SOLAR HOT WATER HEATERS

Solar Hot Water

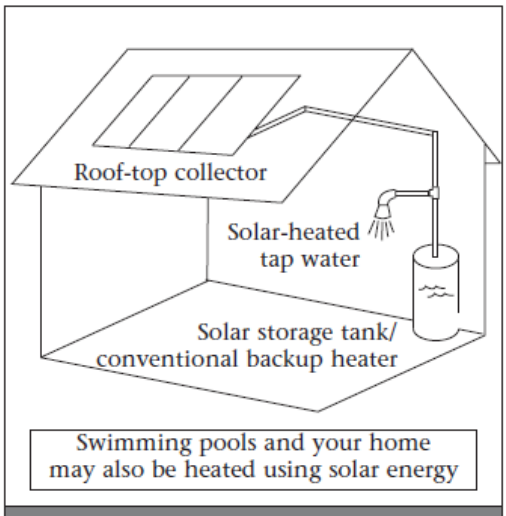
The shallow water of a lake is usually warmer than the deep water. That's because the sunlight can heat the lake bottom in the shallow areas, which in turn, heats the water. It's nature's way of solar water heating. The sun can be used in basically the same way to heat water used in buildings and swimming pools.

Most solar water heating systems for buildings have two main parts: a **solar collector** and a **storage tank**. The most common collector is called a **flat-plate collector**. Mounted on the roof, it consists of a thin, flat, rectangular box with a transparent cover that faces the sun. Small tubes run through the box and carry the fluid — either water or other fluid, such as an antifreeze solution — to be heated. The tubes are attached to an absorber plate, which is painted black to absorb the heat. As heat builds up in the collector, it heats the fluid passing through the tubes .

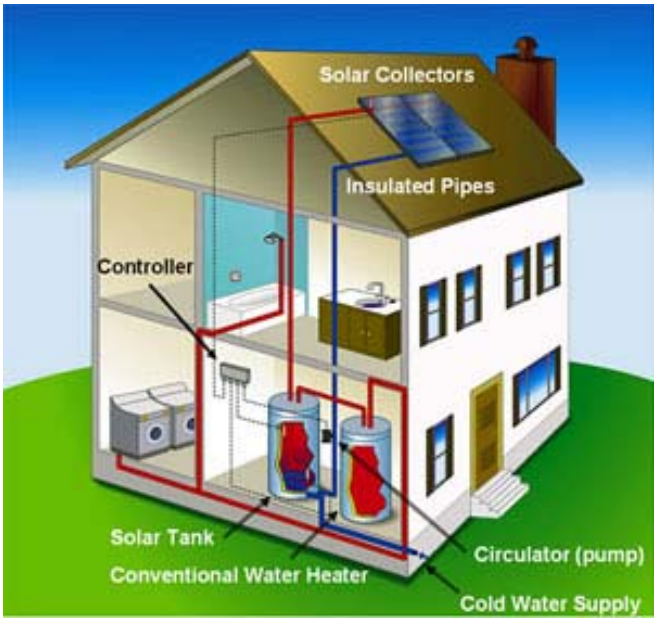
The storage tank then holds the hot liquid. It can be just a modified water heater, but it is usually larger and very well-insulated. Systems that use fluids other than water usually heat the water by passing it through a coil of tubing in the tank, which is full of hot fluid.

Solar water heating systems can be either **active** or **passive**, but the most common are active systems. Active systems rely on pumps to move the liquid between the collector and the storage tank, while passive systems rely on gravity and the tendency for water to naturally circulate as it is heated.

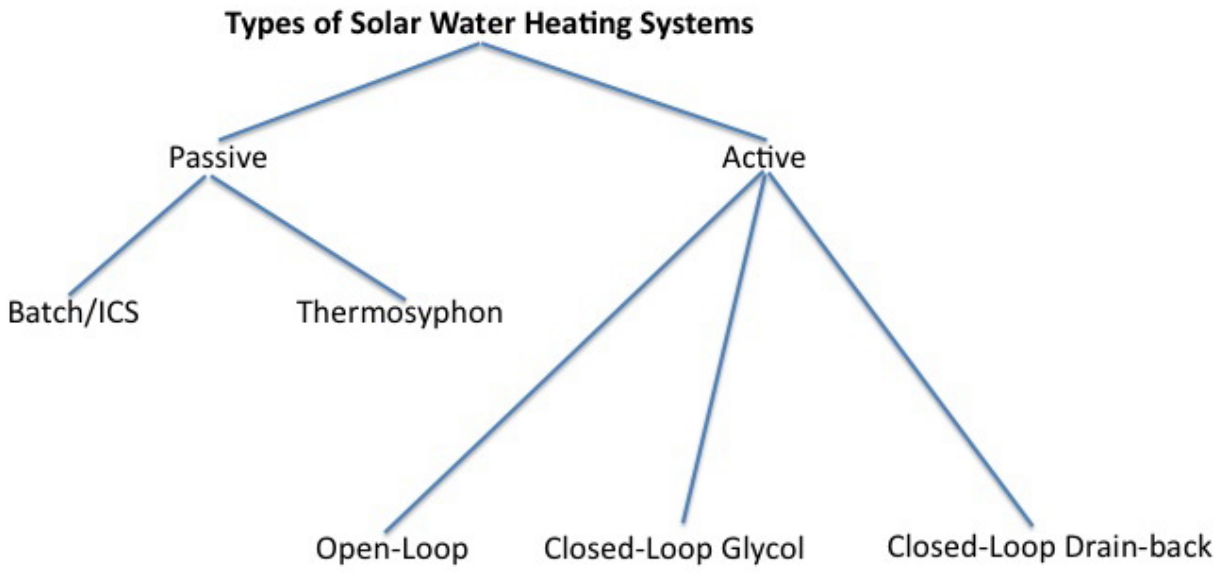
Solar water heaters—also called solar domestic hot water systems—can be a cost-effective way to generate hot water for your home. They can be used in any climate, and the fuel they use—sunshine—is free.



Simplified representation of a solar water-heating system



Solar Water Heating System Types



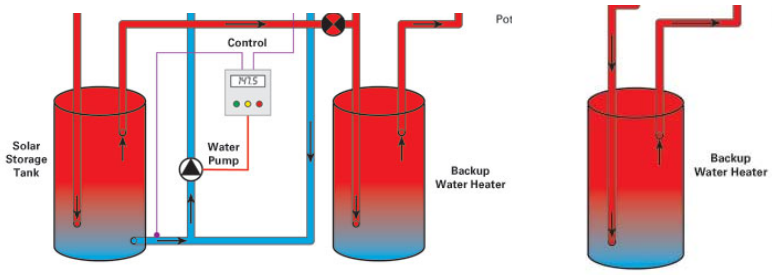
There are 5 main types of Solar Hot Water Heating Systems. Although sometimes people create hybrid Solar Hot Water systems of their own.

Key Ideas to Understand:

Passive vs. Active Systems: The difference being that **active** systems require controls, valves and pumps in order to function. **Passive** systems rely on gravity and thermodynamics in order for the warm water to go where is needed. As a rule of thumb, active systems are more complex and expensive, but are also more efficient and attractive.

Open-Loop and Closed Loop Systems: **Open loop** systems directly circulate and heat the potable water. **Closed loop** systems circulate a ***non-freezing, heat-transfer fluid*** through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates prone to freezing temperatures.

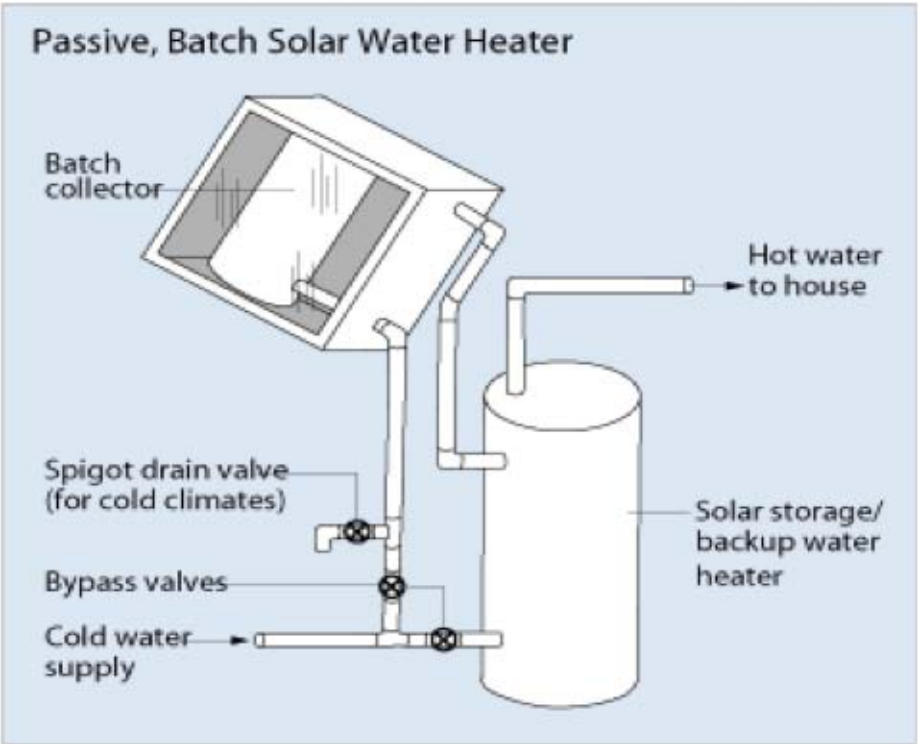
Tanks: Most solar water heaters require a well-insulated storage tank. Solar storage tanks have an additional outlet and inlet connected to and from the collector. In two-tank systems, the solar water heater preheats water before it enters the conventional water heater. In one-tank systems, the back-up heater is combined with the solar storage in one tank.



The 5 Systems

1. Passive Batch/Integrated Collector Systems (ICS)
2. Passive Thermosyphon Systems
3. Active Open Loop Systems
4. Active Closed Loop Heat Exchange Systems (Glycol Systems)
5. Active Closed Loop Drainback Systems (Drainback Systems)

1. Passive Batch/Integrated Collector Systems (ICS) for Solar Water



A batch solar water heater is the simplest and usually cheapest type of solar water heater available. In fact, the majority of them in use today are built and installed by DIY'ers. A batch solar water heater is a collection panel and storage tank rolled into one (hence the name ICS – Integrated Collector Storage). It is basically a box with a glass top and a storage cylinder (usually painted black) inside. Cold water feeds into the tank and is heated naturally due to the ample sunlight flowing in and staying contained in the insulated and sealed box. If you have ever left a bottle of water in a car before, then you understand exactly how a batch heater works. Ah, the beauty of thermal energy – so efficient.

The system requires no pumps or controls as it uses natural water pressure from the city and gravity to operate. The hot shower faucet turns on and the batch heater drains, cold water refills the batch heater and the process continues.

Please keep in mind that this system is better suited for warmer climates. It is not a good idea to install this system in areas susceptible to freezing temperatures as pipes leading to and from the collector as well as water in the heater itself could freeze and ruin the system.

Advantages:

1) Cheapest systems available
2) Simple; very few moving parts, durable
3) DIY-able
4) Low-maintenance (if installed in temperate climates)

Disadvantages:

1) Large and clunky, unattractive
2) Often require structural support on roof due to weight
3) Susceptible to freezing in low temperatures
4) Relatively inefficient as there is heat loss at night

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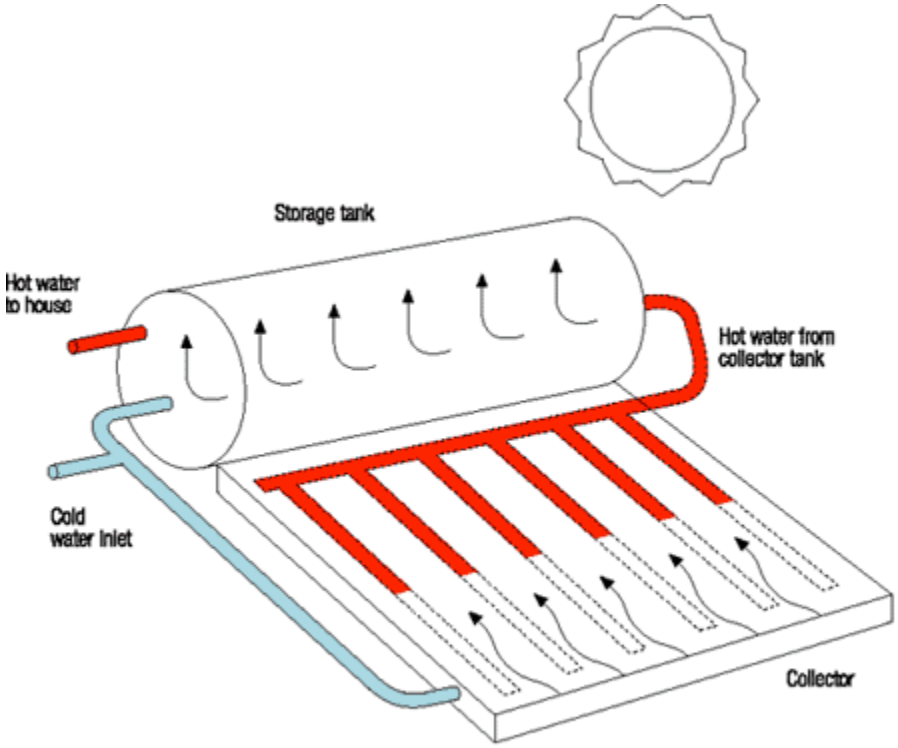
2. Passive Thermosyphon Systems



Thermosyphon Flow

A Thermosyphon system is the other type of system that requires no controls or pumping mechanisms. These systems have a separate collection panel located just below the storage tank, and fluid flows naturally through the system as the sun shines due to the simple principal of convection (heat rises to the top).

The concept is simple. Water gathers heat in the collector and naturally rises up through the collector as it gains heat and flows into the storage tank. As this occurs, the heated water displaces the cooler water inside the tank, which flows out into the bottom of the collector, where it gains heat and rises back into the tank again. And this cycle continues as long as the sun is out and shining.

All in all, Thermosyphon systems get the "workhorse" tag in the solar water industry. They are not the prettiest things in the world, but they get the job done. This could be a good low-cost option for you, but keep in mind the two big drawbacks – you still have a tank on the roof, so building a structural support system might be necessary and you still have a tank outside on your roof at night, so heat loss and efficiency in colder climates is something to consider as well.

Advantages:

1) Inexpensive
2) Low maintenance
3) Durable
4) Requires no electricity or operation

Disadvantages:

1) Storage cylinder on roof is a heavy load
2) Often requires structural support, careful planning for permitting, installation, etc.
3) Unattractive "eyesores" on your roof
4) Heat loss at night as the tank is located outside on the roof

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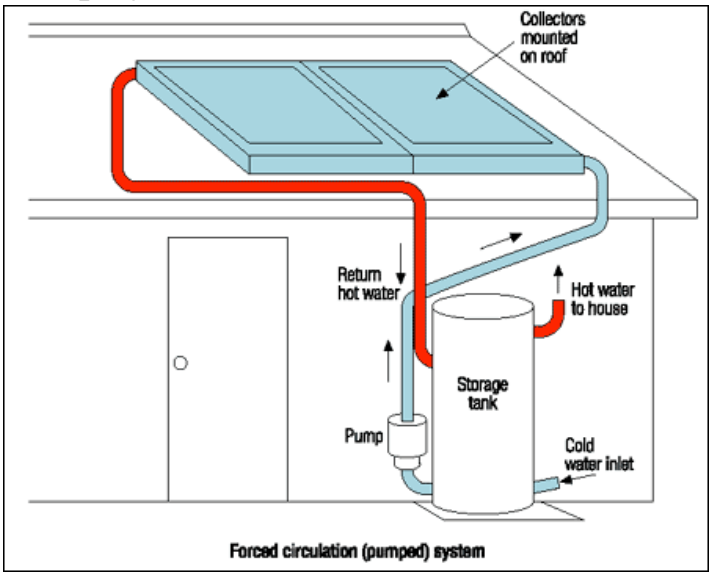
3. Active Open Loop Systems



"Open-loop" means potable water is being circulated through the system and "active" means that pumps, valves, sensors and controllers regulate the system.

As opposed to Batch and Thermosyphon systems, the storage tank in an active system is not located on the roof with the panels. The tanks are installed wherever a typical water heater is located (garage, basement, closet, etc.). The panels are connected to the tank via an insulated line-set (usually made of copper) that runs the length of distance between them. And because of the distance and elevation change, active systems require the use of a pump to get the water from the tank to the collector.

You can think of active systems as smarter and more sophisticated than their passive brethren. They only run the pump when the system knows it is able to collect energy from the sun. At night, the water stays nice and cozy in the garage. This is regulated in one of two ways: Differentiated Temperature Control and PhotoVoltaic (PV) or Solar Electric Control

A Differentiated Temperature Control system simply means that there is a temperature sensor in the panel and a temperature sensor in the tank. When the temperature sensor in the panel shows a higher temperature than the temperature in the tank, the control triggers the pump to run and water begins to circulate.

A PV Control system has a small PV panel located next to the solar water panel. As sun hits the PV panel, it creates an electrical current, which powers the pump to run and fluid begins to circulate through the system.

Each system works well and has its own advantages and disadvantages. In short, the PV powered system requires no additional electricity to run the pump, but has less control and efficiency than the Differentiated Temperature Control system. Typically the cost to run the pump in a Differentiated Control System is offset by the systems' overall increased efficiency, so this should not be a deciding factor when deciding which system to purchase.

Though these systems are typically the most efficient solar hot water systems available, they are typically recommended in only hot climates due to their lack of freeze-protection. Many systems are designed to circulate warm water through the pipes at night, but there is a significant loss of efficiency of the overall system with this freeze protection strategy. Many places don't allow Open-loop systems due to their lack of freeze protection.

Advantages:

1) Sleek/attractive panels
2) Most efficient system type in hot climates
3) Integrates easily with existing systems
4) Typically the least expensive Active option

Disadvantages:

1) Not recommended in climates that reach 40 degrees F.
2) More "moving parts" leads to less durability than a passive system
3) More expensive than Passive solar water heaters
4) Susceptible to scaling/hard water/lime build-up in the system

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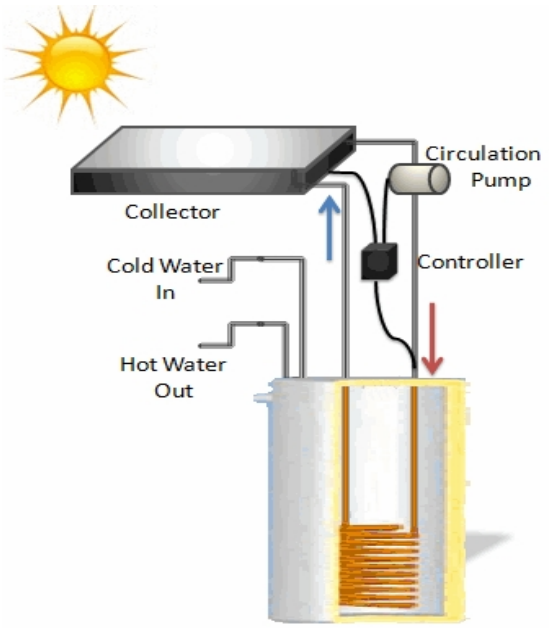
4. Active Closed Loop Heat Exchange Systems (Glycol Systems)



"Closed-loop" refers to a heat exchange fluid (typically propylene glycol, which is a food-grade anti-freeze) circulating through the panel and the heat exchanger located inside the storage tank. The potable water is simply heated indirectly by the hot fluid running through the copper coils. These are the most common types of systems in the US. They function much the same way an Open-loop system does, but offer much greater freeze protection at the cost of only slightly lower efficiency.

Like the Open-loop systems, Closed-loop systems can either be controlled via Differentiated Temperature Control or by PV power. The closed loop glycol lines are pressurized so as to minimize the needed horsepower of the recirculation pump. In this sense, the recirculation pump merely facilitates the movement of the fluid and is not sized to pump fluid against gravity.

Though these systems offer a great balance of efficiency and freeze-production, they arguably require the most maintenance of all systems. For these systems, it is recommended that the PH levels of the glycol are checked every few years, and it is likely that the glycol be replaced every 5-10 years. This is a relatively inexpensive replacement.

One other note about these systems is that they often require what is called a double-walled heat-exchanger. What this means is that there needs to be two layers of metal between the propylene glycol and the water so that if one of the walls springs a leak, glycol will not get into the potable water. Interestingly, propylene glycol is food-grade and would cause no harm if ingested. However, the regulation is required in most jurisdictions so as to prevent people from mistakenly filling their solar water heaters with ethylene glycol (which would be toxic if ingested

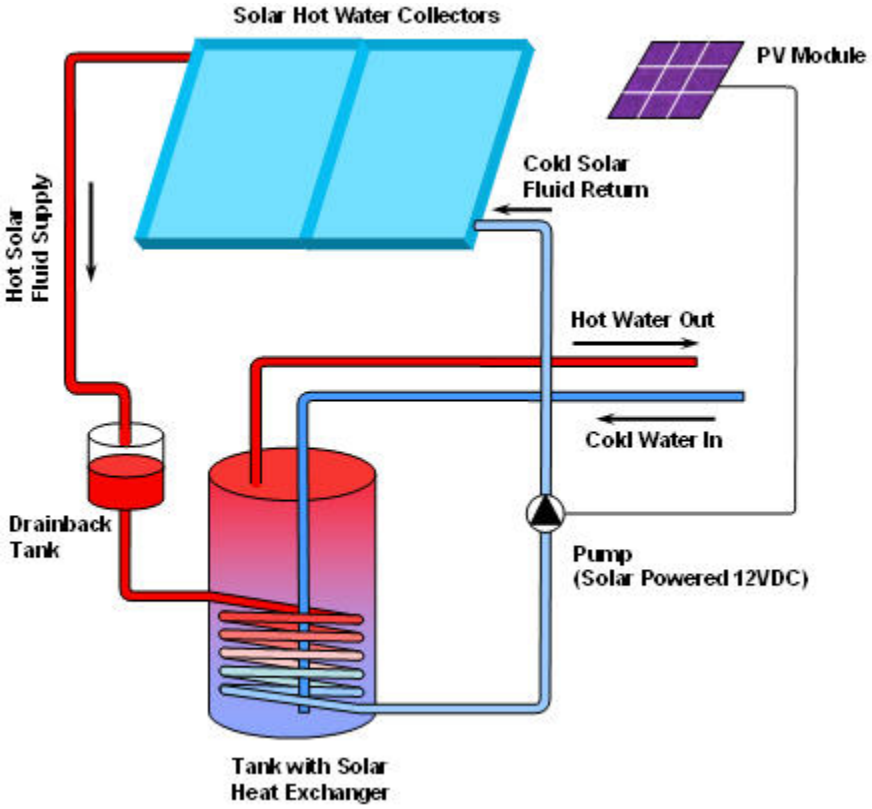
Advantages:

1) Sleek/attractive
2) Great Freeze protection
3) No Problem with Hard Water or Scale Build up
4) More Efficient than Passive Models

Disadvantages:

1) Higher maintenance
2) Lower efficiency than an Open-loop system in warm climates
3) More complicated than other systems
4) More Expensive typically than Open-loop systems

5. Active Closed Loop Drainback Systems (Drainback Systems)



The Closed-loop Drain-back system is similar to a Pressurized Glycol system in that it uses a heat exchanger to transfer heat to the potable water, the difference being that there is a tank in which the fluid from the collector drains into to prevent overheating and freezing. These are popular systems because they eliminate any chance whatsoever of freezing, but sometimes require some additional installation headaches because of the installation of the drain-back tank. There are also some issues with pumping. As the systems are not pressurized like a Pressurized Glycol System, a high-powered pump must sometimes be needed to pump the heat exchange fluid from the Drain-back tank back up to the collector once the controller tells it to do so. For this reason, it is advantageous to have the collector as close as possible to the collector, which in most cases means in the attic.

The system is designed to completely drain the collector into the drain-back tank when there is not good solar energy output. Because distilled water can be used as the heat exchange fluid, a single-wall heat exchanger can be used (one layer of copper between heat-exchange fluid and potable water), which leads to higher efficiency.

Advantages:

1) Sleek/attractive panels
2) Excellent freeze and overheat protection
3) Single-wall heat exchanger leads to greater efficiency
4) No issues with hard water

Disadvantages:

1) Installation typically more difficult
2) Adequate slope of panel needed in order to drain collector properly
3) Usually requires a higher-powered pump to lift water
4) Typically the most expensive systems

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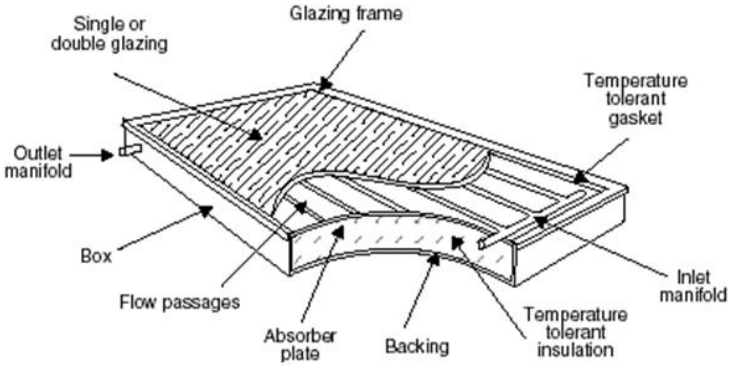
Solar Collectors

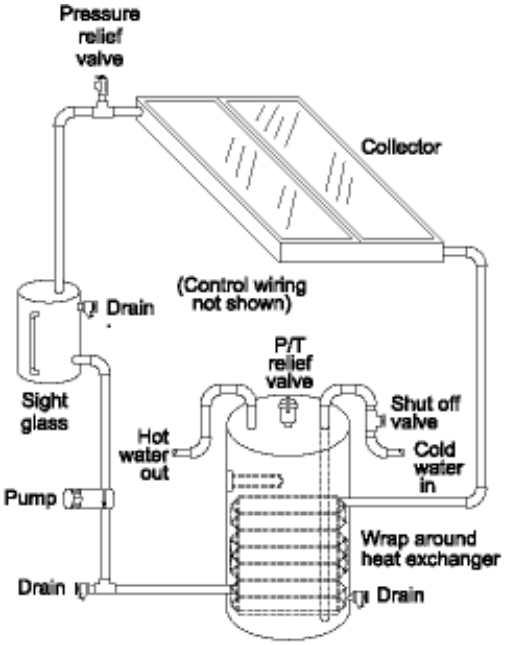
There are three types of solar collectors are used for residential applications:

1) Flat-plate collector
2) Integral collector-storage systems
3) Evacuated-tube solar collectors



1) Flat-plate collector

Glazed flat-plate collectors are insulated, weatherproofed boxes that contain a dark absorber plate under one or more glass or plastic (polymer) covers. Unglazed flat-plate collectors—typically used for solar pool heating—have a dark absorber plate, made of metal or polymer, without a cover or enclosure.

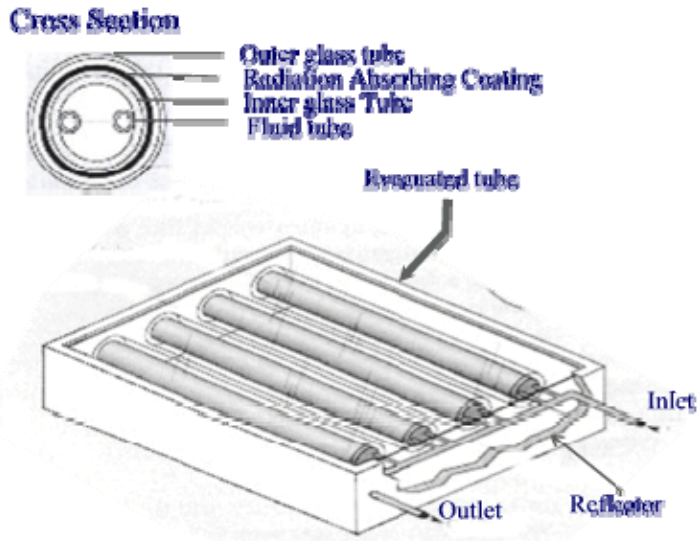


2) Integral collector-storage systems

Also known as ICS or *batch* systems, they feature one or more black tanks or tubes in an insulated, glazed box. Cold water first passes through the solar collector, which preheats the water. The water then continues on to the conventional backup water heater, providing a reliable source of hot water. They should be installed only in mild-freeze climates because the outdoor pipes could freeze in severe, cold weather.

3) Evacuated-tube solar collectors

They feature parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits radiative heat loss. These collectors are used more frequently for U.S. commercial applications.



Backup System

Solar water heating systems almost always require a backup system for cloudy days and times of increased demand. Conventional storage water heaters usually provide backup and may already be part of the solar system package. A backup system may also be part of the solar collector, such as rooftop tanks with thermosyphon systems. Since an integral-collector storage system already stores hot water in addition to collecting solar heat, it may be packaged with a demand (tankless or instantaneous) water heater for backup.

Selecting and installing a solar water heater

The proper installation of solar water heaters depends on many factors. These factors include solar resource, climate, local building code requirements, and safety issues; therefore, it's best to have a qualified, solar thermal systems contractor install your system.

Before you purchase and install a solar water heating system, you want to do the following:

- Consider the economics of a solar water heating system
- Evaluate your site's solar resource
- Determine the correct system size
    - *(As with any other system, look at additional energy-saving strategies to help lower the required water heating bills, especially if you require a back-up system, such as low-flow shower heads.)*
- Determine the system's energy efficiency
- Estimate and compare system costs
- Investigate local codes, covenants, and regulations.

After installation, proper maintenance will help keep the system running smoothly. Passive systems don't require much maintenance. Plumbing and other conventional water heating components require the same maintenance as conventional systems. Glazing may need to be cleaned in dry climates where rainwater doesn't provide a natural rinse. Regular maintenance on simple systems can be as infrequent as every 3–5 years, preferably by a solar contractor. Systems with electrical components usually require a replacement part or two after 10 years.

Sizing a solar hot water system

Just as conventional water heaters come in different sizes, so do solar water heaters. Sizing a residential solar water heater involves determining the total collector area and storage volume you need to meet 90% to 100% of your household's hot water needs during the summer. Solar equipment experts use worksheets and computer programs to help determine system requirements and collector sizing. In Michigan, contractors usually follow a guideline of about 20 square feet (2 square meters) of collector area for each of the first two family members. For every additional person, add 12 to 14 square feet (1.1 to 1.3 square meters).

For active systems, the size of the solar storage tank increases with the size of the collector—typically 1.5 gallons per square foot of collector. A small, 66-gallon system is usually big enough for one to three people; a medium-size, 80-gallon system works well for a three- or four-person household; and a large, 120-gallon system is appropriate for four to six people.

Swimming pools are another great reason to have a solar hot water system. It can take a lot of energy to heat and maintain such a mass of water. Heating a swimming pool with solar energy requires a collector that is 50%

to 100% of the surface area of the pool. The geographic location and other factors determine the exact size. For example, a 15-by-30 foot swimming pool in Florida typically requires a collector that equals 100% of the pool's square footage, which translates to 450 square feet of unglazed flat-plate collectors. This is because many Florida swimming pool owners use their pools year round. In contrast, in northern California, most pools are used only 6 to 8 months per year, so systems are typically sized at 60% to 70% of the pool's surface area.
In general, adding more square footage to the solar collector system lengthens the swimming season and allows owners to use the pool in colder weather. A pool cover or blanket reduces heat loss and helps maintain warm temperatures for a longer period.

Questions

1. Approximately, what size solar hot water system would the following family need?

a. Number of Family Members: _____

b. Total Collector Area Needed: _____

c. Size of the Solar Storage Tank: _____

2. The same family a few years later installs a 25' x 30' pool. They plan on using it from April to September. How many square feet of unglazed flat-plate collectors do they need approximately?

a. Area of pool: _____

b. Square feet of unglazed flat-plate collectors needed? _____

Information taken from:

www.energysavers.gov
www.nrel.gov
www.sunstuffenergy.com
US Department of Energy