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ENERGY EFFICIENCY AND RENEWABLE ENERGY CLEARINGHOUSE

Solar Water Heating

This publication provides basic information on the components and types of solar water heaters currently available and the economic and environmental benefits of owning a system. Although the publication does not provide information on building and installing your own system, it should help you discuss solar water heating systems intelligently with a solar equipment dealer.

Solar water heaters, sometimes called solar domestic hot water systems, may be a good investment for you and your family. Solar water heaters are cost competitive in many applications when you account for the total energy costs over the life of the system. Although the initial cost of solar water heaters is higher than that of conventional water heaters, the fuel (sunshine) is free. Plus, they are environmentally friendly. To take advantage of these heaters, you must have an unshaded, south-facing location (a roof, for example) on your property.

These systems use the sun to heat either water or a heat-transfer fluid, such as a water-glycol antifreeze mixture, in collectors generally mounted on a roof. The heated water is then stored in a tank similar to a conventional gas or electric water tank. Some systems use an electric pump to circulate the fluid through the collectors.

Homes such as this one use solar water heaters to supply most of the hot-water needs for the household.

Using less hot water reduces the size (and cost) of the solar water heater you will need.

Solar water heaters can operate in any climate. Performance varies depending, in part, on how much solar energy is available at the site, but also on how cold the water coming into the system is. The colder the water, the more efficiently the system operates. In almost all climates, you will need a conventional backup system. In fact, many building codes require you to have a conventional water heater as the backup.

First Things First

Before investing in any solar energy system, it is more cost effective to invest in making your home more energy efficient. Taking steps to use less hot water and to lower the temperature of the hot water you use reduces the size and cost of your solar water heater.

Good first steps are installing low-flow showerheads or flow restrictors in shower heads and faucets, insulating your current water heater, and insulating any hot-water pipes that pass through unheated areas. If you have no dishwasher, or your dishwasher is equipped with its own automatic water heater, lower the thermostat on your water heater to 120°F (49°C). For more information on ways to use less energy for water heating, contact The Energy Efficiency and Renewable Energy Clearinghouse (EREC—see *Source List* at the end of this publication).

You'll also want to make sure your site has enough available sunshine to meet your needs efficiently and economically. Your local solar equipment dealer can perform a solar site analysis for you or show you how to do your own. You can also contact EREC for more information.

Remember: Local zoning laws or covenants may restrict where you can place your collectors. Check with your city, county, and homeowners association to find out about any restrictions.

Solar Water Heater Basics

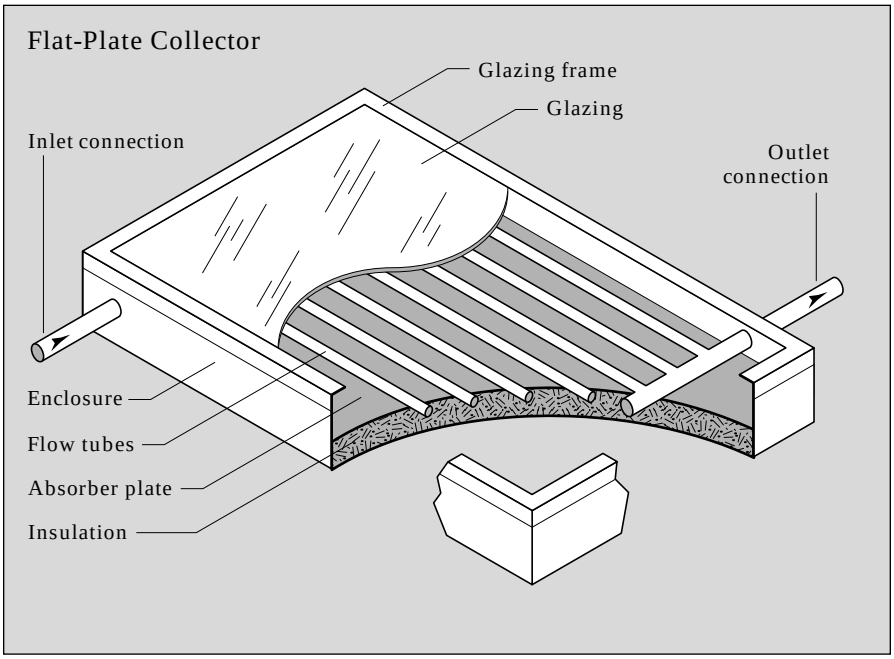
Solar water heaters are made up of collectors, storage tanks, and, depending on the system, electric pumps.

There are basically three types of collectors: flat-plate, evacuated-tube, and concentrating. A flat-plate collector, the most common type, is an insulated, weatherproofed box containing a dark absorber plate under one or more transparent or translucent covers.

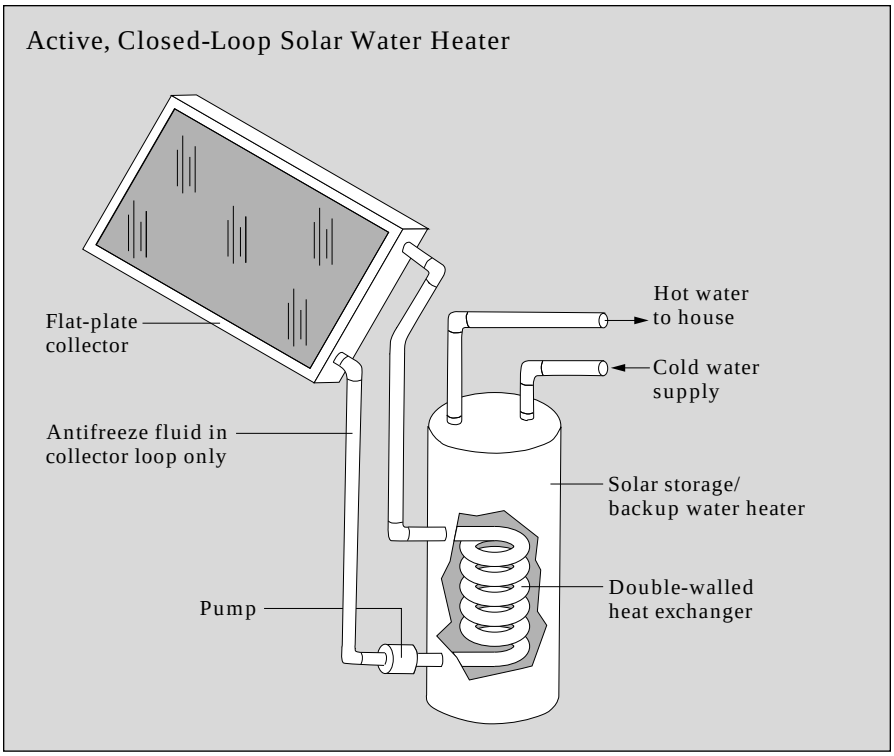
Evacuated-tube collectors are made up of rows of parallel, transparent glass tubes. Each tube consists of a glass outer tube and an inner tube, or absorber, covered with a selective coating that absorbs solar energy well but inhibits radiative heat loss. The air is withdrawn ("evacuated") from the space between the tubes to form a vacuum, which eliminates conductive and convective heat loss.

Concentrating collectors for residential applications are usually parabolic troughs that use mirrored surfaces to concentrate the sun's energy on an absorber tube (called a receiver) containing a heat-transfer fluid. For more information on solar collectors, contact EREC.

Most commercially available solar water heaters require a well-insulated storage tank. Many systems use converted electric



A flat-plate collector is an insulated, weatherproofed box containing a dark absorber plate. The plate heats up and transfers the heat to the fluid flowing through tubes in or near the absorber plate.



An active, closed-loop system heats a heat-transfer fluid (such as water or antifreeze) in the collector and uses a heat exchanger to transfer the heat to the household water.

Active systems use electric pumps, valves, and controls to circulate fluid through the collectors.

water heater tanks or plumb the solar storage tank in series with the conventional water heater. In this arrangement, the solar water heater preheats water before it enters the conventional water heater.

Some solar water heaters use pumps to recirculate warm water from storage tanks through collectors and exposed piping. This is generally to protect the pipes from freezing when outside temperatures drop to freezing or below.

Types of Solar Water Heaters

Solar water heaters can be either active or passive. An active system uses an electric pump to circulate the heat-transfer fluid; a passive system has no pump. The amount of hot water a solar water heater produces depends on the type and size of the system, the amount of sun available at the site, proper installation, and the tilt angle and orientation of the collectors.

Solar water heaters are also characterized as open loop (also called "direct") or closed loop (also called "indirect"). An open-loop system circulates household (potable) water through the collector. A closed-loop system uses a heat-transfer fluid (water or diluted antifreeze, for example) to collect heat and a heat exchanger to transfer the heat to household water.

Active Systems

Active systems use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. They are usually more expensive than passive systems but are also more efficient. Active systems are usually easier to retrofit than passive systems because their storage tanks do not need to be installed above or close to the collectors. But because they use electricity, they will not function in a power outage. Active systems range in price from about $2,000 to $4,000 installed.

Open-Loop Active Systems

Open-loop active systems use pumps to circulate household water through the collectors. This design is efficient and lowers operating costs but is not appropriate if your water is hard or acidic because scale and corrosion quickly disable the system.

These open-loop systems are popular in nonfreezing climates such as Hawaii. They should never be installed in climates that experience freezing temperatures for sustained periods. You can install them in mild but occasionally freezing climates, but you must consider freeze protection.

Recirculation systems are a specific type of open-loop system that provide freeze protection. They use the system pump to circulate warm water from storage tanks through collectors and exposed piping when temperatures approach freezing. Consider recirculation systems *only* where mild freezes occur once or twice a year at most. Activating the freeze protection more frequently wastes electricity and stored heat.

Of course, when the power is out, the pump will not work and the system will freeze. To guard against this, a freeze valve can be installed to provide additional protection in the event the pump doesn't operate. In freezing weather, the valve dribbles warmer water through the collector to prevent freezing.

Passive systems are generally more reliable, easier to maintain, and possibly longer-lasting than active systems.

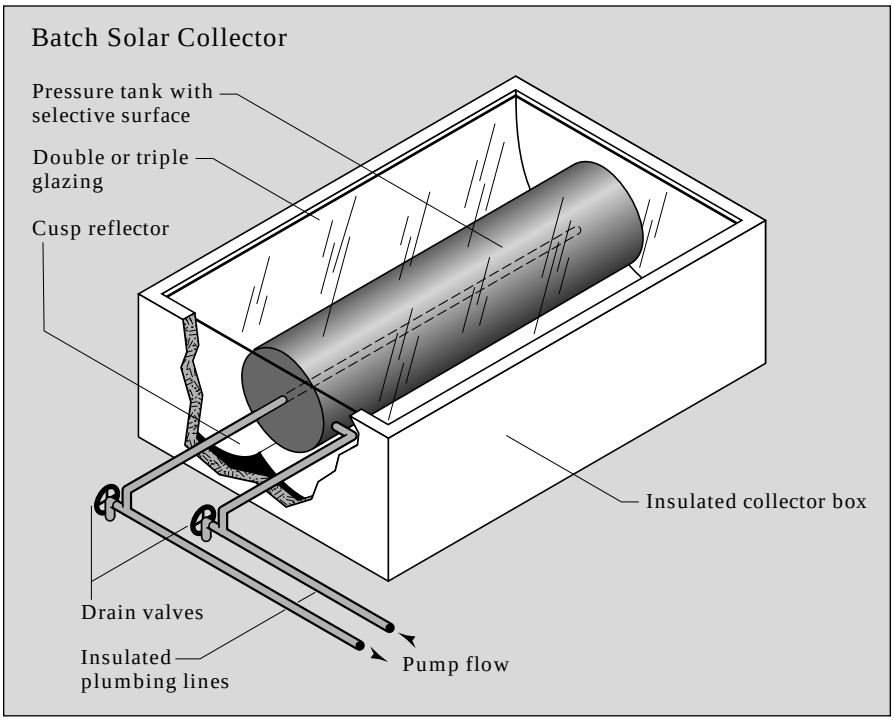
Closed-Loop Active Systems

These systems pump heat-transfer fluids (usually a glycol-water antifreeze mixture) through collectors. Heat exchangers transfer the heat from the fluid to the household water stored in the tanks.

Double-walled heat exchangers prevent contamination of household water. Some codes require double walls when the heat-transfer fluid is anything other than household water.

Closed-loop glycol systems are popular in areas subject to extended freezing temperatures because they offer good freeze protection. However, glycol antifreeze systems are a bit more expensive to buy and install, and the glycol must be checked each year and changed every 3 to 10 years, depending on glycol quality and system temperatures.

Drainback systems use water as the heat-transfer fluid in the collector loop. A pump circulates the water through the collectors. The water drains by gravity to the storage tank and heat exchanger; there are no valves to fail. When the pumps are off, the collectors are empty, which assures freeze protection and also allows the system to turn off if the water in the storage tank becomes too hot.



An open-loop system heats household water directly in the collectors. One such type of open-loop system is the batch heater. This system is simply a black tank filled with water and placed inside a south-facing, insulated, glazed box, where it absorbs solar energy.

Pumps in Active Systems

The pumps in solar water heaters have low power requirements, and some companies now include direct current (DC) pumps powered by small solar-electric (photovoltaic, or PV) panels. PV panels convert sunlight into DC electricity. Such systems cost nothing to operate and continue to function during power outages.

Passive Systems

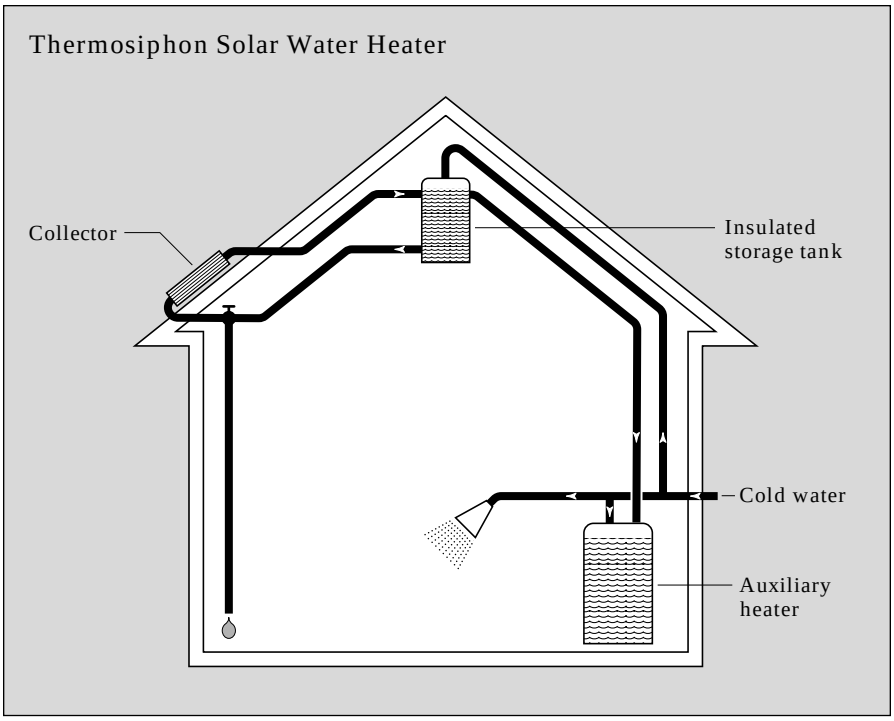
Passive systems move household water or a heat-transfer fluid through the system without pumps. Passive systems have no electric components to break. This makes them generally more reliable, easier to maintain, and possibly longer lasting than active systems.

Passive systems can be less expensive than active systems, but they can also be less efficient. Installed costs for passive systems range from about $1,000 to $3,000, depending on whether it is a simple batch heater or a sophisticated thermosiphon system.

Batch Heaters

Batch heaters (also known as “bread box” or integral collector storage systems) are simple passive systems consisting of one or more storage tanks placed in an insulated box that has a glazed side facing the sun. Batch heaters are inexpensive and have few components—in other words, less maintenance and fewer failures. A batch heater is mounted on the ground or on the roof (make sure your roof structure is strong enough to support it). Some batch heaters use “selective” surfaces on the tank(s). These surfaces absorb sun well but inhibit radiative loss.

In climates where freezing occurs, batch heaters must either be protected from freezing or drained for the winter. In well-designed systems, the most vulnerable components for freezing are the pipes, if located in uninsulated areas, that lead to the solar water heater. If these pipes are well insulated, the warmth from the tank will prevent freezing. Certified systems



A thermosiphon solar water heater uses natural convection to circulate water through the collectors. Cold water flows from the bottom of the insulated storage tank to the bottom of the collector, and then returns to the storage tank when warmed.

It makes economic sense to think beyond the initial purchase price and consider lifetime energy costs.

clearly state the temperature level that can cause damage. In addition, you can install heat tape (electrical plug-in tape to wrap around the pipes to keep them from freezing), insulate exposed pipes, or both. Remember, heat tape requires electricity, so the combination of freezing weather and a power outage can lead to burst pipes. If you live in an area where freezing is infrequent, you can use plastic pipe that does not crack or burst when it freezes. Keep in mind, though, that some of these pipes can't withstand unlimited freeze/thaw cycles before they crack.

Thermosiphon Systems

A thermosiphon system relies on warm water rising, a phenomenon known as natural convection, to circulate water through the collectors and to the tank. In this type of installation, the tank must be above the collector. As water in the collector heats, it becomes lighter and rises naturally into the tank above. Meanwhile, cooler water in the tank flows down pipes to the bottom of the collector, causing circulation throughout the system. The storage tank is attached to the top of the collector so that thermosiphoning can occur.

These systems are reliable and relatively inexpensive but require careful planning in new construction because the water tanks are heavy. They can be freeze-proofed by circulating an antifreeze solution through a heat exchanger in a closed loop to heat the household water.

Sizing Your System

Just as you have to choose a 30-, 40-, or 50-gallon (114-, 151-, or 189-liter) conventional water heater, you need to determine the right size solar water heater to install. Sizing a solar water heater involves determining the total collector area and the storage volume required to provide 100% of your household's hot water during the summer. Solar-equipment experts use worksheets or special computer programs to assist you in determining how large a system you need.

Solar storage tanks are usually 50-, 60-, 80-, or 120-gallon (189-, 227-, 303-, or 454-liter) capacity. A small (50 to 60 gallon) system is sufficient for 1 to 3 people, a medium (80-gallon) system is adequate for a 3- or 4-person household, and a large (120-gallon) system is appropriate for 4 to 6 people.

A rule of thumb for sizing collectors: allow about 20 square feet (about 2 square meters) of collector area for each of the first two family members and 8 square feet (0.7 square meter) for each additional family member if you live in the Sun Belt. Allow 12 to 14 additional square feet (1.1 to 1.3 square meters) per person if you live in the northern United States.

A ratio of at least 1.5 gallons (5.7 liters) of storage capacity to 1 square foot (0.1 square meter) of collector area prevents the system from overheating when the demand for hot water is low. In very warm, sunny climates, experts suggest that the ratio should be at least 2 gallons (7.6 liters) of storage to 1 square foot (0.1 square meter) of collector area. For example, a family of four in a northern climate would need between 64 and 68 square feet (5.9 and 6.3 square meters) of collector area and a 96- to 102-gallon (363- to 386-liter) storage tank. (This assumes 20 square feet of collector area for the first person, 20 for the second person,

Tax Incentives and Rebates

Some local or state governments offer tax incentives to encourage residents to invest in solar energy technologies. Check with your state or local energy office or Department of Revenue for information. Some electric utilities offer rebates to customers who install solar energy equipment because these installations help utilities reduce peak loads. Peak loads are periods when the utility must generate extra power to meet a high demand. Heating water in the evening is one example.

When you have calculated the net cost of your solar water heater, figure the annual fuel savings, and divide the net investment by this number to determine the simple payback.

12 to 14 for the third person, and 12 to 14 for the fourth person. This equals 64 to 68 square feet, multiplied by 1.5 gallons of storage capacity, which equals 96 to 102 gallons of storage.) Because you might not be able to find a 96-gallon tank, you may want to get a 120-gallon tank to be sure to meet your hot water needs.

Benefits of Solar Water Heaters

There are many benefits to owning a solar water heater, and number one is economics. Solar water heater economics compare quite favorably with those of electric water heaters, while the economics aren't quite so attractive when compared with those of gas water heaters. Heating water with the sun also means long-term benefits, such as being cushioned from future fuel shortages and price increases, and environmental benefits.

Economic Benefits

Many home builders choose electric water heaters because they are easy to install and relatively inexpensive to purchase. However, research shows that an average household with an electric water heater spends about 25% of its home energy costs on heating water.

It makes economic sense to think beyond the initial purchase price and consider lifetime energy costs, or how much you will spend on energy to use the appliance over its lifetime. The Florida Solar Energy Center (FSEC—see *Source List*) studied the potential savings to Florida homeowners of common water-heating systems compared with electric water heaters. It found that solar water heaters offered the largest potential savings, with solar water-heater owners saving as much as 50% to 85% annually on their utility bills over the cost of electric water heating.

The FSEC analysis illustrates that the initial installed cost of the solar water heater ($1,500 to $3,000) is higher than that of a gas water heater ($350 to $450) or an electric water heater ($150 to $350). The costs vary from region to region, so check locally for costs in your area. Depending on the price of fuel sources, the solar water heater can be more economical over the lifetime of the system than heating water with electricity, fuel oil, propane, or even natural gas because the fuel (sunshine) is free.

However, at the current low prices of natural gas, solar water heaters cannot compete with natural gas water heaters in most parts of the country except in new home construction. Although you will still save energy costs with a solar water heater because you won't be buying natural gas, it won't be economical on a dollar-for-dollar basis.

Paybacks vary widely, but you can expect a simple payback of 4 to 8 years on a well-designed and properly installed solar water heater. (Simple payback is the length of time required to recover your investment through reduced or avoided energy costs.) You can expect shorter paybacks in areas with higher energy costs. After the payback period, you accrue the savings over the life of the system, which ranges from 15 to 40 years, depending on the system and how well it is maintained.

You can determine the simple payback of a solar water heater by first determining the net cost of the system. Net costs include the total installed cost less any tax incentives or utility rebates. (See the box for more information.) After you calculate the net cost of the system, calculate the annual fuel savings and divide the net investment by this number to determine the simple payback.

An example: Your total utility bill averages $160 per month and your water heating costs are average (25% of your total utility costs) at $40 per month. If you purchase a solar water heater for $2,000 that provides an average of 60% of your hot water each year, that system will save you $24 per month ($40 x 0.60 = $24) or $288 per year (12 x $24 = $288). This system has a simple payback of less than 7 years ($2,000 ÷ $288 = 6.9). For the remainder of the life of the solar water heater, 60% of your hot water will be free, saving you $288 each year. You will need to account for some operation and maintenance costs, which are estimated at $25 to $30 a year. This is primarily to have the system checked every 3 years.

When a solar water heater replaces an electric water heater, the electricity displaced over 20 years represents more than 50 tons of avoided carbon dioxide emissions alone.

Consider only certified and labeled systems when choosing a solar water heater.

If you are building a new home or refinancing your present home to do a major renovation, the economics are even more attractive. The cost of including the price of a solar water heater in a new 30-year mortgage is usually between $13 and $20 per month. The portion of the federal income tax deduction for mortgage interest attributable to the solar system reduces that amount by about $3 to $5 per month. If your fuel savings are more than $15 per month, the investment in the solar water heater is profitable immediately.

Long-Term Benefits

Solar water heaters offer long-term benefits that go beyond simple economics. In addition to having free hot water after the system has paid for itself in reduced utility bills, you and your family will be cushioned from future fuel shortages and price increases. You will also be doing your part to reduce this country's dependence on foreign oil. The National Remodelers Association reports that adding a solar water heater to an existing home raises the resale value of the home by the entire cost of the system. You may be able to recoup your entire investment when you sell your home.

Environmental Benefits

Solar water heaters do not pollute. By investing in one, you will be avoiding carbon dioxide, nitrogen oxides, sulfur dioxide, and the other air pollution and wastes created when your utility generates power or you burn fuel to heat your household water. When a solar water heater replaces an electric water heater, the electricity displaced over 20 years represents more than 50 tons of avoided carbon dioxide emissions alone. Carbon dioxide traps heat in the upper atmosphere, thus contributing to the "greenhouse effect."

Be a Smart Consumer

Take the same care in choosing a solar water heater that you would in the purchase of any major appliance. Your best protection is to consider only certified and labeled systems. One such label is put on by the Solar Rating & Certification Corporation (SRCC), a nonprofit, independent third-party organization formed by the solar industry, state energy officials, and consumer advocates to certify and rate solar water heaters.

A national standard (OG-300) addresses a variety of concerns, including safety and health, durability and reliability, installation, performance, and operation and maintenance. To meet this standard, a system is rigorously tested. A certified solar water heater carries the SRCC OG-300 label, and the system performance is listed in a published directory. A similar program has been established for Florida by FSEC. Both SRCC and FSEC provide collector testing and rating programs.

Find out if the manufacturer offers a warranty, and, if so, what the warranty covers and for how long. If the dealer you are buying the equipment from goes out of business, can you get support and parts from the manufacturer, or from a local plumbing contractor?

Make sure that the workers who are actually installing the system are qualified to do the work. Ask the installation contractor for references and check them. When the job is finished, have the contractor walk you through the system so you are familiar with the installation. And be sure that an owner's manual with maintenance instructions is included as part of the package.

A Bright Future

A solar water heater is a long-term investment that will save you money and energy for many years. Like other renewable energy systems, solar water heaters minimize the environmental effects of enjoying a comfortable, modern lifestyle. In addition, they provide insurance against energy price increases, help reduce our dependence on foreign oil, and are investments in everyone's future.

You might also consider other solar energy systems for your home. Systems similar to the solar water heater are used for space heating and swimming pool heating. In fact, pool heating is a major market for solar energy systems. For more information on these systems, contact EREC.

Source List

The following organizations can provide you with information to help you find the solar water heater that is right for you.

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

ASES is a nonprofit educational organization founded in 1954 to encourage the use of solar energy technologies. ASES publishes a bimonthly magazine, *Solar Today,* and offers a variety of solar publications through its catalogue.

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

FSEC is an alternative energy center. The FSEC staff conducts research on a range of solar technologies, offers solar energy workshops, and distributes many free publications to the public.

Solar Energy Industries Association (SEIA)
122 C Street, NW, 4th Floor
Washington, DC 20001
(202) 383-2600
Fax: (202) 383-2670

SEIA provides lists of solar-equipment manufacturers and dealers and publishes a magazine called the *Solar Industry Journal.*

Solar Rating & Certification Corporation (SRCC)
122 C Street, NW, 4th Floor
Washington, DC 20001
(202) 383-2570

SRCC publishes the thermal-performance ratings of solar energy equipment. The SRCC offers a directory of certified solar systems and collectors as well as a document (OG-300-91) that details the operating guidelines and minimum standards for certifying solar hot-water systems.

For information about many kinds of energy efficiency and renewable energy topics, contact:

The Energy Efficiency and Renewable Energy Clearinghouse (EREC)
P.O. Box 3048
Merrifield, VA 22116
(800) DOE-EREC (363-3732)
Fax: (703) 893-0400
Email: doe.erec@nciinc.com

EREC provides free general and technical information to the public on the many topics and technologies pertaining to energy efficiency and renewable energy.

You may also contact your state and local energy offices for region-specific information on solar water heaters.

Reading List

The following publications provide further information about solar water heaters. The list is not exhaustive, nor does the mention of any publication constitute a recommendation or endorsement.

Articles

"Let the Sun Provide Your Shower," S. Baldassari, *Countryside & Small Stock Journal,* (78) p. 55, November / December 1994.

"Solar Hot Water for the 90s," M. Rosenbaum, *Solar Today,* (5:5), p. 20, September / October 1991.

"Solar Water Heaters Now," *Home Mechanix,* (87:760) p. 67, November 1, 1991.

"Solar Water Heating: A Viable Technology Alternative," M. Sheffer, *Energy User News,* (19:9), p. 44, September 1994.

"Solar Water Heating in Pennsylvania," M.B. Sheffer and A.S. Lau, *Solar Today,* (8:1), p. 12, January / February 1994.

"Wisconsin Public Service Company's Orphan Solar Program," J. DeLaune, *Solar Today,* (9:3), p. 32, May / June 1995.

Books, Pamphlets, and Reports

Consumer Guide to Solar Energy, S. Sklar and K. Sheinkopf, Bonus Books, Inc., 160 East Illinois Street, Chicago, IL 60611, 1991.

The Homeowner's Handbook of Solar Water Heating Systems, B. Keisling, Rodale Press, 1983.

Periodicals

Home Energy Magazine, 2124 Kittredge Street, No. 95, Berkeley, CA, 94704-9942. (510) 524-5405. *Home Energy Magazine* is a source of information on reducing energy consumption.

Solar Industry Journal, Solar Energy Industries Association, 122 C Street, NW, 4th Floor, Washington, DC 20001. *Solar Industry Journal* has information on commercializing new technologies, case studies of commercially available technologies, and articles on government policies and regulations that affect renewable-energy businesses.

Solar Today, 2400 Central Avenue, Unit G-1, Boulder, CO, 80301. (303) 443-3130. *Solar Today* covers all the solar technologies, both mature and emerging, in a general-interest format.