ACTIVE SOLAR SYSTEMS

ENGS-44 Sustainable Design

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There are situations where one may wish to go beyond passive solar gain.

Some of the reasons may be:

- There is not enough sun at the location, or the building's facade is too heavily shaded by adjacent structures or trees, but the roof is well exposed.
- One wishes to go beyond supplementing heating needs to complete energy self-sufficiency.
- Solar energy is sought to produce warm water rather than heat the building.

A few numbers:

For a family of four in the US, the typical hot-water usage is

70 to 100 gallons per day

(count 20 gallons of hot-water per person per day),

thus using 3990 to 5700 kWh (13.6 to 19.4 x 10^6 BTUs)

per year to heat the water.

If electricity is used, the cost ranges

from \$678 to \$969 per year (at 17¢ per kWh).

It is possible to design solar-panel systems that have no pumps, controls, or moving parts other than water.

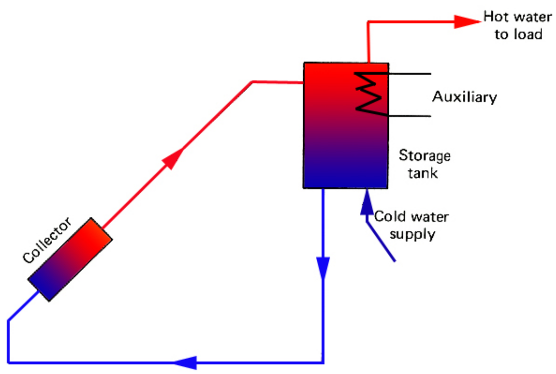
These systems come in two basic designs.

● One is the “batch type” integrated collector-storage, which relies on municipal water pressure to move the hot water from the panel to the domestic storage tank.

● The other type is the “thermosiphon”, which uses the natural flow of gravity to move the hot water into a solar storage tank located above the panel.

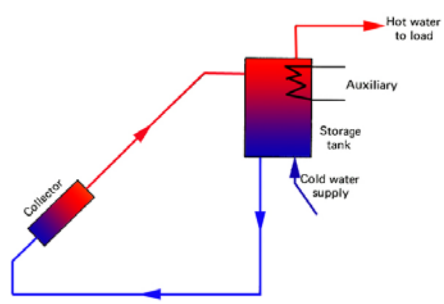
Thermosiphon

Warm water from solar panel to delivery, using only natural convection



For the warm water to rise by buoyancy from the collector into the storage tank, the collector must be placed **below** the storage tank. This is desirable but not always possible.

Other requirement is that the outdoor collector should not be subject to freezing.



Compared to systems that use pumps to circulate the water through the collectors, no-pump systems produce smaller volumes of hot water, usually between 60-80 gallons per day.

Their simple nature provides the most reliable and cost-effective solution for solar water heating on a smaller scale. They are ideal in developing countries where there is a premium on simplicity and where electricity is not available.

Example of a thermosiphon system, with solar collectors placed on the ground at a level below the house.

Thermosiphon system installed on a roof in Jerusalem.

The more common situation, however, is one with solar panels on top and water tank below.

(http://flanaganandsun.com/)

An ideal placement of thermal panels is not in the front yard but on the roof, because:
- It is naturally sloping;
- It is generally easier to catch more sun higher up;
- It can be more directly connected to the house.

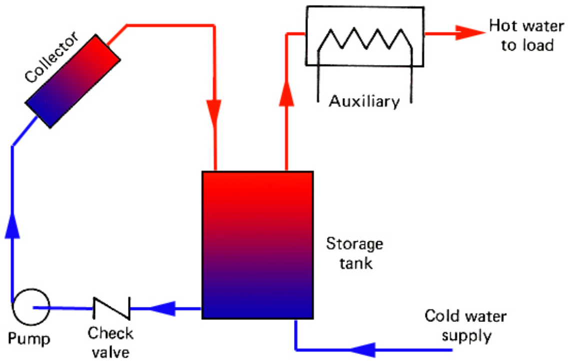
The natural placement of the water tank is in the basement.

(photo by Benoit Cushman-Roisin)

Eanet-Lamperti house in Norwich, Vermont

The common, upside-down arrangement

The solar collector is on the roof and the storage tank in the basement

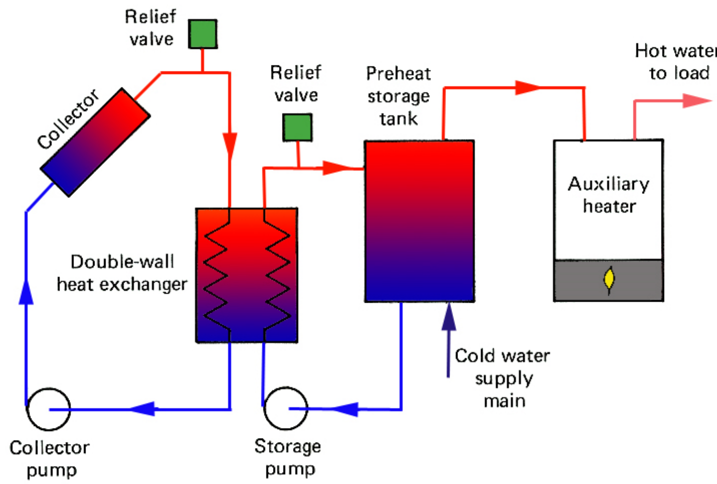


Because the tank is below the solar panel, a pump is required to move the warm water downward and the cold water upward against gravity. The pump is actuated by a differential-temperature thermostat. The check value is to let pressure escape should water reach the boiling point. This system is more complicated but offers more control.

In situations where there is no roof facing south, one needs to be a little more creative…

(renewableenergyengineering.com/projects-rd)

But, there is the chance that the water exposed on the roof will freeze in winter…



Remedy: Use an anti-freeze solution (ethylene glycol) in the loop that goes to the roof and a heat exchanger to transfer the heat to the potable domestic water.

Example

Buderus solar water heating package with 3 solar panels and a 79 gallon tank for 4 to 6 person household

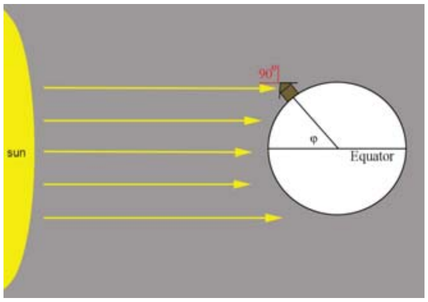
Sold by eComfort USA for $9,376 (incl. shipping)

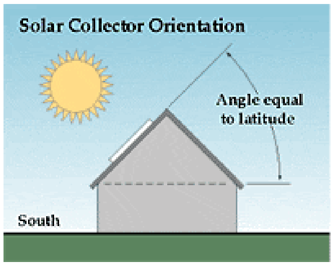
http://ecomfort.com/sks-40-3-residential-solar-energy-water-heating-package-4-to-6-person-household-2715.html

A 2005 entry to DoE's Solar Decathlon

This house designed by the University of Maryland features two Apricus AP-30 solar collectors on the south wall (middle, vertical). The collectors provide both hot water and underfloor heating, with electric boosting as required.

Ideal inclination





Basic challenge in solar thermal technology

The system is typically sized for winter conditions (lower efficiency, more heating demand) and is unavoidably oversized for summer conditions.

If the fluid in the panel becomes too hot, it may vaporize, create elevated pressures, and cause mechanical failure of the system.

A typical scenario is: It is summer, people are away on vacation, hot water is being produced, but there is no consumption; temperature rises and water turns into steam; the system explodes, water with antifreeze runs into the house; people return home from vacation and discover damage. They complain to their neighbors, and the technology acquires a bad reputation.

This was a typical problem in the early days (late 1970s and 1980s).
Solar thermal technology is still slowly recovering from its bad earlier reputation.

Remedy:

Include a drain-flow tank in the basement.

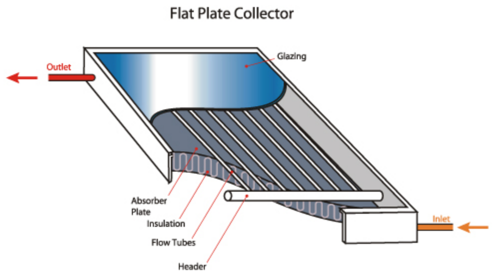
When the system is not in use, water from the system drains down to the tank, and air rises to the roof panels.
Air-filled panels run no risk at high temperatures.

http://www.solaradiant.com/thermal/

Two types of solar collectors:

Flat panels (left) and evacuated tubes (right).

http://www.southface.org/learning-center/library/solar-resources/how-solar-thermal-works



http://www.soltrac.co.uk/Solar-thermal/flat-plates.html

The most familiar type of solar panel is the flat plate collector. This device is basically a highly insulated box containing a grid of copper pipes bonded to a flat black absorber plate. The special glass enhances solar absorption by turning the panel into a mini greenhouse. It also helps reduce heat conduction loss to the air as well as drain rain and snow.

Build your own hot water solar panel







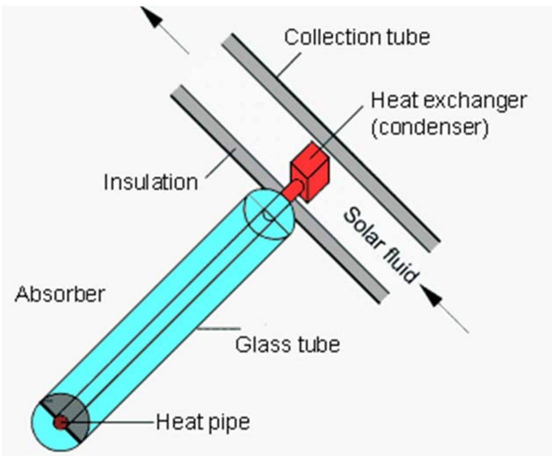

http://www.thesietch.org/projects/solarthermalpanel2/index.htm

Evacuated tube collectors use multiple vacuum-filled glass tubes, each with a tiny amount of antifreeze hermetically sealed within a small central copper pipe.

The advantage of the evacuated tube is the much reduced heat loss by conduction. Whereas heat is leaked by conduction through the panel surface of a conventional system, it is prevented to leak here by virtue of the vacuum inside the glass tube.

Disadvantages include higher cost and risk of failure by loss of vacuum.

In the heat pipe collector, the special fluid vaporizes at low temperatures. The steam rises in the individual heat pipes and warms up the carrier fluid (water) in the main pipe by means of a heat exchanger. The condensed special fluid then flows back into the base of the heat pipe.



Note how heat is not only collected by temperature rise (sensible heat) but chiefly by phase transition, from liquid to steam (latent heat).

Apricus system installed by Sensible Heat Ltd. in 2004 on the guest cottages of the Wanaka Homestead in New Zealand.

The 270 tube installation provides hot water and underfloor heating.

Older technology: Optical concentration of solar beam

Concentrating Collectors

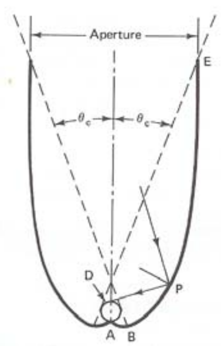


Figure 5-14 Compound parabolic concentrator with a tubular absorber.

Figure 5-15 A solar collector constructed by compound parabolic concentrator troughs with evacuated tubular receivers. (Courtesy of Energy Design Corporation, Memphis, Tenn.)

(From J. S. Hsieh, 1986)

But parabolic forms are difficult to manufacture and are therefore costly.
Flat-plate collector panels and evacuated tubes are now preferred technologies.

This technology survives in concentrated solar energy plants.

http://is.njit.edu/competition/2009/Cat2_2_Winner_Group142/about.html

Parabolic dish technology, with Stirling engine to turn steam into electricity

Parabolic trough technology

http://www.nrel.gov/solar/parabolic_trough.html

Engineering calculations:

First, calculate the daily demand, including one or both of

1. Space heating need to keep the house warm

    (see lecture on insulation)

2. Warm-water need, calculated from

Daily energy demand for warm water =

$$D = V_p \times \rho \times c \times (T_w - T_{in})$$

where

V_p = volume of hot water needed per day

= 20 gallons/day.person x number of persons

ρ = density of water = 8.33 lb/gal

c = heat capacity of water = 1 BTU/(lb.ºF)

T_w = desired hot-water temperature = 140ºF

T_{in} = intake-water temperature, usually 50ºF

The area A (in ft^2) of collector area is determined from the equation:

$$A \times I \times \eta = D$$

where

I = incident solar radiation flux (in BTUs/ft^2 day)

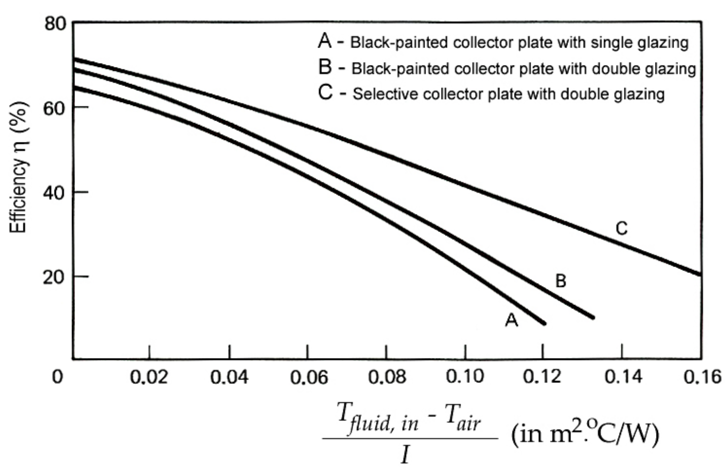
η = collector efficiency ($0 < \eta < 1$)

D = daily demand (in BTUs) – from previous slide

The efficiency η is less than 1 because of

1. Partial light reflection, and
2. Conductive heat loss between heated fluid in the collector and cold outside air. So, η depends on the temperature difference between circulating fluid in tubes and ambient air, which varies along the fluid path.

For a practical reason, η is expressed in terms of the temperature difference between the fluid as it enters the collector and ambient air.



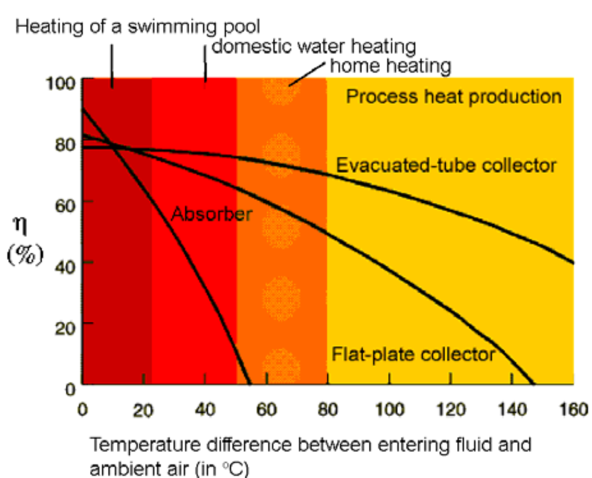
(Hsieh, page 145)

The top value on the left is less than 100% because of partial optical reflection.
The decrease from left to right is due to conductive loss to the atmosphere.

Flat-plate solar collector panels come nowadays with selective coating on the water pipes.

This is a special coating, black in appearance, that has
- high-absorption (takes more of the sun), and
- low-emissivity (radiates less away).

This combination improves the efficiency of the device.



Comparison of efficiencies for different panel technologies.

Different technologies are preferred for different applications.

(assuming a solar radiation of 1000 W/m^2)

► At low ΔT, the flat-plate panel is more efficient.
► At high ΔT, the evacuated tube is more efficient.
Typical residential applications for hot water range in the zone where one type is not clearly better than the other, with flat-plate collectors a bit better in winter and evacuated tubes a bit better in summer.

Fafco SunSaver
Solar Bear Ultra Solar Panel
Heating System 4x20
$289.95

Fafco Sunsaver™ solar collector

http://www.bestbuypoolsupply.com/fafco-sunsaver-bear-solar-panel.html