishwashers without automatic water heating features require that the water be heated to 140°F). Try wrapping a blanket of insulation around the hot water tank to reduce heat loss. Insulating blankets are readily available from building supply

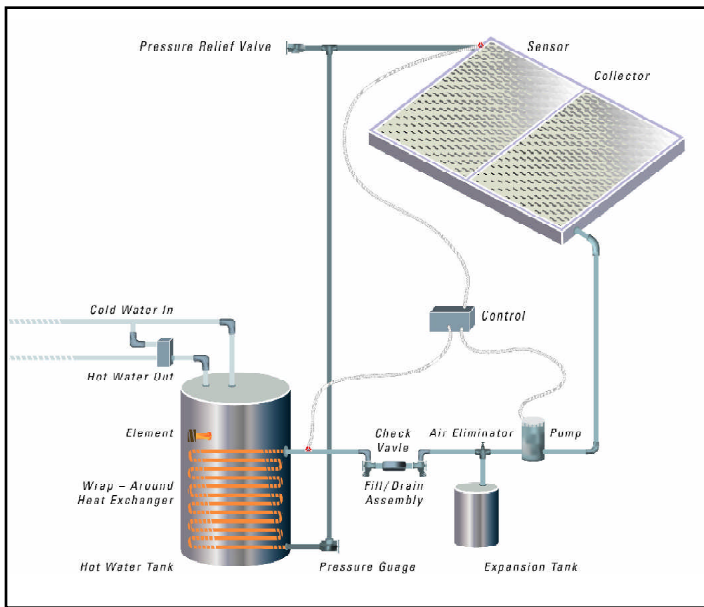


Figure 7. Pressurized Glycol Solar Water Heating System

stores or home centers. Finally, insulate hot water pipes if they pass through unheated areas and can be reached.

For more information on conserving hot water, read the Energy Efficiency and Renewable Energy Network’s (EREN) fact sheet *Energy Efficient Water Heating*.

Sizing

If hot water consumption is reduced, hot water demands may be filled by a small solar array that is easy to install. Small systems are also cheaper and will pay for themselves sooner through energy savings. System sizing of course depends on your hot water consumption but rules of thumb can help give an idea of system size. In general, you will need about 10 to 18 ft² of collector area per person in your household. You will want around 1.5 to 2.0 gallons of storage per ft² of collector area. For a family of four, these guidelines translate into 40 to 72 ft² of collector area and 60 to 140 gallons of storage. Collectors dimensions are roughly 4’ X 8’ or 32 square feet, therefore, a system for a family of four generally will have 1 to 3 collectors.

Location

A solar energy system needs to be located where plenty of sunshine strikes its collector surface. The following recommendations will help ensure that your collector receives the greatest amount of sunlight.

First, determine which way is south. Although your solar collectors will perform best if they are oriented toward true south, this rule of thumb can be modified to accommodate weather conditions, roof orientation, and other local factors. Facing collectors 20 to 30 degrees east or west of true south will not significantly affect collector performance for water heating applications. For more detailed information on how to determine collector siting, read the North Carolina Solar Center’s factsheet “Siting of Active Solar Collectors and Photovoltaic Modules.”

In addition to orientation of your collectors, the horizontal tilt of the collectors will affect their performance. A solar collector receives maximum solar radiation when the sun’s rays strike the surface at right angles. Because the sun’s angle above the horizon changes throughout the year, collectors are usually tilted to receive maximum solar radiation either seasonally or annually. To optimize annual performance for a domestic hot water system, solar collectors should be tilted at an angle equal to the local latitude. For North Carolina the latitude angle will be between 34 and 36 degrees. Many people will want to mount collectors directly to their roof. The exact tilt of a collection area is not crucial; a 10° variation to suit a roof’s pitch makes almost no difference. Some efficiency may be sacrificed to allow placement of collectors to be more aesthetic and less intrusive.

Now that it is fairly clear how to use the sun to your advantage, it is necessary to check your present home or future house site for any obstructions or restrictions that could prevent solar collectors from getting adequate exposure to solar radiation. Consider factors such as collector location, access to sunlight, and potential installation complications. Any of these could hamper – and some might rule out the installation of a solar energy system on the property.

Look around for a generally unshaded south facing surface that is large enough for the collectors. Avoid shading, especially when the sun’s rays are the most intense, generally between 9 AM and 3 PM.

Shading most likely comes from two sources:

- Parts of the house, such as chimneys, dormers, and overhangs.
- Buildings or trees to the south, such as large evergreens, that may not cause shade in summer but may cast long shadows when the winter sun is low in the sky. Trees that shed their leaves may still reduce the efficiency of the collectors in the winter because trunks and branches may block out the sun.

In a few cases, obstructions to sunlight provide less of an obstacle than certain characteristics of your house. Consider the following questions and think about discussing them later with an installer, particularly with respect to costs:

- Piping or ductwork: How difficult will it be to route pipes or ducts from the basement or ground floor to the roof? Will sections of wall or floor need to be cut open?
- Storage tank: Is there room in the basement or on the ground floor for a solar storage tank that measures 3 feet in diameter and 6 feet in height? Will it fit near your water heater? Can it be brought through your stairways and doors?
- Working conditions: If you are planning for a roof-mounted collector, is there easy access to the attic? What about the slope and accessibility of the roof? Could an installer easily work there?
- Roofing materials: Can the collectors' supports be readily fastened to the roof? Slate and clay tile, which are brittle and chip easily, are materials requiring unusual care.
- Aesthetics: How will the collectors alter the appearance of the house? Will you like the way it looks? Are the neighbors likely to object?

Conclusion

Properly installed domestic solar hot water systems are efficient and reliable. System configurations can range from simple systems that rely on gravity to more complex systems that require pumps, controllers, and heat exchangers. Although they have a higher initial cost than a conventional water heater, they will dramatically reduce fuel consumption and can have a payback of 5-10 years. Again, it is recommended that you hire a professional to install your solar hot water system. If additional technical assistance is needed, contact the North Carolina Solar Center.

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The NC Solar Center is sponsored by the State Energy Office, NC Department of Administration, and the US Department of Energy, with state Energy Program funds, in cooperation with North Carolina State University.