SERVICE IN ACTION

COLORADO STATE UNIVERSITY EXTENSION SERVICE

Solar domestic water heating systems

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Quick Facts

A homeowner interested in utilizing solar energy to reduce energy bills should consider installing a solar domestic water heating system.

They have a reasonable first cost, provide a good return on the investment and can be easily retrofitted on existing homes.

A simple type of solar domestic water heater is a batch heater or a passive device used to heat water, but the systems that give better performance are active systems that use flat plate collectors to trap solar energy.

A solar water heating system should be sized to provide up to 75 percent of the annual energy needs for hot water in a home in Colorado; a conventional system is needed to provide the remailing 25 percent.

A consumer should consider the reliability, durability and cost effectiveness of a water heating system before purchase.

Installation of a solar domestic water heating system is fairly simple because of its small size.

The homeowner interested in utilizing solar energy to reduce energy bills should consider installing a solar domestic water heating system. This system has several advantages, namely:

- It has a reasonable first cost. System costs range up to $3,000 depending upon the system type, size and complexity of installation.
- It provides a good return on the investment. Heating water can account for as much as 30 percent of a home's annual heating energy bill. A well designed solar domestic water heating system can provide up to 75 percent of the annual energy needs for heating water. Present energy tax credits allow a 40 percent federal tax credit and a 30 percent state tax credit for a solar domestic water heating system. Thus, the initial investment can be recovered in reduced energy bills and tax credits within six years. A solar domestic water heating system also will improve the resale value of a house.
- It can be easily retrofitted onto existing homes due to the small collector area—less than 80 square feet (7 square meters)—the small storage tank size—up to 120 gallons (454 liters)—and the capacity to be easily plumbed into the existing conventional water heating system.

Solar domestic water heating systems work on the following principles: solar radiation enters the collector through the glass or plastic cover; it is absorbed by a black surface and the heat produced is transferred to a fluid flowing through the collector; the heated fluid then flows to a storage tank.

System Types

The simplest type of solar domestic water heater is a batch heater. This is a "passive" solar device consisting of an insulated weather-tight box containing a black painted water tank (see Figure 1). The south side of the box is glazed to allow the sun to shine on the tank and warm the water in it. It is plumbed into the cold water main ahead of the conventional water heater and serves as a solar water pre-heater. This type of system has the advantages of low cost (under $600), ease of construction by a homeowner and simplicity of operation. Its disadvantages include susceptibility to freezing (requiring the system to be drained during the winter months) and low efficiency (a batch heater can provide up to 35 percent of the annual household energy needs for heating water).

Solar domestic water heating systems that give better performance are "active" systems that use flat plate collectors to trap the sun's energy, a heat transfer fluid that flows through the collector to absorb heat, a water storage tank, a pump, a control system and piping (see Figure 2). This type of system can provide up to 75 percent of a household's annual energy needs for water heating.

The active system most suited for Colorado climate is called a closed loop system. In a closed loop system, a heat transfer fluid circulates through the collectors absorbing heat. The heat is

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transferred to potable water through a double-walled heat exchanger located in the storage tank. The water storage system can be composed of either one or two tanks depending upon the type of conventional energy employed for supplemental heating. With a gas fired water heating system, the solar heated water is stored in a tank separate from the conventional tank. With an electric powered system, the water storage can be combined into one tank where the solar heated water is stored in the lower portion of the tank and the upper portion of the tank has an electric element to maintain water temperatures at levels required for household needs.

Components of the closed loop system include (see Figure 2):

- liquid flat plate solar collectors mounted on the room or south side of the house;
- the water storage system with a double-walled heat exchanger;
- heat transfer fluid (a mixture of ethylene or propylene glycol and water is commonly used to prevent freezing problems);
- a circulating pump;
- an expansion tank to allow for expansion of the fluid due to temperature rises in the system;
- a thermostatic control system with temperature sensors located in the storage tank and a collector;
- mounting hardware consisting of adjustable brackets that mount the collectors on the roof or on the ground at the desired collector tilt angle;
- a pressure and temperature relief valve as a safety device if overheating conditions are experienced;
- a tempering or mixing valve used to mix cold water with the solar heated water to provide water of uniform temperature to the house;
- a check valve to prevent reverse flow of fluid through the collector at night.

A closed loop solar domestic water heating system operates as follows:

1) Cold water flows into the solar storage tank.

2) When the temperature at the collector temperature sensor is 10 degrees higher than the temperature at the tank temperature sensor, the differential thermostat controller turns on the circulating pump that circulates the heat transfer fluid through the collectors.

3) The heat transfer fluid absorbs heat as it passes through the collectors.

4) The fluid transfers heat to the potable water as it passes through the double-walled heat exchanger.

5) The heated water is stored in the solar storage tank.

6) When hot water is needed in the house (for a shower, dishes, etc.) it is drawn from the conventional hot water tank in a gas filled system or the top of the single water storage tank in an electric system.

7) The conventional hot water tank is replenished with solar heated water. If the solar heated water is not at the required temperature, the conventional tank will switch on and heat the water as needed.

Sizing a Solar Water Heating System

A solar domestic water heating system should be sized to provide up to 75 percent of the annual energy needs for hot water in a home in Colorado. Thus, a conventionally fueled system will be needed as a backup to provide the remaining 25 percent. Sizing a solar domestic water heating system to provide 100 percent of solar heated water is not economically feasible. To properly size a system requires several variables to be considered including:

- the amount of energy used in heating water;
- the amount of solar radiation available;
- the efficiency of the solar domestic water heating system.

The amount of energy required for water heating by a household is dependent on the number of occupants and required temperature rise of the water. The average use of hot water in a household is 15 to 20 gallons (57-76 l) per person per day. Thus, a family of four would require 60 to 80 gallons (228-304 l) of hot water per day. The energy requirement also is dependent on the temperature difference between the cold water coming into the house and the hot water required at the tap. The performance of a solar water heating system can be improved if water and energy conservation measures are employed. Reducing hot water temperature to 120 to 140 degrees F (49-60°C), adding an insulating jacket to the conventional water heater, using warm or cold water cycles when washing clothes, installing shower head flow restrictors, repairing leaks, and conscientiously turning off water taps are several ways of improving the performance of the system.

Determining the amount of energy needed, the solar radiation available and the efficiency of the system will provide a basis for establishing the amount of collector area required. With the collector area determined, water storage is sized at 1.25 to 1.75 gallons per square foot (52 to 73 liters per square meter) of collector. As an example, the collector area (assuming system efficiency of 40 percent) needed to provide 75 percent of the hot water needs for a family of four for Front Range solar conditions is 50 to 80 square feet (4.5 to 7.2 sq m). This would require two to four collector panels. A 75- to 120-gallon (284-454 l) water storage tank would be necessary.

Purchasing a Solar Water Heating System

When purchasing a solar domestic water heating system, the main criteria to evaluate the system are reliability, durability and cost effectiveness.

Reliability should be supported by a warranty, in writing, provided by the dealer. Also look for a system that meets the requirements of the Housing and Urban Development (HUD) Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems. Check the availability of parts and service to

assure the system can be repaired or maintained as needed.

Durability requires a system that has quality components and construction, and weather-proof collectors that can endure daily temperature fluctuations and temperature extremes (temperatures of over 350 degrees F—176°C—under no flow conditions). With liquid systems, durability is related to corrosion resistance provided by compatibility of materials and fluids in the system.

Cost effectiveness is determined by initial cost, installation cost, useful life of the system, efficiency of the system and frequency of maintenance.

When purchasing a solar domestic water heating system from a solar equipment dealer, consider the following:

- check the dealer's reputation; inspect installations; talk to system owners;
- check with the Better Business Bureau or district attorney for consumer complaints against a dealer;
- check the availability of parts and service;
- check warranty coverage on equipment; and
- obtain written cost estimates from several dealers.

Installing a Solar Water Heating System

Installation of the system is made easier by its small size. The collectors require an area of less than 80 square feet (7.2 sq m) and they must be oriented within 20 degrees of due south and tilted to an angle of 30 to 50 degrees (see Figures 3 and 4).

The collectors can be mounted either on the roof or on the ground. If the roof pitch is within the required tilt angle (30 to 50 degrees), the collectors can be mounted flush with the roof (see Figure 5). However, with many houses, the roof pitch is too shallow requiring the collectors to be mounted on stand-off racks (see Figure 6). They also can be mounted on a rack on the ground (see Figure 7). Regardless of how the collectors are mounted, they must have unobstructed year-round access to the sun between the hours of 9 a.m. and 3 p.m. (standard time) each day.

The solar storage tank is only slightly larger than a conventional water heating tank and should be installed as close to the conventional water heater as possible. Expansion tank, pump and controller can be mounted on or near the storage tank. The use of a liquid system requires only pipes for connection between the collector and tank making the retrofit installation easy.

When selecting a solar equipment installer

- check solar experience;
- check experience in related fields such as plumbing, heating or air conditioning;
- check the system manufacturer's recommendations for installers;
- check the installer's certification from the manufacturer;
- check the location of the installer (a local established business is preferred);
- get written cost estimates from several installers;
- determine who will repair and service the unit.

Sources of Plans

Homeowners wishing to construct their own batch water heater can obtain plans from the following organizations:

- Zomeworks
  P.O. Box 712
  Albuquerque, New Mexico 87103

- Farallones Institute
  15290 Coleman Valley Road
  Occidental, California 95465

- Solstice Publications
  P.O. Box 2043
  Evergreen, Colorado 80439

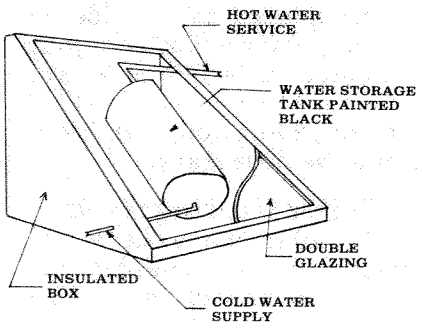

Figure 1: A batch heater for solar water heating.

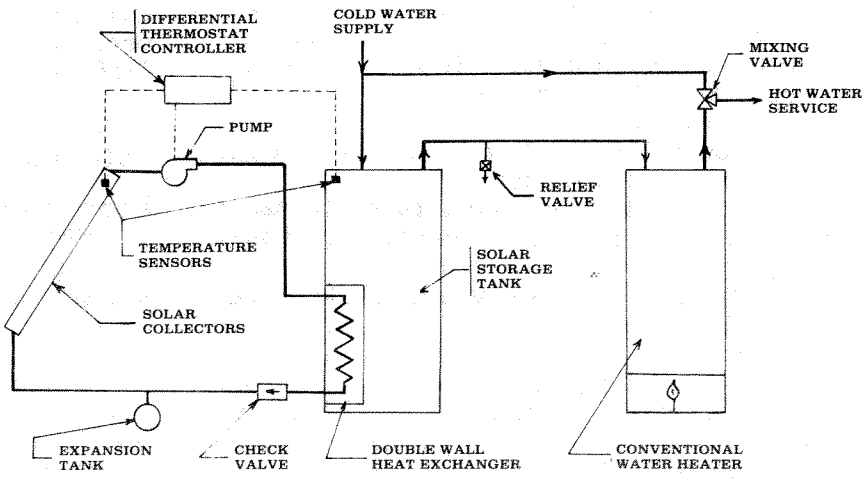

Figure 2: Schematic of an active, closed loop solar domestic water heating system.

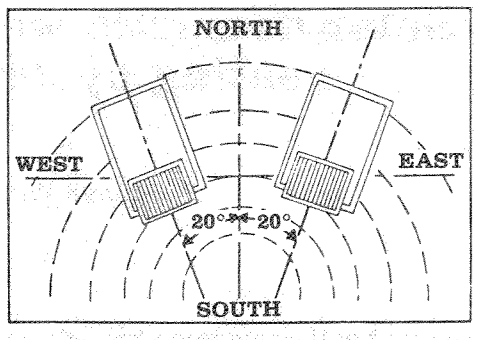

Figure 3: Collector orientation for domestic hot water. A collector orientation of 20 degrees to either side of true south is acceptable.

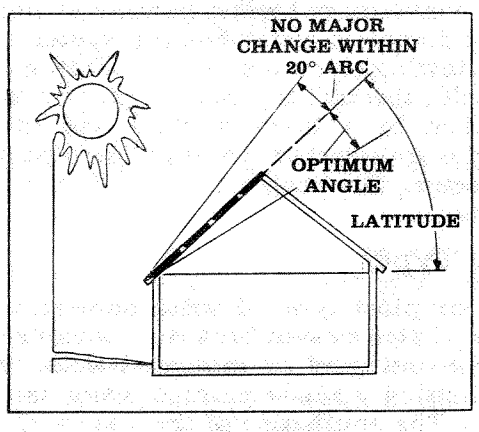

Figure 4: Collector tilt for domestic hot water. The optimum collector tilt for domestic water heating alone is usually equal to the site latitude (use 40° for Colorado). Variations of 10 degrees on either side of the optimum are acceptable.

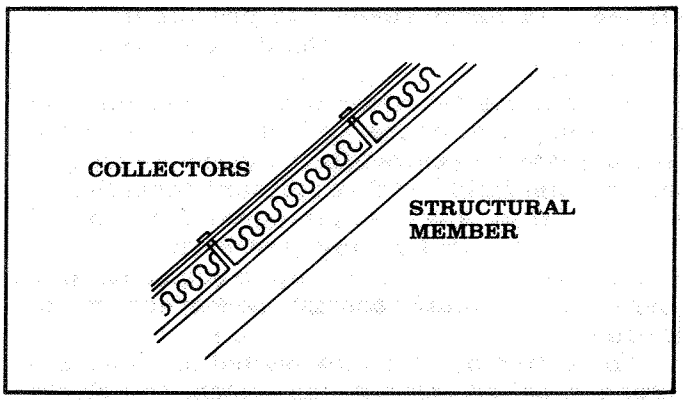

Figure 5: Direct mounting. Collectors can be mounted directly on the roof surface. Generally, the collectors are placed on a water-proof membrane on top of the roof sheathing. The finished roof surface, together with the necessary collector structural attachments and flashing, are then built up around the collector. A weatherproof seal between the collector and the roof must be maintained, or leakage, mildew and rotting may occur.

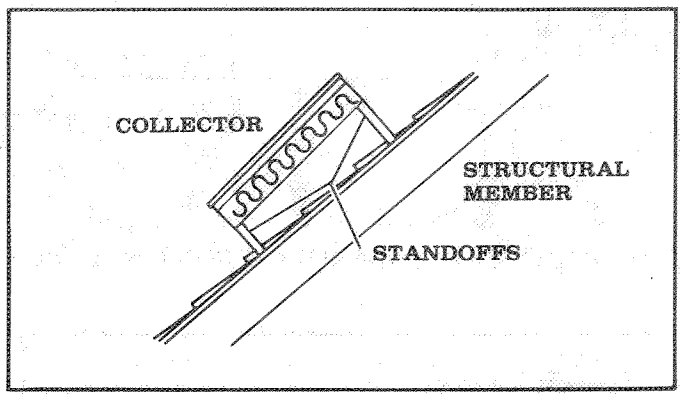

Figure 6: Stand-off mounting. Elements that separate the collector from the finished roof surface are known as stand-offs. They allow air and rain water to pass under the collector thus minimizing problems of mildew and leakage. The stand-offs also must have adequate structural properties. Stand-offs often are used to support collectors at an angle other than that of the roof to optimize collector tilt.

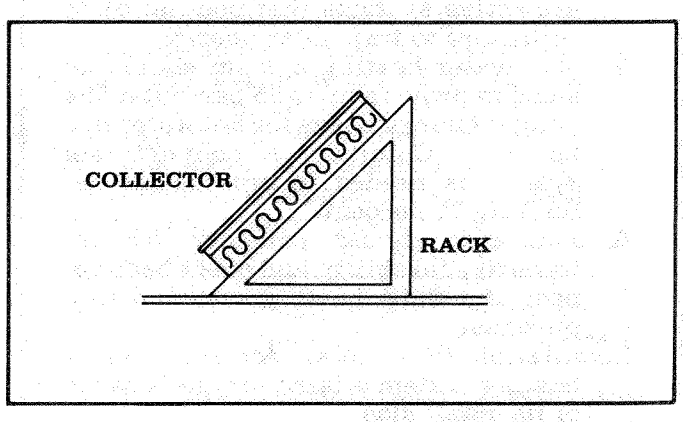

Figure 7: Rack mounting. Collectors can be mounted at the prescribed angle on a structural frame located on the ground or attached to the building. The structural connection between the collector and the frame and the frame and the building or site must be adequate to resist any impact loads such as wind.