Solar Water Heaters

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Solar Water Heater

Solar water heaters, sometimes 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 is free.

How They Work

Solar water heating systems include storage tanks and solar collectors. There are two types of solar water heating systems: active, which have circulating pumps and controls, and passive, which don't.

Active Solar Water Heating Systems

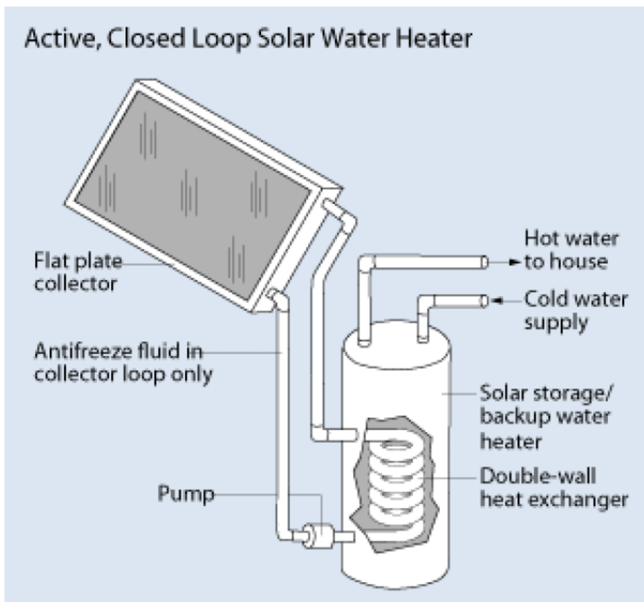


Figure 1: Active Solar Water Heater

There are two types of active solar water heating systems:

- **Direct circulation systems**

  Pumps circulate household water through the collectors and into the home. They work well in climates where it rarely freezes.

- **Indirect circulation systems**

  Pumps circulate 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.

Passive Solar Water Heating Systems

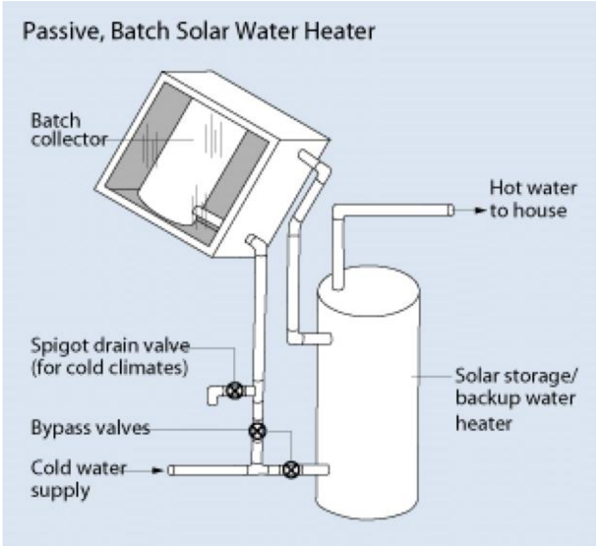


Figure 2: Passive Solar Water Heater

Passive solar water heating systems are typically less expensive than active systems, but they're usually not as efficient. However, passive systems can be more reliable and may last longer. There are two basic types of passive systems:

- **Integral collector-storage passive systems**

  These consist of a storage tank covered with transparent material to allow the sun to heat the water. Water from the tank then flows into the plumbing system. These work best in areas where temperatures rarely fall below freezing. They also work well in households with significant daytime and evening hot-water needs.

- **Thermosyphon systems**

  Water is heated in a collector on the roof and then flows through the plumbing system when a hot water faucet is opened. The majority of these systems have a 40 gallon capacity.

Heat Transfer Fluids for Solar Water Heating Systems

Heat-transfer fluids carry heat through solar collectors and a heat exchanger to the heat storage tanks in solar water heating systems. When selecting heat-transfer fluid, you and your solar heating contractor should consider the following criteria:

- Coefficient of expansion – the fractional change in length (or sometimes in volume, when specified) of a material for a unit change in temperature
- Viscosity – resistance of a liquid to sheer forces (and hence to flow)
- Thermal capacity – the ability of matter to store heat
- Freezing point – the temperature below which a liquid turns into a solid
- Boiling point – the temperature at which a liquid boil
- Flash point – the lowest temperature at which the vapor above a liquid can be ignited in air.
- Corrosivity – compatibility with other materials and additives to reduce corrosion
- Toxicity- only non-toxic fluids can be used in a potable water system.

For example, in a cold climate, solar water heating systems require fluids with low freezing points. Fluids are exposed to high temperatures and should have a high boiling point. Viscosity and thermal capacity determine the amount of energy required. A fluid with low viscosity and high specific heat is easier to pump, because it is less resistant to flow and transfers more heat. Other properties that help determine the effectiveness of a fluid are stability and replacement lifetime.

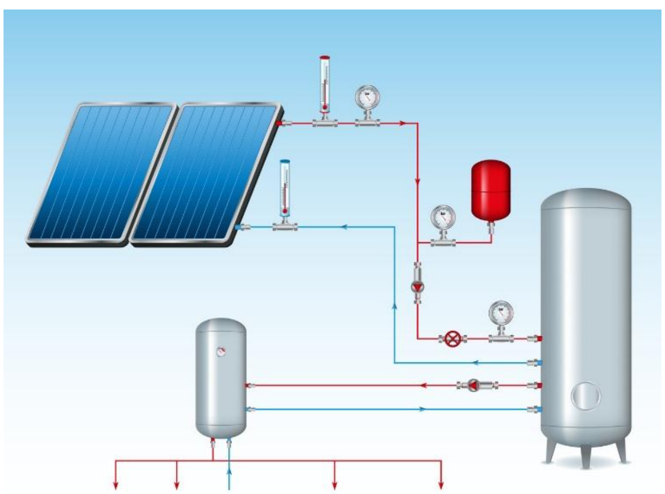


Figure 3: Illustration of a Solar Water Heater

Types of Heat-Transfer Fluids

The following are some of the most used heat-transfer fluids and their properties. Consult a solar heating professional or the local authority having jurisdiction to determine the requirements for heat transfer fluid in solar water heating systems in your area.

- **Air**: Air will not freeze or boil and is non-corrosive. However, it has a very low heat capacity, requires a large heat exchanger to heat the water, and tends to leak out of collectors, ducts, and dampers.
- **Water**: Water is nontoxic and inexpensive. With a high specific heat, and a very low viscosity, it's easy to pump. Unfortunately, water has a relatively low boiling point and no protection against freezing. It can also be corrosive if the pH (acidity/alkalinity level) is not maintained at a neutral level. Water with a high mineral content (i.e., "hard" water) can cause mineral deposits to form in collector tubing and system plumbing.
- **Propylene glycol/water mixtures**: Propylene glycol/water mixtures have a glycol-to-water ratio of 50%/50%, and higher or lower as indicated by the freeze hazard. Ethylene Glycol must not be used due to toxicity, so non-toxic Propylene Glycol is used. These mixtures provide effective freeze protection as long as the proper antifreeze concentration is maintained. Antifreeze fluids degrade over time and normally should be changed every 3–5 years. These types of systems are pressurized and should only be serviced by a qualified solar heating professional. Corrosion inhibitors are added to prevent corrosion by providing some reserve alkalinity to counter corrosive acids.
- **Silicon Fluids**: Silicone fluids have a very low freezing point, and a very high boiling point. They are noncorrosive and long-lasting. Because silicones have high viscosity and low heat capacities, they require more energy to pump. Silicones also leak easily, even through microscopic holes in a solar loop.

Other types of heat transfer fluids include synthetic, mineral, or aromatic hydrocarbon fluids; refrigerants such as found in heat-pump systems; methyl alcohol; and Ammonia. Many of these are toxic, flammable, highly regulated, or entail environmental impacts. While perhaps having industrial uses, these heat transfer fluids would not be found in a household solar water heating system.

Heat Exchangers for Solar Water Heating Systems

Solar water heating systems use heat exchangers to transfer solar energy absorbed in solar collectors to potable (drinkable) water.

Heat exchangers can be made of steel, copper, bronze, stainless steel, aluminum, or cast iron. Solar heating systems usually use copper, because it is a good thermal conductor and has greater resistance to corrosion. Stainless steel is also common in "compact" heat exchangers.

Types of Heat Exchangers

Solar water heating systems use three types of heat exchangers:

- **Liquid-to-liquid**
  A liquid-to-liquid heat exchanger uses a heat-transfer fluid (often a mixture of propylene glycol and water) that circulates through the solar collector, absorbs heat, and then flows through a heat exchanger to transfer its heat to potable water in a storage tank. Heat-transfer fluids, such as propylene glycol antifreeze, protect the solar collector from freezing in cold weather. Liquid-to-liquid heat exchangers have either one or two barriers (single wall or double wall) between the heat-transfer fluid and the domestic water supply. A "double-wall" heat exchanger will drain any leak of heat transfer fluid from a gap before it could get into the potable water.

A single-wall heat exchanger is a pipe or tube surrounded by fluid. Either the fluid passing through the tubing or the fluid surrounding the tubing can be the heat-transfer fluid, while the other fluid is the potable water. An easy way to construct such a heat-exchanger is to put a small pipe into a larger pipe and circulate the fluid to be heated in the outer pipe.

Double-wall heat exchangers have two walls between the two fluids. Two walls with drainage between the two and leak detection is required when the heat-transfer fluid is toxic and are often used even with non-toxic heat transfer fluids such as propylene glycol (antifreeze). Double walls are required as a safety measure in case of leaks, helping ensure that the antifreeze does not mix with the potable water supply. An example of a double-wall, liquid-to-liquid heat exchanger is the "wrap-around heat exchanger," in which a tube is wrapped around and bonded to the outside of a hot water tank. The tube must be adequately insulated to reduce heat losses.

While double-wall heat exchangers increase safety, they are less efficient because heat must transfer through two surfaces rather than one. To transfer the same amount of heat, a double-wall heat exchanger must be larger than a single-wall exchanger.

- **Air-to-liquid or liquid to-air**
  Solar heating systems with air-heating solar collectors usually do not need a heat exchanger between the solar collector and the air distribution system. Those systems with air heater collectors that heat water use air-to-liquid heat exchangers, which are similar to liquid-to-

air heat exchangers. These are similar in appearance to the radiator on the front of a large truck engine.

Heat Exchanger Designs

- **Coil-in-tank**
  The heat exchanger is a coil of tubing in the storage tank. It can be a single tube (single-wall heat exchanger) or the thickness of two tubes (double-wall heat exchanger)), depending on the heat transfer fluid. . A less efficient alternative is to place the coil on the outside of the collector tank with a cover of insulation.

- **Shell-and-tube**
  The heat exchanger is separate from (external to) the storage tank. It has two separate fluid loops inside a case or shell. The fluids flow in opposite directions to each other through the heat exchanger, maximizing heat transfer. The potable water to be heated circulates through a shell surrounding the tubes and the heat transfer fluid from the solar collectors circulates through the inner tubes. The tubes and shell should be made of the same material. When the collector or heat-transfer fluid is toxic, double-wall tubes are used, and a gap is placed between the outer and inner walls of the tubes.

- **Tube-in-tube**
  In this very efficient design, the tubes of water and the heat-transfer fluid are in direct thermal contact with each other. A tube-in-tube heat exchanger is created by putting a small pipe into a larger pipe, and the assembly may be coiled to occupy less space. The water and the heat-transfer fluid flow in opposite directions to each other. This type of heat exchanger has two loops similar to those described in the shell-and-tube heat exchanger.

- **“Compact” heat exchanger**
  In so-called “compact” heat exchangers a very large surface area is created by plates stamped out of stainless steel. Because of the strength and corrosion-resistance of stainless stell these plates can be very thin and close together.

Sizing of Heat Exchanger

A heat exchanger must be sized correctly to be effective. There are many factors to consider for proper sizing, including the following:

- Type of heat exchanger
- Characteristics of the heat-transfer fluid (specific heat, viscosity, and density)
- Flow rate
- Inlet and outlet temperatures for each fluid

Usually, manufacturers will supply heat transfer ratings for their heat exchangers (in Btu/hour) for various fluid temperatures and flow rates. Also, the size of a heat exchanger's surface area affects its speed and efficiency: a large surface area transfers heat faster and more efficiently. There are two methods to size heat exchangers:

- The log-mean temperature difference method divides required heat transfer rate by a log-mean incoming and exiting temperature differences and by heat transfer coefficient to determine the required surface area.
- "Effectiveness" method, where the required size is the required heat transfer rate divided by an "effectiveness" and by the maximum temperature difference (hot solar minus cold water). Effectiveness depends on the heat transfer coefficient and flow rates and is typically on the order of 60%.

A designer might use calculators provided on supplier's websites to do these calculations.

Installation

For the best performance, always follow the manufacturer's installation recommendations for the heat exchanger. Be sure to choose a heat-transfer fluid that is compatible with the type of heat exchanger you will be using. If you want to build your own heat exchanger, be aware that using different metals in heat exchanger construction may cause corrosion. Also, because dissimilar metals have different thermal expansion and contraction characteristics, leaks or cracks may develop. Either of these conditions may reduce the life span of your heat exchanger.

Storage Tanks and Solar Collectors

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.

Three types of solar collectors are used for residential applications:

- **Flat-plate collector**

  Glazed flat-plate collectors are insulated, weatherproof 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.

- **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-freezing climates because the outdoor pipes could freeze in severe, cold weather.

- **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.

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 tankless or demand-type water heater for backup.

Storage Water Heaters

Conventional storage water heaters remain the most popular type of water heating system for the home. Here you'll find basic information about how storage water heaters work; what criteria to use when selecting the right model; and some installation, maintenance, and safety tips.

How They Work

A single-family storage water heater offers a ready reservoir -- from 20 to 80 gallons -- of hot water. It operates by releasing hot water from the top of the tank when you turn on the hot water tap. To replace that hot water, cold water enters the bottom of the tank through the dip tube where it is heated, ensuring that the tank is always full.

Conventional storage water heater fuel sources include natural gas, propane, fuel oil, and electricity.

Since water is heated in the tank until the thermostat setpoint temperature is reached, energy can be wasted even when a hot water tap isn't running due to standby heat losses, which result from the tank losing heat to the surrounding environment. Only tankless water heaters -- such as demand-type water heaters and tankless coil water heaters -- avoid standby heat losses. Some storage water heater models have heavily insulated tanks, which significantly reduce standby heat losses and lower annual operating costs. Look for models with tanks that have a thermal resistance (R-Value) of R-24 and above to avoid adding an insulation blanket (electric water heaters only).

Gas and oil water heaters also have venting-related energy losses. Two types of water heaters -- a fan-assisted gas water heater and an atmospheric sealed-combustion water heater -- reduce these losses.

For low energy bills the best choice to consider are heat pump water heaters and solar water heaters. These water heaters are usually more expensive but they have significantly lower annual operating costs that result in short payback periods.

Tankless or Demand-Type Water Heaters

Tankless water heaters, also known as demand-type or instantaneous water heaters, provide hot water only as it is needed. They don't produce the standby energy losses associated with storage water heaters, which can save money.

Here you'll find basic information about how they work, whether a tankless water heater might be right for your home, and what criteria to use when selecting the right model.

How Tankless Water Heaters Work

Tankless water heaters heat water instantaneously without the use of a storage tank. When a hot water faucet is turned on, cold water flows through a heat exchanger in the unit, and either a natural gas burner or an electric element heats the water.

As a result, tankless water heaters deliver a constant supply of hot water. You don't need to wait for a storage tank to fill up with enough hot water. However, a tankless water heater's output limits the flow rate.

Typically, tankless water heaters provide hot water at a rate of 2–5 gallons (7.6–15.2 liters) per minute. Gas-fired tankless water heaters produce higher flow rates than electric ones.

Sometimes, however, even the largest, gas-fired model cannot supply enough hot water for simultaneous, multiple uses in large households. For example, taking a shower and running the dishwasher at the same time can stretch a tankless water heater to its limit.

To overcome this problem, you can install two or more tankless water heaters. You can also install separate tankless water heaters for appliances -- such as a clothes washer or dishwater -- that use a lot of hot water in your home. However, additional water heaters will cost more and may not be worth the additional cost.

Other applications for demand water heaters include the following:

- Remote bathrooms or hot tubs
- Booster for appliances, such as dishwashers or clothes washers
- Booster for a solar water heating system.

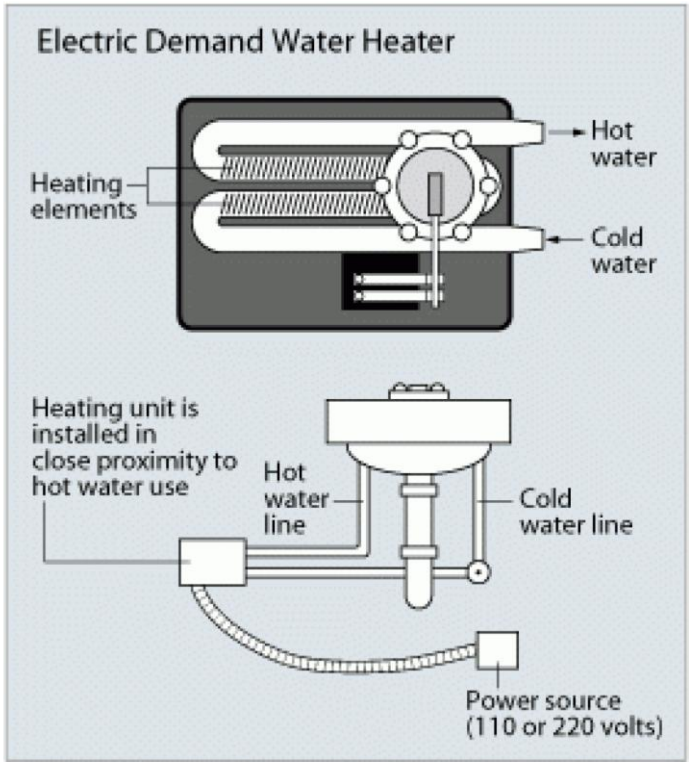


Figure 4: Demand Water Heater

Advantages and Disadvantages of Tankless Water Heaters

For homes that use 41 gallons or less of hot water daily, demand water heaters can be 24%–34% more energy efficient than conventional storage tank water heaters. They can be 8%–14% more energy efficient for homes that use a lot of hot water -- around 86 gallons per day. In some cases you may be able to achieve even greater energy savings if you install a demand water heater at each hot water outlet.

The initial cost of a tankless water heater is greater than that of a conventional storage water heater, but tankless water heaters will typically last longer and have lower operating and energy costs, which could offset their higher purchase price. Most tankless water heaters have a life expectancy of more than 20 years. They also have easily replaceable parts that may extend their life by many more years. In contrast, storage water heaters last 10–15 years.

Tankless water heaters avoid the standby heat losses associated with storage water heaters. However, although gas-fired tankless water heaters tend to have higher flow rates than electric ones, they can waste energy if they have a pilot light. This can sometimes offset the elimination of standby energy losses when compared to a storage water heater. In a gas-fired storage water heater, the pilot light heats the water in the tank, so the energy isn't wasted.

The cost of operating a pilot light in a tankless water heater varies from model to model. Review the manufacturer's literature to determine how much gas the pilot light uses for the model you're considering. Look for models that have an intermittent ignition device (IID) instead of a standing pilot light. This device resembles the spark ignition device on some natural gas furnaces and kitchen ranges and ovens.

Selecting a Demand Water Heater

Before buying a demand water heater, you also need to consider the following:

- Size
- Fuel type and availability
- Energy efficiency (energy factor)
- Costs

Installing and Maintaining a Tankless Water Heater

Proper installation and maintenance of your demand water heater can optimize its energy efficiency.

Proper installation depends on many factors. These factors include fuel type, climate, local building code requirements, and safety issues, especially concerning the combustion of gas-fired water heaters. Therefore, it's best to have a qualified plumbing and heating contractor install your demand water heater. Do the following when selecting a contractor:

- Request cost estimates in writing
- Ask for references
- Check the company with your local Better Business Bureau
- See if the company will obtain a local permit if necessary and understand local building codes.

If you're determined to install your water heater yourself, first consult the manufacturer. Manufacturers usually have the necessary installation and instruction manuals. Also, contact your city or town for information about obtaining a permit, if necessary, and about local water heater installation codes.

Periodic water heater maintenance can significantly extend your water heater's life and minimize loss of efficiency. Read your owner's manual for specific maintenance recommendations.

Selecting a Solar Water Heater

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

Estimating the Cost and Energy Efficiency of a Solar Water Heater

Solar water heating systems cost more to purchase and install than conventional water heating systems. However, a solar water heater can usually save you money in the long run.

How much money you save depends on the following:

- The amount of hot water you use
- Your system's performance
- Your geographic location and solar resource
- Available financing and incentives
- The cost of conventional fuels that your conventional water heater would otherwise use (natural gas, oil, or electricity)

On average, if you install a solar water heater, your water heating bills should drop 50%–80%. Also, because the sun is free, you're protected from future fuel shortages and price hikes.

If you're building a new home or refinancing, the economics are even more attractive. Including the price of a solar water heater in a new 30-year mortgage usually amounts to between $13 and $20 per month. The federal income tax deduction for mortgage interest attributable to the solar system reduces that by about $3–$5 per month. So, if your fuel savings are more than $15 per month, the solar investment is profitable immediately. On a monthly basis, you're saving more than you're paying.

Determining Energy Efficiency of a Solar Water Heater

Use the *solar energy factor* (SEF) and *solar fraction* (SF) to determine a solar water heater's energy efficiency.

The solar energy factor is defined as the energy delivered by the system divided by the electrical or gas energy put into the system. The higher the number, the more energy efficient. Solar energy factors range from 1.0 to 11. Systems with solar energy factors of 2 or 3 are the most common.

Another solar water heater performance metric is the solar fraction. The solar fraction is the portion of the total conventional hot water heating load (delivered energy and tank standby losses). The higher the solar fraction, the greater the solar contribution to water heating, which reduces the energy required by the backup water heater. The solar fraction varies from 0 to 1.0. Typical solar fraction values are 0.5–0.75.

For certified solar hot water systems, the Solar Energy Factor and Solar Fraction are listed by the Solar Rating and Certification Corporation at https://solar-rating.org/. This certification also lists how much heat (kWh or Btu) the system will deliver per day under different conditions of sunlight and temperature.

Don't choose a solar water heating system based solely on its energy efficiency. When selecting a solar water heater, it's also important to consider size and overall cost.

Calculating Annual Operating Costs

Before purchasing a solar water heating system, estimate the annual operating costs and compare several systems. This will help you determine the energy savings and payback period of investing in a more energy-efficient system, which will probably have a higher purchase price.

Before you can choose and compare the costs of various systems, you need to know the system size required for your home.

To estimate the annual operating cost of a solar water heating system, you need the following:

- The system's solar energy factor (SEF)
- The auxiliary tank fuel type (gas or electric) and costs (your local utility can provide current rates).

Then, use the following calculations:

First calculate the amount of energy needed to heat water based on fuel use or gallons of hot water needed.

With A Gas Auxiliary Tank System:

Daily Water Heating Energy

Fuels such as natural gas are often sold in units of "therms." One (1) therm equals 100,000 British thermal units (Btus). Look through your utility bills and see how much fuel you use in summer months, when gas is not used for space heating. If you have gas for cooking and clothes dryer, you might want to take about 60% of that summer total as the energy used to heat water.

A conventional water heater's energy efficiency is the Uniform Energy Factor (UEF) which is the amount of hot water produced per unit of fuel consumed in a standard test. The higher the UEF value is, the more efficient the water heater. UEF is determined by the Department of Energy's test method outlined in 10 CFR Part 430, Subpart B, Appendix E. Household gas water heaters are required to have a UEF of at least 0.64. For electric heaters the UEF is taken to be 1.0 since all the electricity goes into the water.

Daily Water Heating Energy =

(Summer months fuel use)*EF*0.6/(number of days in summer months)

The fuel used is related to the amount of water used and the temperature. The definition of Btu is energy required to raise one pound (lbs) of water by one degree Fahrenheit (F).

Daily Water Heating Energy=

(gallons of hot water per day)*(8.35 lbls/gallon)*(1 btu/lbs/F)*(Hot water temperature-Cold water temperature).

The Daily Water Heating Energy based on the DOE test procedure for hot water heaters assumes an incoming water temperature of 58°F, hot water temperature of 135°F, and total hot water production of 64.3 gallons per day, which is the average usage for a household of three people. This results in a Daily Water Heating Energy of 0.4105 therms/day if natural gas or 12.03 kWh per day if electricity.

Often it is advisable to size a solar system based on such benchmark loads or based on the number of bedrooms in a house instead of current consumption, which depends on the changing number and behavior of occupants of a house.

Annual Cost of Convention Natural Gas Heating

Annual cost of fuel for conventional heating depends on the Daily Water Heating Energy, the efficiency of the conventional heater, and the price of fuel.

Annual Water Heating Cost =

(365 days/year) * ×(Daily Water Heating Energy therms/day) 41,045 ÷ UEFSEF × Fuel Cost ($/thermBtu) = estimated annual cost of operation

For the example of our benchmark values for daily energy requirement, UEF of 0.64, and a natural gas price of $1.10/therm:OR

(365 days/year) × (0.4105 therms/day) ÷ (0.64 USEF) × ($1.10/therm) Fuel Cost (therm) = $257.52/year estimated annual operating cost

Example:

Assuming the SEF is 1.1 and the gas costs $1.10/therm 365 × 0.4105 ÷ 1.1 × $1.10 = $149.83

The energy usage per day in the above equations is based on the DOE test procedure for hot water heaters, which assumes an incoming water temperature of 58°F, hot water temperature of 135°F, and total hot water production of 64.3 gallons per day, which is the average usage for a household of three people.

With An Electric Auxiliary Tank System:

You need to know or convert the unit cost of electricity by kilowatt-hour (kWh). The Average Electricity Rate in the U.S. was 10.42 cents per kilowatt-hour in 2021. Hawaii has the highest average electricity rate of 30.55 cents per kilowatt-hour. Louisiana has the lowest average electricity rate of 7.01cents per kilowatt-hour. With the UEF of 1.0 and an electricity price of $0.1042/kWh and example of Annual Water Heating Costs for electric water heater is:

Annual Water Heating Cost = (365 days/year)× 12.03 kWh/day ÷ (1.0) SEF × ($0.1042) = $457.54/year.

This example shows electricity is more expensive than natural gas which is very often the case.

Comparing Costs and Determining Payback for a Solar Water Heating System

Now that we know the cost of conventional heating, we have to estimate what that would be reduced to and subtract that to estimate the savings in fuel associated with a solar water heater. In the SEF determination, the power required to operate pumps and controls also considered.

Annual Solar Energy Savings =

Daily Hot Water Energy (therms/day)*(365 days/year)((1/EF)-(1/SEF))

For example the natural gas savings consumption from a solar system with an SEF of 2.5 would then be

Annual Solar Energy Savings =

(0.4105 therms/day)*(365 days/year)((1/0.64)-(1/2.5))=174 therms/year

Prices for natural gas vary significantly by location and by month. In May 2021 the US average was $1.776/therm, a significant increase over earlier years. The average from 2011 to 2021 is about $1.50/therms and we will use that in our example.

The associated Annual Solar Cost Savings would be:

(174 therms/year)*($1.50/therm) = $261/year

For and electric water heater with UEF=1.0 and electric price of $0.08/kWh the energy and cost savings per year would be:

Annual Solar Energy Savings =

(12.03 kWh/day)*(365 days/year)((1/1.0)-(1/2.5))= 2634 kWh/year

And the associated Annual Solar Cost Savings would be:

(2634 kWh/year)*($0.1042/kWh) = $274.46/year

Operation and Maintenance Costs

Any cost associated with repairs of the system would subtract from this fuel cost savings. Residential solar hot water systems are designed to operate without intervention and reliability has evolved to the point that O&M costs should be minimal. Still, O&M costs are characterized as about ½ of 1% of initial cost, based on years zero O&M cost punctuated by occasional costs for such things as fluid replacement. Homeowners insurance usually covers damage from hail. If you want to include installation and maintenance costs, consult the manufacturer(s) and a qualified contractor to help estimate these costs. These costs will vary among system types and sometimes even from water heater model to model.

Now we need to determine the Once you know the ppurchase and annual operating costs of the solar water heating system and compare that with the costs associated with conventional water heating systems to calculate a payback on our solar investment.

Installed Cost

Cost estimates for household-sized solar water heaters are on the order of \$100/sf (\$1000/m2). Costs vary by collector type and system configuration as well as local market factors. This price might be typical of a location with local suppliers and robust competition. Reported prices vary all the way from \$50/sf for unglazed swimming pool heater to \$424/sf for a system in a report that uses evacuated tube solar collectors. For example, in 2003, 62 units, each with two 4 ft x 8 ft solar collectors, were installed in a housing area with an average cost of \$4,000 per system, or \$62.50/sf.

The SEF rating will be associated with a system with a certain number of solar collectors (1, 2 or more). A typical size for a home would be two solar collectors for an area of 64 or 80 sf. The cost of such a system might be on the order of \$4,000 as described in the example above. The simple payback period would be the initial cost divided by the annual cost savings. When compared to natural gas in our on-going example:

Payback Period (years) = (Initial Cost \$)/(Annual Cost Savings \$/year)

When compared to natural gas in our on-going example:

(\$4000)/(\$261/year) = 15.3 years

And when compared to electricity:

(\$4000)/(\$274.46/year) = 14.5 years.

In areas where the energy costs are higher than assumed here, the paybacks are lower and it is in those areas where most installation activity occurs. These are areas with high energy prices such as Hawaii and California and places where low-cost natural gas is not available and more expensive fuel oil is used.

System Models	System Price	SEF	Estimated Annual Operating Cost
System Model A			
System Model B (higher SEF)			
Additional cost of more efficient model (Model B)			Price of Sytem Model B - Price of System Model A = $Additional Cost of Model B
Estimated annual operating cost savings (System Model B)			System Model B Annual Operating Cost - System Model A Annual Operating Cost = $Model B's Cost Savings Per Year
Payback period for Model B			$Additional Cost of Model B/$Model B's Cost Savings Per Year = Payback period/years

Example:

Comparison of two solar water heating system models with electric backup systems and electricity costs of $0.08/kWh.

System Models	System Price	SEF	Estimated Annual Operating Cost
System Model A	$1,060	2.0	$176
System Model B	$1,145	2.9	$121
Additional cost of more efficient model (Model B)			$1,145-$1,060 = $85
Estimated annual operating cost savings (Model B)			$176-$120 = $56 per year
Payback period for Model B			$85/$56 per year = 1.5 years

Other Costs

When comparing solar water heating systems, you should also consider installation and maintenance costs. Some systems might cost more to install and maintain.

Consult the manufacturer(s) and a qualified contractor to help estimate these costs. These costs will vary among system types and sometimes even from model to model.

Siting Your Solar Water Heating System

Before you buy and install a solar water heating system, you need to first consider the characteristics of your site: available roof or land area, the solar resource, shading by trees or buildings, as well as the optimal orientation and tilt of your solar collector. The efficiency and design of a solar water heating system depend on how much of the sun's energy reaches your building site.

Solar water heating systems use both direct and diffuse solar radiation. Even if you don't live in a climate that's warm and sunny most of the time -- like the southwestern United States -- your site still might have an adequate solar resource. If your building site has unshaded areas that generally face toward the equator (to the south in the US) , it's a good candidate for a solar water heating system. Your local solar system supplier or installer can perform a solar site analysis.

Shading by surrounding trees or other buildings should be avoided. It is impossible to avoid all shading, but every effort should be made to avoid shading between the hours of 10 am and 2 pm and in winter, when the sun is lowest in the southern sky (in summer the sun is almost directly overhead and there is less shading).

The type, age, and condition of the roof are all important. Roofs covered with composite shingles are easier and less expensive to install solar on than roofs like wood shingles or tile roofs. It is possible to re-roof around solar water heating collectors, but new solar systems should be installed on new or sound roofs that will not need to be replaced in the 25- year life of the solar system. It is often necessary to reinforce the roof structure with blocking between rafters. Care should be taken when installing roof rack stanchions and waterproof flashing- and that job is often done by a professional roofer. Although the roof is the natural place to locate solar collectors, some are installed on ground foundations (piles) to avoid roof issues.

Both the orientation and tilt of the collector will affect your solar water heating system's performance. Your contractor should consider both factors while evaluating your site's solar resource and sizing your system.

Collector Orientation

Solar hot water collectors should be oriented geographically to maximize the amount of daily and seasonal solar energy that they receive. In general, the optimum orientation for a solar collector in the northern hemisphere is true south. However, studies have shown that, depending on your location and collector tilt, your collector can face up to 45º east or west of true south without significantly decreasing its performance.

You'll also want to consider factors such as roof orientation (if you plan to mount the collector on your roof), local landscape features that shade the collector daily or seasonally, and local weather conditions (foggy mornings or cloudy afternoons), as these factors may affect your collector's optimal orientation.

Collector Tilt

Today, most solar water heating collectors are mounted flat on the roof. This is more aesthetically pleasing than rack-mounted collectors, which stick up from the roof at odd angles. Thus, most collectors have the same tilt as the roof.

The optimal tilt angle for your collector that maximizes annual energy delivery with maximum delivery in spring and fall is an angle equal to your latitude. However, because we often need more heat in winter (colder water coming in), it is often advisable to tilt water heating solar collectors up to a steeper tilt angle. This is in contrast to photovoltaic-type solar systems which are often mounted on a flat roof or low tilt angle. You will, however, want to take roof angle into account when sizing your system.

Sizing a New Water Heater

A properly sized water heater will meet your household's hot water needs while operating more efficiently. Therefore, before purchasing a water heater, make sure it's the correct size.

Here you'll find information about how to size these systems:

- Tankless or demand-type water heaters
- Solar water heating system
- Storage and heat pump (with tank) water heaters.

For sizing combination water and space heating systems -- including some heat pump systems, and tankless coil and indirect water heaters -- consult a qualified contractor.

If you haven't yet considered what type of water heater might be best for your home, learn more about selecting a new water heater.

Sizing Tankless or Demand-Type Water Heaters

Tankless or demand-type water heaters are rated by the maximum temperature rise possible at a given flow rate. Therefore, to size a demand water heater, you need to determine the flow rate and the temperature rise you'll need for its application (whole house or a remote application, such as just a bathroom) in your home.

1. **List the number of hot water devices** you expect to use at any one time.
2. **Add up their flow rates** (gallons per minute). This is the desired flow rate you'll want for the demand water heater. For example, let's say you expect to simultaneously run a hot water faucet with a flow rate of 0.75 gallons (2.84 liters) per minute and a shower head with a flow rate of 2.5 gallons (9.46 liters) per minute.

3. **If you don't know the flow rate, estimate it** by holding a pan or bucket under the faucet or shower head and measure the flow for a minute. The flow rate through the demand water heater should be at least 3.25 gallons (12.3 liters) per minute. To reduce flow rates, install low-flow water fixtures.
4. To **determine temperature rise**, subtract the incoming water temperature from the desired output temperature. Unless you know otherwise, assume that the incoming water temperature is 50ºF (10ºC).

You can also estimate the temperature by holding a thermometer under a cold-water faucet. For most uses, you'll want your water heated to 120ºF (49ºC). In this example, you'd need a demand water heater that produces a temperature rise of 70ºF (39ºC) for most uses.

For dishwashers without internal heaters and other such applications, you might want your water heated at 140ºF (60ºC). In that case, you'll need a temperature rise of 90ºF (50ºC). Be cautious of a water temperature of 140ºF because it increases the possibility of scalding.

Most demand water heaters are rated for a variety of inlet temperatures. Typically, a 70ºF (39ºC) water temperature rise is possible at a flow rate of 5 gallons per minute through gas-fired demand water heaters and 2 gallons per minute through electric ones. Faster flow rates or cooler inlet temperatures can sometimes reduce the water temperature at the most distant faucet.

Some types of tankless water heaters are thermostatically controlled; they can vary their output temperature according to the water flow rate and inlet temperature.

Sizing a Solar Water Heating System

Sizing your solar water heating system basically involves determining the total collector area and the storage volume you'll need to meet 90%–100% of your household's hot water needs during the summer. Solar system contractors use worksheets and computer programs to help determine system requirements and collector sizing.

Collector Area

Contractors usually follow a guideline of around 20 square feet (2 square meters) of collector area for each of the first two family members. For every additional person, add 8 square feet (0.7 square meters) if you live in the U.S. Sun Belt area or 12–14 square feet if you live in the northern United States.

Storage Volume

A small (50- to 60-gallon) storage tank is usually sufficient for one to two three people. A medium (80-gallon) storage tank works well for three to four people. A large tank is appropriate for four to six people.

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. This helps prevent the system from overheating when the demand for hot water is low. In very warm, sunny climates, some experts suggest that the ratio should be increased to as much as 2 gallons of storage to 1 square foot of collector area.

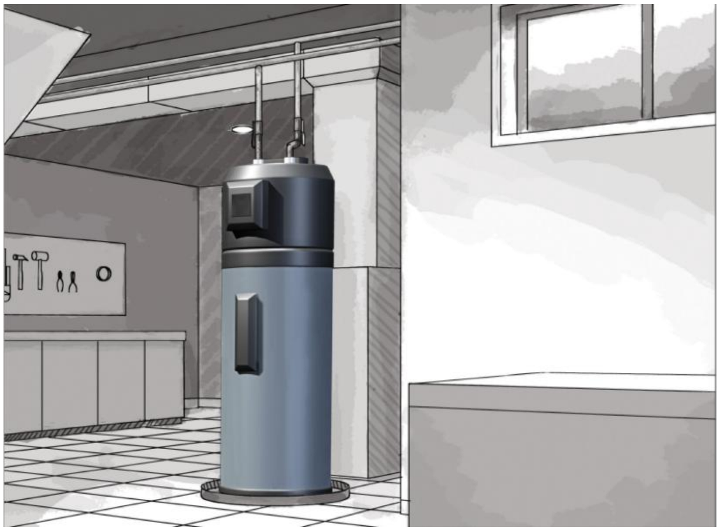


Figure 5: Is your water heater the right size for your house?

Sizing Storage and Heat Pump (with Tank) Water Heaters

To properly size a storage water heater for your home -- including a heat pump water heater with a tank -- use the water heater's first hour rating. The first hour rating is the number of gallons of hot water the heater can supply per hour (starting with a tank full of hot water). It depends on the tank capacity, source of heat (burner or element), and the size of the burner or element.

The EnergyGuide label lists the first hour rating in the top left corner as "Capacity (first hour rating)." The Federal Trade Commission requires an EnergyGuide label on all new conventional storage water heaters but not on heat pump water heaters. Product literature from a manufacturer may also provide the first hour rating. Look for water heater models with a first hour rating that at least matches within your peak hour demand (the highest energy use during a single 1-hour period for your home).

To estimate your peak hour demand:

- Determine what time of day (morning, noon, evening) you use the highest amount of hot water in your home. Keep in mind the number of people living in your home.
- Use the worksheet below to estimate your maximum usage of hot water during this one-hour period of the day, this is your peak hour demand. Note: the worksheet does not estimate total daily hot water usage.

The worksheet example shows a total peak hour demand of 66 gallons. Therefore, this household would need a water heater model with a first hour rating of 66 gallons or more.

Worksheet for Estimating Peak Hour Demand/First Hour Rating*

Use	Average gallons of hot water per usage		Times used during 1 hour		Gallons used in 1 hour
Shower	20	×		=	
Shaving (.05 gallon per minute)	2	×		=	
Hand dishwashing or food prep (2 gallons per minute)	3	×		=	
Automatic dishwasher	7	×		=	
Clothes washer		×		=	
- Top-loader	25				
- H-Axis	15				
			Total Peak Hour Demand	=	

EXAMPLE

3 showers	**20**	×	**3**	=	**60**
1 shave	2	×	1	=	2
1 hand dishwashing	3	×	1	=	3
Peak Hour Demand				=	66

**Estimates are based on averages from a variety of information published on websites. Some water heater manufacturer websites also provide calculators based on the duration for the use case and other factors.*

Building Codes and Regulations for Solar Water Heating Systems

Before installing a solar water heating system, you should investigate local building codes, zoning ordinances, and subdivision covenants, as well as any special regulations pertaining to the site. You will probably need a building permit to install a solar energy system onto an existing building.

Not every community or municipality initially welcomes residential renewable energy installations. Although this is often due to ignorance or the comparative novelty of renewable energy systems, you must comply with existing building and permit procedures to install your system.

The matter of building code and zoning compliance for a solar system installation is typically a local issue. Even if a statewide building code is in effect, it's usually enforced locally by your city, county, or parish.

Common problems homeowners have encountered with building codes include the following:

- Exceeding roof load
- Unacceptable heat exchangers
- Improper wiring
- Unlawful tampering with potable water supplies.

Potential zoning issues include the following:

- Obstructing sideyards
- Erecting unlawful protrusions on roofs
- Siting the system too close to streets or lot boundaries.

Special area regulations -- such as local community, subdivision, or homeowner's association covenants -- also demand compliance. These covenants, historic district regulations, and flood-plain provisions can easily be overlooked.

To find out what's needed for local compliance, contact the following:

- Your local jurisdiction's zoning and building enforcement divisions
    - Briefly describe your intended construction, asking for other relevant ordinances/codes that might be in effect.
    - Find out if there are any additional local amendments or modifications to the regulations in effect.

  - Ask how to determine whether you are located in a historic district, flood-plain area, or any other special category regulated by a government body.
  - Ask where you may find pertinent ordinances/codes (local library, government office, etc.).
  - Read pertinent sections of the regulations, making photocopies of information you wish to file for future review and design/installation analysis.
- Homeowner's, subdivision, neighborhood, and/or community association(s)
  - Ask if they have any ordinances, provisions, or covenants that may affect the design and installation of the system.
  - Copy and file pertinent sections for reference.

Installing and Maintaining the System

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.

After installation, properly maintaining your system will keep it running smoothly. Passive systems don't require much maintenance. For active systems, discuss the maintenance requirements with your system provider, and consult the system's owner's manual. 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.

When screening potential contractors for installation and/or maintenance, ask the following questions:

- *Does your company have experience installing and maintaining solar water heating systems?*
  Choose a company that has experience installing the type of system you want and servicing the applications you select.

- *How many years of experience does your company have with solar heating installation and maintenance?*
  The more experience the better. Request a list of past customers who can provide references.

- *Is your company licensed or certified?*
  Having a valid plumber's and/or solar contractor's license is required in some states. Contact your city and county for more information. Confirm licensing with your state's contractor licensing board. The licensing board can also tell you about any complaints against state-licensed contractors.

Solar Water Heating System Maintenance and Repair

Solar energy systems require periodic inspections and routine maintenance to keep them operating efficiently. Also, from time to time, components may need repair or replacement. You should also take steps to prevent scaling, corrosion, and freezing.

You might be able to handle some of the inspections and maintenance tasks on your own, but others may require a qualified technician. Work that requires going up ladders, walking on roofs, soldering or hot work, or cutting back tree limbs should be performed by professional service for safety reasons. Ask for a cost estimate in writing before having any work done. For systems with extensive damage, it may be more cost effective to replace, shut off, or remove the solar system than to have it repaired.

Periodic Inspection List

Here are some suggested inspections of solar system components. Also read your owner's manual for a suggested maintenance schedule and keep track of previous maintenance activities in order to manage preventative maintenance intervals and better track elusive problems

- **Collector shading**

  Visually check for shading of the collectors during the day (mid-morning, noon, and mid-afternoon) on an annual basis. Shading can greatly affect the performance of solar collectors. Vegetation growth over time or new nearby construction may produce shading that wasn't there when the collectors were installed.

- **Collector soiling**

  Dusty or soiled collectors will perform poorly. Periodic cleaning may be necessary in areas with specific sources of soiling such as birds or dust from plowing and if rain is not sufficient to rinse them off.

- **Collector glazing and seals**

  Look for cracks in the collector glazing, and check to see if seals are in good condition. Plastic glazing, if excessively yellowed, may need to be replaced.

- **Plumbing, ductwork, and wiring connections**

  Look for fluid leaks at pipe connections. Check duct connections and seals. Ducts should be sealed with a mastic compound. All wiring connections should be tight.

- **Piping, duct, and wiring insulation**

  Check that all valves are in the proper operating position. Look for damage or degradation of insulation covering pipes, ducts, and wiring. Cover the pipe insulation with protective plastic or aluminum wrapping and replace if necessary. Protect wiring in conduits

- **Roof penetrations**

  Maintain flashing and sealant around roof penetrations as needed. Watch for any signs of water leakage on the underside of the roof (if visible).

- **Support structures**

  Check all nuts and bolts attaching the collectors to any support structures for tightness. Watch for corrosion on steel parts- and clean and paint if necessary.

- **Pressure relief valve (on liquid solar heating collectors)**

  Actuate the lever to make sure the valve is not stuck open or closed.

- **Dampers (in solar air heating systems)**

  If possible, make sure the dampers open and close properly and are in the proper position.

- **Pumps or blowers**

  Verify that pumps or blowers (fans) are operating. Listen to see if they come on when the sun is shining on the collectors after mid-morning. If you can't hear a pump or blower operating, then either the controller has malfunctioned, or the pump or blower has. The problem is often the starting capacitor, which can be replaced without replacing the pump or motor.

- **Controls**
  Solar water heating controls consist of a temperature sensor on the solar collector outlet, another at the bottom of the solar storage tank, and a circuit (delta-T controller) to start the pump when the collector is hotter than the tank and stop the pump if it's not. If the pump is running at night, it could be that the collector sensor is short circuited, or the tank sensor open circuited. If the pump is not running during the day the reverse could be the case, and the resistance of these sensors should be compared to reference value to determine which one has failed. A common problem is temperature sensors simply falling off the surface they are intended to measure- ensure that they are fastened with a lug or stainless steel clamp.

- **Heat transfer fluids**

  The propylene glycol antifreeze solutions in liquid (hydronic) solar heating collectors need to be replaced periodically. The pH (acidity) and freezing point of the fluid can be measured with hand-held instruments and replaced if out of specification. It's the best task left to a qualified technician. If water with a high mineral content (i.e., hard water) is circulated directly in the collectors, mineral buildup in the piping may need to be removed by adding a de-scaling or mild acidic solution to the water every few years.

- **Storage systems**

  Check storage tanks, etc., for cracks, leaks, rust, or other signs of corrosion. Steel storage tanks have a "sacrificial anode" which corrodes before the tank does and should be replaced at an interval recommended by the supplier. It is a good idea to flush storage tanks periodically to remove sediment.

Preventing Scaling and Corrosion

Two major factors affecting the performance of properly sited and installed solar water heating systems include scaling (in liquid or hydronic-based systems) and corrosion (in hydronic and air systems).

Scaling

Domestic water that is high in mineral content (or "hard water") may cause the buildup or scaling of mineral deposits on heat transfer surfaces. Scale buildup reduces system performance in a number of ways. If your system uses water as the heat-transfer fluid, scaling can occur in the collector, distribution piping, and heat exchanger. In systems that use other types of heat-transfer fluids (such as propylene glycol, scaling can occur on the surface of the heat exchanger in contact with potable water that transfers heat from the solar collector to the domestic water. Scaling may also cause valve and pump failures on the potable water loop.

You can avoid scaling by using water softeners or by circulating a mild acidic solution (such as vinegar) through the collector or domestic hot water loop every 3–5 years, or as necessary depending on water conditions. You may need to carefully clean heat exchanger surfaces. A "wrap-around" external heat exchanger is an alternative to a heat exchanger located inside a storage tank.

Corrosion

Most well-designed solar systems experience minimal corrosion. When they do, it is usually *galvanic corrosion*, an electrolytic process caused by two dissimilar metals encountering each other. One metal has a stronger positive electrical charge and pulls electrons from the other, causing one of the metals to corrode. The piping connection from the copper pipe to the steel tank should thus be a "bi-metallic" type of connector that uses a plastic sleeve to separate the dis-similar metals. The heat-transfer fluid in some solar energy systems can also provide a bridge over which this exchange of electrons occurs.

Oxygen entering into an open loop hydronic solar system will cause rust in any iron or steel component. Such systems should have copper, bronze, brass, stainless steel, plastic, rubber components in the plumbing loop, and plastic or glass lined storage tanks.

Freeze Protection

Solar water heating systems, which use liquids as heat-transfer fluids, need protection from freezing in climates where temperatures fall below 42ºF (6ºC).

Don't rely on collector's and the piping's (collector loop's) insulation to keep them from freezing. The main purpose of the insulation is to reduce heat loss and increase performance. For protecting the collector and piping from damage due to freezing temperatures, you basically have two options:

- Use an antifreeze solution as the heat-transfer fluid.
- Drain the collector(s) and piping (collector loop), either manually or automatically, when there's a chance the temperature might drop below the liquid's freezing point.

Using an Antifreeze Solution

Solar water heating systems that use an antifreeze solution (always propylene glycol, never or ethylene glycol because of toxicity) as a heat-transfer fluid have effective freeze protection as long as the proper antifreeze concentration is maintained. Antifreeze fluids degrade over time and normally should be changed every 3–5 years. Since these systems are pressurized, it is not practical for the average homeowner to check the condition of the antifreeze solution. If you own this type of system, have a solar heating professional check it periodically.

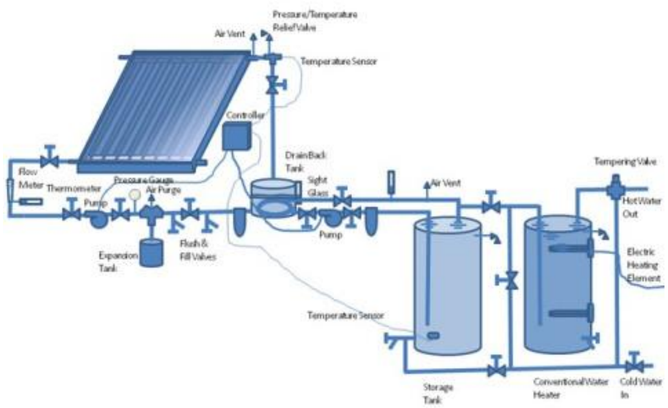
Overheating

Overheating occurs when there is little hot water use in the home but the sun continues to heat the water. The controller will turn the pump off when the solar storage tank hits an upper limit (default 180F but often set lower to prevent scalding). The collector will continue to heat up, which most systems can tolerate, but can lead to discharge of fluid out a pressure relief valve and premature degradation of the heat transfer fluid. Draining the fluid back into a drainback tank can avoid this damage to the fluid caused by overheating. Some systems include a solenoid valve that will open to drain some water from the tank if overheated.

Draining the Collector and Piping

Solar water heating systems that use only water as a heat-transfer fluid are the most vulnerable to freeze damage. "Draindown" or "drainback" systems typically use a controller to drain the collector loop automatically. Sensors on the collector and storage tank tell the controller when to shut off the circulation pump, to drain the collector loop, and when to start the pump again.

Improper placement or the use of low-quality sensors can lead to their failure to detect freezing conditions. The controller may not drain the system, and expensive freeze damage may occur. Make sure that the freeze sensor(s) have been installed according to the manufacturer's recommendations, and check the controller at least once a year to be sure that it is operating correctly.



To ensure that the collector loop drains completely, there should also be a means to prevent a vacuum from forming inside the collector loop as the liquid drains out. Usually, an air vent is installed at the highest point in the collector loop. It is good practice to insulate air vents so that they do not freeze. Also make sure that nothing blocks the airflow into the system when the drain cycle is active.

Collectors and piping must slope properly to allow the water to drain completely. All collectors and piping should have a minimum slope of 0.25 inches per foot (2.1 centimeters per meter).

In integral collector storage or "batch" systems, the collector is also the storage tank. Placing large amounts of insulation around the unglazed parts of the collector and covering the glazing at night or on cloudy days will help to protect the collector from cold temperatures. However, water in the collector can freeze over extended periods of very cold weather. The collector supply and return pipes are also susceptible to freezing, especially if they run through an unheated space or outside. This can happen even when the pipes are well insulated. It is best to drain the entire system before freezing temperatures occur to avoid any possible freeze damage.

Improving Energy Efficiency

After your water heater is properly installed and maintained, try some additional energy-saving strategies to help lower your water heating bills, especially if you require a back-up system. Some energy-saving devices and systems are more cost-effective to install with the water heater.

Reduce Hot Water Use for Energy Savings

Faucets and appliances can use a lot of hot water, which costs you money. You can lower your water heating costs by using and wasting less hot water in your home. Water heating is the second largest energy expense in your home, accounting for about 18% of your utility bill. To conserve hot water, you can fix leaks, install low-flow fixtures, insulate accessible hot water lines, and purchase an ENERGY STAR certified dishwasher and clothes washer.

Showerheads

There are two basic types of low-flow showerheads: aerating and laminar-flow. Aerating showerheads mix air with water, forming a misty spray. Laminar-flow showerheads form individual streams of water. If you live in a humid climate, you might want to use a laminar-flow showerhead because it won't create as much steam and moisture as an aerating one.

Before 1992, some showerheads had flow rates as high as 5.5 gpm. Therefore, if you have fixtures that pre-date 1992, you might want to replace them if you're not sure of their flow rates. Here's a quick test to determine whether you should replace a showerhead:

1. Place a bucket -- marked in gallon increments -- under your shower head.
2. Turn on the shower at the normal water pressure you use.
3. Time how many seconds it takes to fill the bucket to the 1-gallon (3.8 liter) mark.

If it takes less than 20 seconds to reach the 1-gallon mark, you could benefit from a low-flow shower head.

Install Low-Flow Fixtures

You can purchase quality, low-flow fixtures for around \$10 to \$20 apiece and achieve water savings of 25%–60%.

Fix Leaks

You can significantly reduce hot water use by simply repairing leaks in fixtures -- for instance, faucets and showerheads -- or pipes. A leak of one drip per second wastes 1,661 gallons of water and can cost up to $35 per year. If your water heater tank is leaking you will need to replace it with a new water heater.

Faucets

The aerator -- the screw-on tip of the faucet -- ultimately determines the maximum flow rate of a faucet. Typically, new kitchen faucets come equipped with aerators that restrict flow rates to 2.2 gpm, while new bathroom faucets have ones that restrict flow rates from 1.5 to 0.5 gpm.

Aerators are inexpensive to replace, and they can be one of the most cost-effective water conservation measures. For maximum water efficiency, purchase aerators that have flow rates of no more than 1.0 gpm. Some aerators even come with shut-off valves that allow you to stop the flow of water without affecting the temperature. When replacing an aerator, bring the one you're replacing to the store with you to ensure a proper fit.

Purchase Energy-Efficient Dishwashers and Clothes Washers

The biggest cost of washing dishes and clothes comes from the energy required to heat the water. You'll significantly reduce your energy costs if you purchase and use an ENERGY STAR certified dishwasher and clothes washer.

Dishwashers

It's commonly assumed that washing dishes by hand saves hot water. However, washing dishes by hand several times a day can use significantly more water and cost more than operating an energy-efficient dishwasher. You can consume less energy with an energy-efficient dishwasher when properly used and when only operating it with full loads.

When purchasing a new dishwasher, look for the ENERGY STAR label, and check the EnergyGuide label to see how much energy it uses. Dishwashers fall into one of two categories: compact capacity and standard capacity. Although compact capacity dishwashers may appear to be more energy efficient on the EnergyGuide Label, they hold fewer dishes, which may force you to use it more frequently. In this case, your energy costs could be higher than with a standard-capacity dishwasher.

One feature that makes a dishwasher more energy efficient is a booster heater. A booster heater increases the temperature of the water entering the dishwasher to the 140ºF recommended for cleaning. Some dishwashers have built-in boosters, while others require manual selection before the wash cycle begins. Some also only activate the booster during the heavy-duty cycle. Dishwashers with booster heaters typically cost more, but they pay for themselves with energy savings in about 1 year if you also lower the water temperature on your water heater.

Another dishwasher feature that reduces hot water use is the availability of cycle selections. Shorter cycles require less water, thereby reducing energy costs.

If you want to ensure that your new dishwasher is energy efficient, purchase one with an ENERGY STAR® label.

Clothes Washer

Unlike dishwashers, clothes washers don't require a minimum temperature for optimum cleaning. Therefore, to reduce energy costs, you can use either cold or warm water for most laundry loads. Cold water is always sufficient for rinsing.

Inefficient clothes washers can cost three times as much to operate than energy-efficient ones. Select a new machine that allows you to adjust the water temperature and levels for different loads. Efficient clothes spin-dry your clothes more effectively too, saving energy when drying as well. Also, front-loading machines use less water and, consequently, less energy than top loaders.

Small-capacity clothes washers often have better EnergyGuide label ratings. However, a reduced capacity might increase the number of loads you need to run, which could increase your energy costs.

When purchasing a new clothes washer, choose one with an ENERGY STAR label.

Average Hot Water Usage

Activity	Gallons per Use
Clothes Washer	25
Shower	10
Dishwasher	6
Kitchen faucet flow	2 per minute
Bathroom faucet flow	2 per minute
Total daily average	**64**

You can reduce the amount of water you use at home and save on your water and water heating bills. Solar water heaters can also improve the quality of your water, along with energy efficiency prolonging the life of faucets, pipes, and water-using appliances, further saving you money.