4108

SOLAR DOMESTIC WATER HEATING

FACTSHEET

WASHINGTON ENERGY EXTENSION SERVICE

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INTRODUCTION

Does solar domestic water heating make sense in the Pacific Northwest? Should I buy a house that has a solar hot water system installed? Is installing one on an older home a smart move? Is it cost effective to install a solar system as part of the construction on a new home? These questions confront anyone trying to evaluate solar hot water heating systems. This factsheet will help the reader determine whether solar hot water heating makes sense for a particular household. It will help familiarize the reader with some of the terms and concepts common to the solar water heating industry. It will not teach how to design, build or install a solar water heater.

It is a common misconception that it is too cloudy in the Northwest for solar water heating to work. Even in cloudy conditions, usable amounts of solar radiation reach the earth. Over the past fifteen years it has been well demonstrated by successful installations that a properly designed solar hot water heating system can meet between 25 - 60 percent of a household's annual hot water needs. This is true both east and west of the Cascades.

Given that it is technically possible to get a useful amount of water from a solar system in the Northwest, will it be economical? The answer to this question depends on the design chosen, its cost, your local electric rates, how much hot water you use, and on the type of financing and economic analysis method chosen. There are two basic economic methods available. The first is simple payback, useful for quick analysis and low cost investments. The other is life cycle costing, more complicated but necessary to evaluate major investments and financing arrangements. These methods are fully explained in the WEES Factsheet "Economics of Energy Conservation Investments".

A well installed, well maintained, working solar hot water system already installed on a house you plan to purchase is definitely a plus. It will help reduce the cost of living in the house and provide insurance against increasing energy expenses.

Electric utility rates have a dramatic effect on the savings potential of solar hot water systems. The same solar hot water system installed in two different utility companies service territories can vary dramatically in cost effectiveness. The difference between 3.6 cents and 7.2 cents electric rates doubles savings produced. (Call your local utility to determine your rate.)

The aesthetic impact of a solar hot water system also needs to be considered. Will the collector array detract from the appearance of the house? Does it blend with the architectural style? Will reflection from the collector cause a glare problem for the neighbors?

HOW MUCH DO SOLAR HOT WATER SYSTEMS COST?

The cost of a solar hot water heating system ranges from a low of about $100 dollars for a simple system made from recycled materials to over $5,000 for a contractor installed multiple collector, automated, freeze protected system. Material costs for a homemade system that uses new materials and is designed for durability will typically range between $400 - $1,200. Factory built systems usually range between $1,200 - $3,500 for material costs, with contractor installation costing about one third more.

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CHOOSING A SOLAR HOT WATER SYSTEM

There are many different types of domestic solar hot water heaters on the market. Choosing between them will involve many of the considerations outlined in the first part of this factsheet. The best system for a particular application depends on local weather, the household's site, its location on the lot, the structure of the house, the household's hot water requirements, the technical abilities of the homeowner, and the amount of money the homeowner chooses to spend.

Types of Systems

Most descriptions of solar water heating systems put them into two types, active and passive. Active systems utilize mechanical pumping systems, whereas passive systems do not. Another way of categorizing solar hot water systems is by the method employed for collecting solar energy. The two most common collecting methods are the integral and flat plate design. The basic principles of both these designs are the same. They utilize a glazing system, an absorber system, insulation, and a protective box. Infrared radiation enters through the glazing, strikes the interior, and causes it to heat up. Some of the heat radiates back through the glazing and the insulated box and some is transferred to the fluid inside the absorbing surface. In the integral system, the hot water is stored in the collector itself. Flat plate collectors have a system of risers and headers that transfer the heated water to a remote storage tank.

The glazing in a collector should be tempered glass or high temperature plastic. Plate glass will break if there is a high temperature difference between the back and front side of the glazing. The absorber system is painted flat black in color. In better quality solar collectors, this paint is usually a selective surface coating that is highly efficient at retaining radiation in the infrared spectrum. The collector box is insulated wherever possible to reduce heat loss to the surrounding air. The insulation should be either a high temperature foam or low binder fiberglass. Residential grade fiberglass contains binders which will outgas and condense on the collector's glazing. Ideally, the protective box that encloses the absorber system will be made of a durable material such as aluminum, especially if the collector has a high efficiency absorber. Wood components in flat plate collectors have spontaneously ignited during malfunction. Wood is safer in low efficiency collectors.

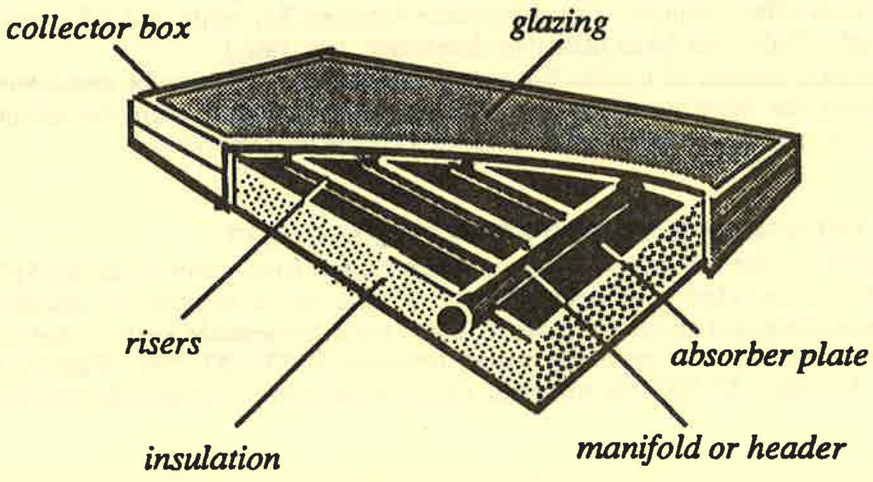


Figure 1. Flatplate Collector

Flat Plate Collectors

Flat plate collectors are a grid of pipes attached to a blackened metal plate and enclosed in an insulated box with glazing on one side (See Figure 1). Solar energy strikes the metal plate which conducts the heat to fluid in the pipes which in turn transports the heat gained to a remote storage tank. The fluid may be pumped to the storage tank or it may move by natural convection. Flat plate collectors utilizing convection are called thermosyphon systems. Pumped systems are called active systems. Active systems require a controlling device to turn on the pump when there is energy to be gained by circulating water through the collector. This may be a set of temperature sensors along with a differential temperature (or Delta-T) controller.

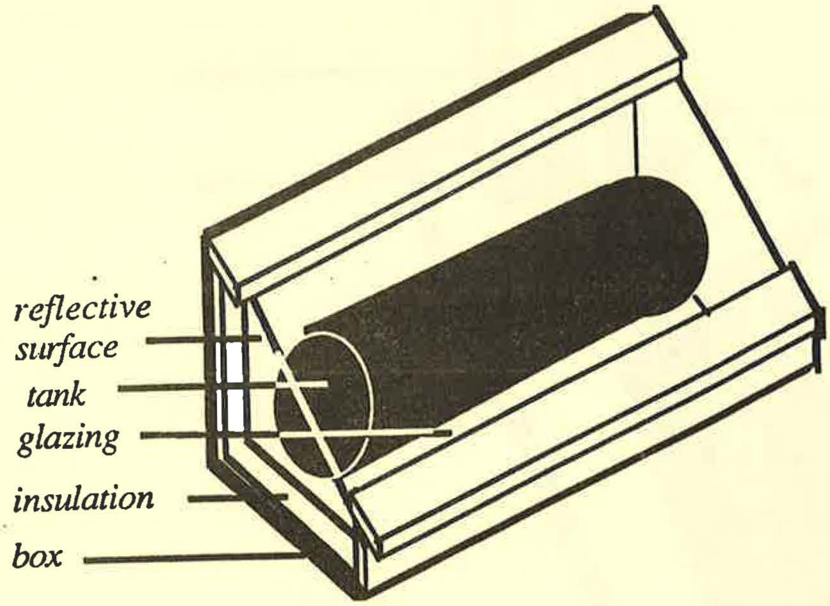


Figure 2. Integral Or A Breadbox Collector

Integral Collectors

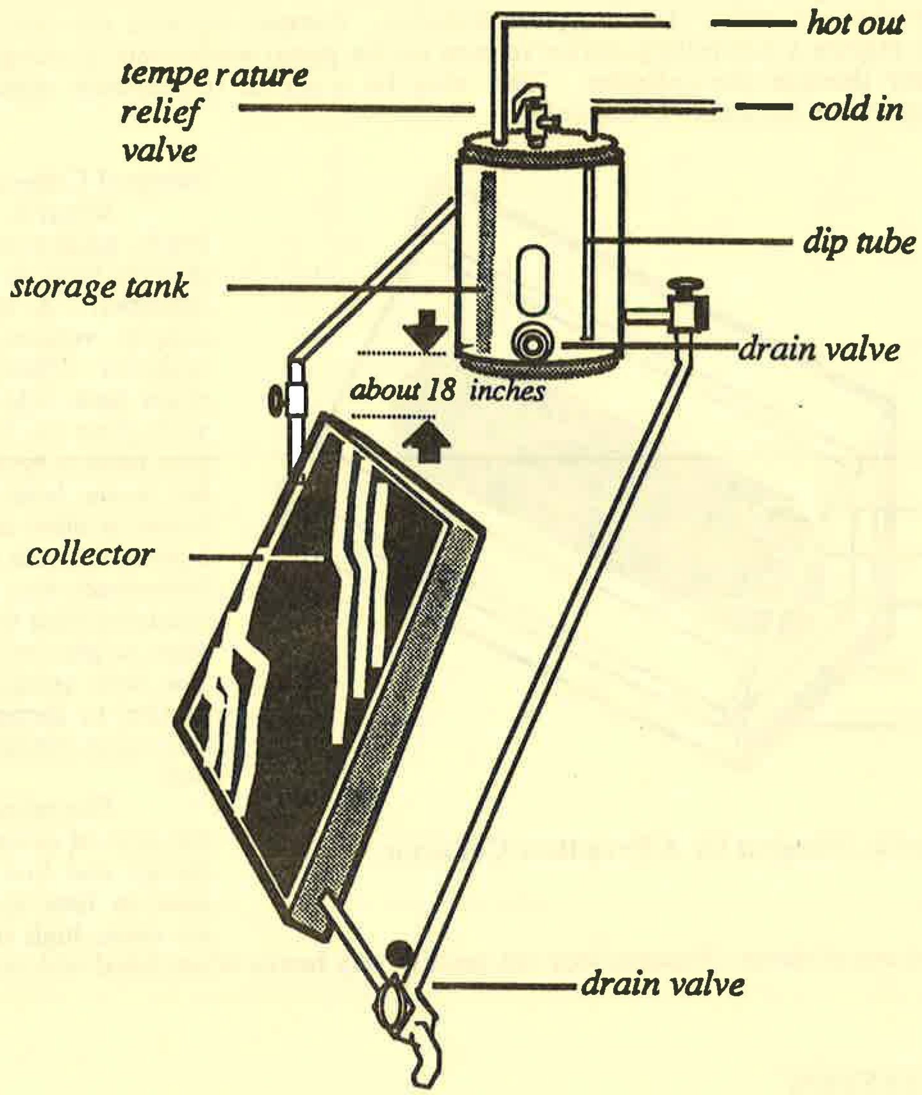
Integral, also known as batch, collectors use a hot water storage tank as the solar energy absorber. A black bucket is a simple version of an integral collector. Change the bucket to a water tank, add an insulated box with glass on the south side and you have a typical integral solar hot water heater. This type of heater is often called a "breadbox heater" because of its appearance. Sometimes they are built with an insulated door that closes over the glass to prevent heat loss at night. The door usually has a reflective surface to increase heat gains by reflecting additional light into the box.

The primary advantages of this type of system is simplicity of design and low cost. They are slow to heat up and heat losses are rather high since the system is usually installed out of doors. Because they are usually very heavy when filled with water, siting can be a problem.

SITING THE SYSTEM

Before installing a solar hot water system, a careful site analysis should be undertaken. Potential problems such as shading, building code restrictions, and development covenants should be considered. In a residential neighborhood, the effects of new construction are important considerations. Is it possible that a neighbor could build a second story addition that would shade your solar collector? Lastly, the weight of the system should be considered. Is a ground location more suitable than a roof location?

Figure 3. Thermosyphon System



Orientation

Historically, people have been told that solar collectors must be pointed within 15° of true south and that the collector's tilt should be within 10° of the site's latitude. Both performance and research have shown that collectors can be oriented 90° off true south and tilt can range from 15° to 65° without significantly impacting performance. A tilt of 45° or more may be worth considering in an area with significant snowfall.

Sizing

To size a solar hot water heating system, first determine the amount of hot water the household uses. A good rule of thumb is about 20 gallons per day per person. A three member household will want about 60 gallons of storage. One square foot of collector will produce about one to one-and-one half gallons per day per person. Therefore, the three person household will need between 45 - 60 sq. ft. of collector area. It may be difficult to locate an integral water heater with this amount of absorber surface. One solution is to install multiple breadboxes in series, another is to consider a flatplate system.

Ground Mount

Ground mounting a solar collector can eliminate a number of problems. If the system being installed is an integral design, ground mounting can prevent damage caused by overloading the roof. It can also simplify plumbing runs. Ground mounted systems are subject to possible shading problems however.

Roof Mount

Roof mounts overcome shading, but can lead to plumbing and rack design problems. Usually they require roof penetrations for attaching the collector and installing the plumbing. These penetrations need to be carefully sealed. Racks should be built from either metal or treated wood. The system support rack needs to be carefully designed to resist wind damage to both the system and the roof.

FREEZE PROTECTION METHODS

Several strategies have been developed to provide freeze protection for solar hot water systems. There are advantages and disadvantages to all of them, both economic and practical. For all systems, the outside plumbing runs should be insulated. This will not only help protect them from freezing, it will also reduce heat loss. Most pipe insulation can be painted to prevent deterioration from sunlight.

Seasonal Use

The simplest way of protecting a solar hot water system against freezing is seasonal use. When the system is drained for the season, it is important to make certain that there is no residual water in the collector or outside plumbing runs. Seasonal systems operate at reduced efficiency since they cannot utilize solar energy available throughout the colder months of the year. There is also a danger of freezing during an unexpected fall or spring cold snap. Water in a flatplate collector can freeze on a cold clear night even though ambient air temperature never drops to 32°F. On clear nights enough heat can be lost to the night sky to cause collector temperatures to drop well below freezing.

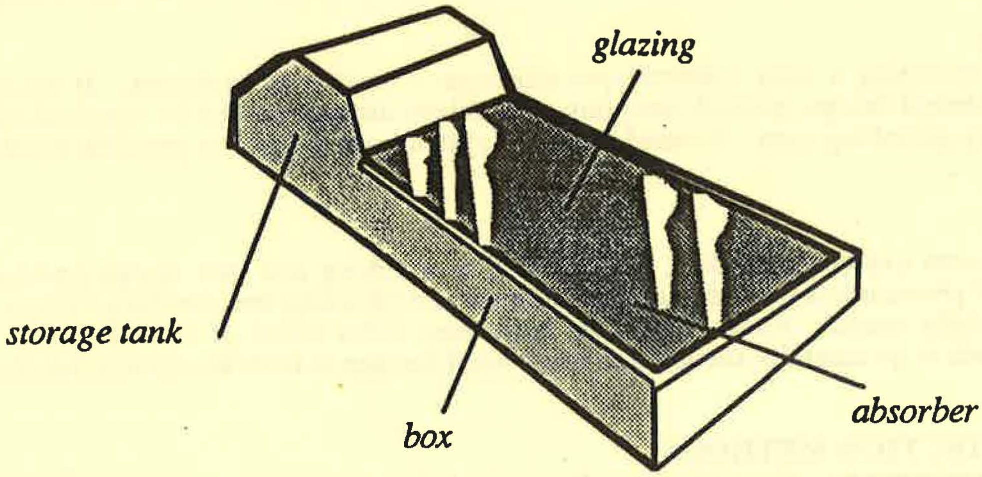
Mass

In moderate climates, integral collectors can survive occasional freezing periods because of their large internal mass. Shutters or insulated doors will help. Special attention must be given to protecting the plumbing runs. Heat tape and insulation have been used for this successfully. Some attempts have been made to provide freeze protection by locating breadbox heaters in sunspaces with mixed results.

Antifreeze or Closed Loop

Antifreeze is a very effective method of freeze protecting flatplate collector systems. A glycol or silicon fluid is circulated through the flatplate collector to a heat exchanger installed next to or in the storage tank, where the heat is transferred to the domestic water stored in the tank. Most building codes require that the heat exchanger be double walled and/or a non-toxic antifreeze solution be used. Many local jurisdictions also require that any antifreeze system have a back flow preventer installed on the city supply line to prevent accidental contamination of the city water supply with antifreeze. There are efficiency loses associated with a heat exchangers, and antifreeze itself is not as good a heat exchange fluid as water. Antifreeze can become acidic when exposed to high temperatures and must be checked annually.

Figure 4. Phase Change Collector



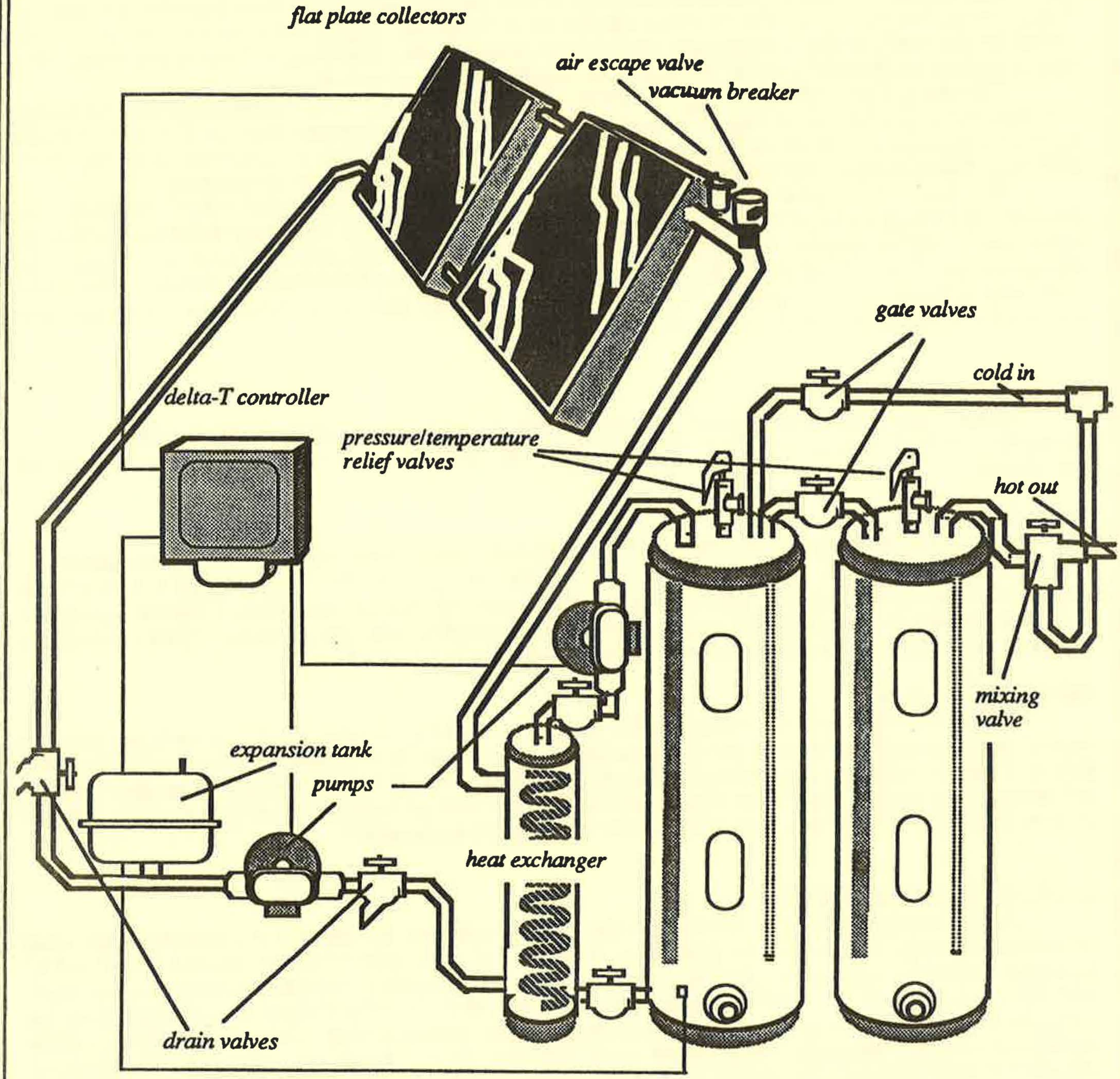
Draindown

Draindown control systems employ a set of electrically activated valves to empty flat plate collectors whenever a near freezing condition is sensed by the Delta-T controller. A vacuum relief valve on the roof allows air to enter the top of the system while one valve isolates the collector piping from the storage tank and another valve system drains the water in the system. This system eliminates the inefficiencies of antifreeze by pumping domestic water through the collectors. Special care must be taken to make certain that water cannot become trapped in the plumbing when the system drains down. Hard water can also clog these valves. Drain down systems may require multiple freeze sensors on the plumbing runs. In the winter of 1984, many draindown systems in the Puget Sound area were damaged by a period of subfreezing weather. The causes were varied but generally the valves failed, a freezing condition was not accurately sensed by the sensors, or water was trapped in the plumbing runs.

Drainback

Drainback systems are similar to drain down in that they are designed for active systems, but rather than utilizing solenoid valves to empty the collector, the pump shuts off to drain the system. Whenever the pump shuts off, air enters through a vacuum relief valve, and the system drains back into a separate tank. Drainback systems can have the same problems with trapped water as the draindown. Similar to antifreeze systems, the collector fluid is separate from the domestic supply and heat exchanger is used in the drainback tank.

Figure 5. Active Heat Exchange System



Phase Change

Phase change systems have the most reliable freeze protection of the passive solar hot water systems. They are also the most efficient because they can absorb heat from the air even if it is not sunny.

There are two basic types of phase change systems on the market. Both utilize a refrigerant fluid (freon) that is able to transfer significant amounts of heat as it changes phase from liquid to gas and vice versa. When heated by the sun or warm air, the freon boils and begins rising in the collector. When cooled by the water in the storage tank, the refrigerant condenses, releasing its heat to the water. One type resembles an integral system; the other type acts like an active system.

The integral type phase change collectors actually have a flat plate incorporated into the design. It is something of a hybrid, storing hot water in a tank located immediately above the flatplate. Freon is circulated through the panel via thermosyphoning which transfers heat to the reservoir at the top of the collector. These systems are extremely heavy and require careful installation on rooftops.

The active type phase change collectors may or may not require mechanical pumping. It's possible for fluid to circulate from the heat exchanger to the collector by expanding bubbles, in much the same way a coffee percolator works. Liquid in the collector is converted by heat into a gas. The expanding gas forces fluid down the pipe from the roof of the condenser/heat exchanger. The gas is converted to liquid, liberating heat. Pipe runs must be carefully planned to insure that the system does not develop a vapor lock as in the thermosyphon systems.

INSTALLING THE SYSTEM

Once it has been determined that a solar hot water system is desirable, the home owner needs to determine the best way to go about installing it. The options are to do it yourself or contract the installation.

Doing it on your own

If you decide to do it yourself, you should carefully assess your abilities in carpentry, plumbing, and electrical wiring. Do you have the necessary tools for the job? Will you damage the roof while doing the installation yourself? You need to consider local building codes and how long the installation will take. A breadbox system or a simple thermosyphon flatplate will take a couple of full weekends, a flat plate collector with an antifreeze loop may take a month of weekends.

Hiring a contractor

Hiring a contractor is the logical choice for anyone lacking the time, ability, or tools required. A careful assessment of dealers and installers should be undertaken. Is the dealer knowledgeable about the product? Is the installer experienced? Has the company been in business long? Can they provide references from people they have done work for? What sort of warranty do they provide? Ask for product and labor warranties. They should offer both. Are they bonded?

SAFETY AND MAINTENANCE

Proper maintenance will assure that the system will last its full life expectancy. All solar collectors will require cleaning the glazing as needed. Collector plumbing runs should be labeled as either an outflow or return line. Any pipes carrying other than potable water should be labeled as such. The label should indicate what the pipe contains. All faucet handles should be removed from the collector loop valves to prevent accidental drainage of the collector loop. Passive systems are fairly maintenance free, requiring only annual emptying for freeze protection and sediment removal. Occasional inspection of pipe insulation is a good idea. Depending on its original finish material, the collector housing may need to be painted now and then. For a more complex active system, the way to begin a proper maintenance program is by reading the owner's manual and following the manufacturer's instructions.

HOW LONG WILL IT LAST?

The life expectancy of a solar hot water heater is a matter of maintenance. The weakest element in most solar hot water heaters is the tank. They are prone to the same problems of corrosion as conventional hot water tanks, that is, developing pin hole leaks. Ten to twelve years is the normal life expectancy of a hot water tank. Stone lined tanks, while more expensive, will usually outlast glass lined tanks. The pump is another element that is prone to failure. The bearings, brushes and impellers need to be inspected and replaced occasionally. A well designed and installed solar hot water system that is properly maintained should last for over twenty years.

SUMMARY

Solar domestic hot water can be a wise investment if planned carefully. It is especially cost effective if the system is already installed on a home you plan to purchase, or if you are having it installed on a house you are building. It is important to make certain that the system installed properly and that it is well maintained. A well done, do it yourself system is more cost effective than a commercially installed one. Passive systems, both breadbox, and thermosyphon are the easiest to install and the lowest cost. The best freeze protection systems are those which do not use water in the collector loop.

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SUGGESTED READING

Homeowner's Handbook of Solar Water Heating Systems, The, Keisling, Bill, Rodale Press, 1983.
Integral Passive Solar Water Heater Book, The, Bainbridge, David A, The Passive Solar Institute, 1981.
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Solar Water and Pool Heating Installation and Operation, Chandra, et al., Florida Solar Energy Center, 1979.
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