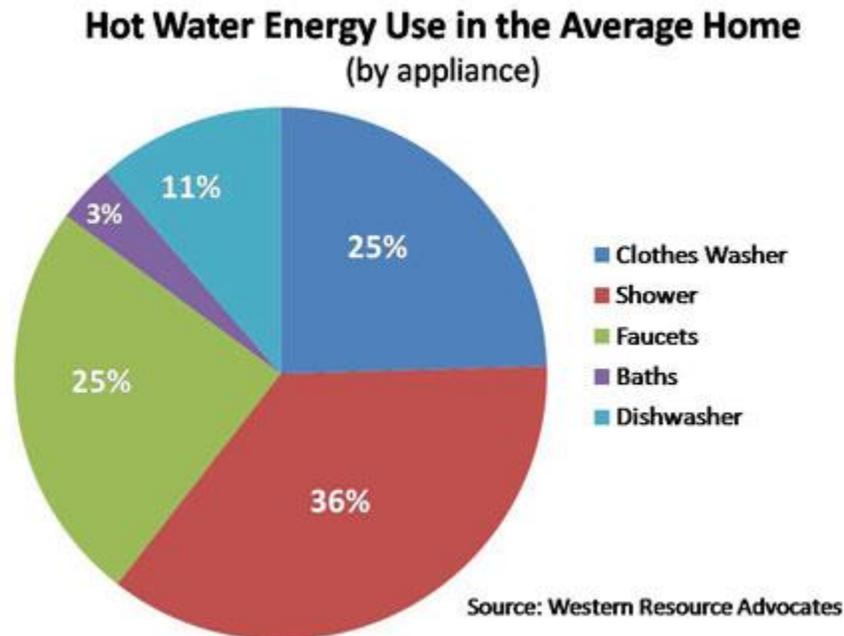


Solar Thermal Water Heating

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Homes use hot water for numerous tasks

As modern Americans, we take the instant availability of hot water in our homes for granted. When we turn on a faucet or switch on the clothes washer, we expect that we'll be supplied with heated water on demand. As shown in the Figure below, we use hot water in our homes for a variety of tasks, most of which are associated with cleaning our bodies, clothes, or dishes.



Caption: A modern American home requires heated water for a variety of activities.

Source: <http://www.hrwc.org/take-action/save-water-save-energy/>

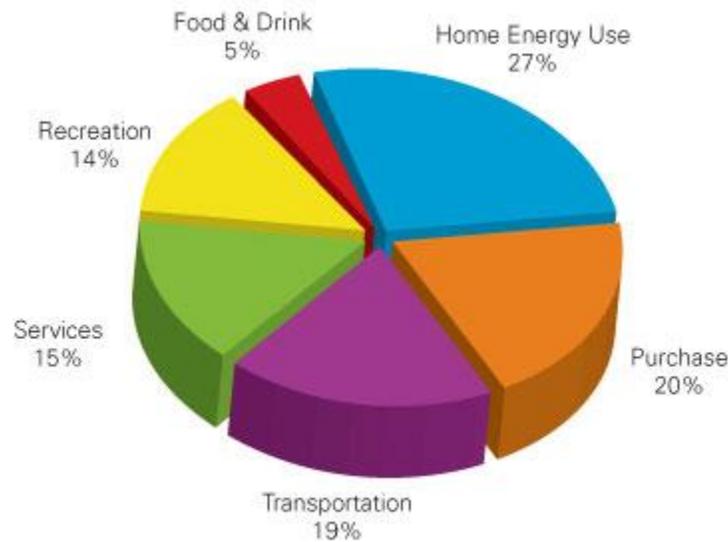
Water heating comprises about 20% of a typical home's energy usage, making it one of the single largest energy uses in the home (it is often second behind space heating/cooling, but the relative contributions of space heating and water heating vary greatly by location). Adopting a more efficient, sustainable approach to hot water heating can result in savings of 50 – 80% on water heating costs. Looking at alternatives to conventional water heaters not only makes sense for your pocketbook, but also for the environment, as we'll see in the next section.

Reducing energy use for water heating reduces carbon emissions

We have seen that water heating is a major energy use in our homes, and the energy sources that drive our homes often come from fossil fuels. Many water heaters burn natural gas to heat water, while others use electricity which is produced by burning coal. When these energy sources are used, they release carbon dioxide, a heat-trapping gas, to Earth's atmosphere.

Anthropogenic (human-induced) climate change caused by releases of greenhouse gases such as carbon dioxide is one of the greatest environmental challenges facing humanity in the 21st Century, so anything people can do to reduce fossil fuel combustion aids efforts toward sustainability.

The average home electric water heater releases around 6,600 lbs (2,900 kg) of carbon dioxide in a year, and a natural gas water heater about 3,900 lbs (1,750 kg) of CO₂ a year. Transitioning to a solar water heater that uses 50 – 80% less energy would therefore confer equivalent reductions in carbon dioxide emissions. Considering that home energy use is the largest carbon source in a modern American's lifestyle (**Figure**), and water heating is one of the biggest energy uses in the home, wide-scale adoption of this technology could have profound environmental benefits.



Caption: Home energy use comprises the largest portion of the average American's carbon dioxide "footprint".

Source: http://www.energystar.gov/index.cfm?c=windows_doors.pr_benefits

Most homes have conventional hot water heaters

Most homes use conventional hot water heaters, typically located in a basement or laundry room. These water heaters hold 40 – 60 gal (151 – 227 L) in a cylindrical tank and keep the water inside at temperatures ranging from 120 to 140 degrees F (49 – 60 °C) using electric coils or a natural gas burner as a heat source (**Figure**). If a home's incoming water is around 70 ° F, the water heater must therefore heat the water to twice its existing temperature, and maintain the tank at that temperature around the clock.

Cold water is piped into the bottom of the tank and rises as it is heated, as hot water is less dense than cold water. When hot water is needed, it is drawn from the top of the tank.

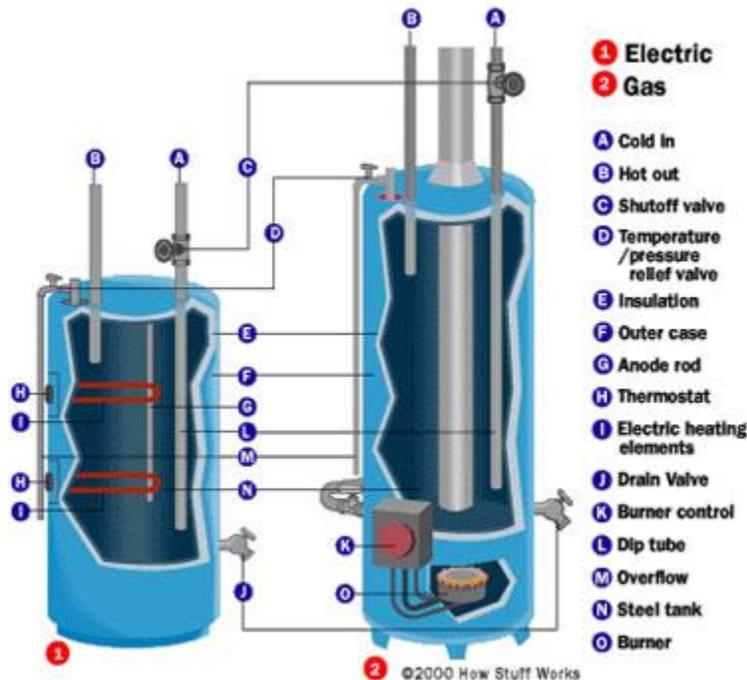


Figure: Conventional hot water heaters use electricity (left) or natural gas (right) to heat water inside the tank.

Source: <http://www.howstuffworks.com/water-heater.htm>

Different models of water heaters have differing efficiency, which is influenced by the design of the heating element, the tank's degree of insulation, and other factors. Carefully considering the energy rating of a conventional hot water heater is therefore one of the best steps consumers can take to reduce energy use and energy costs for water heating.

Title: "How Water Heaters Work" (4 pp.)

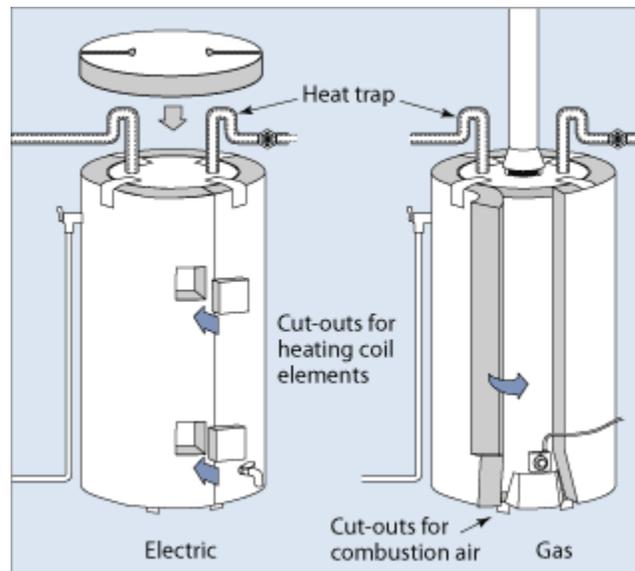
Description: Learn more about the operation of conventional water heaters.

URL: <http://www.howstuffworks.com/water-heater.htm>

Insulate your conventional hot water heater for greater efficiency

If your home has a conventional hot water heater that is not in need of upgrading or replacing, you can still make your home more sustainable. Recall that these hot water heaters keep a large volume of water at elevated temperatures 24 hours a day, seven days a week. If they are not well-insulated, the heat from the hot water inside the tank can escape, requiring additional inputs of energy to heat the water back up again. Such heat losses are pronounced in colder climates, especially when the tank is housed in a part of the home – such as the basement – that is typically cooler than the rest of the home.

The links below describe how to insulate your hot water heater, a process which costs less than \$30 and takes minutes to complete, and pays back its investment in energy savings in only about two years. The process involves wrapping the tank in an insulating cover to reduce heat loss through the tank walls, and then insulating the hot water pipe leaving the tank to further reduce heat loss (**Figure**).



Caption: Insulating jackets help water heaters reduce heat loss through the heater casing.

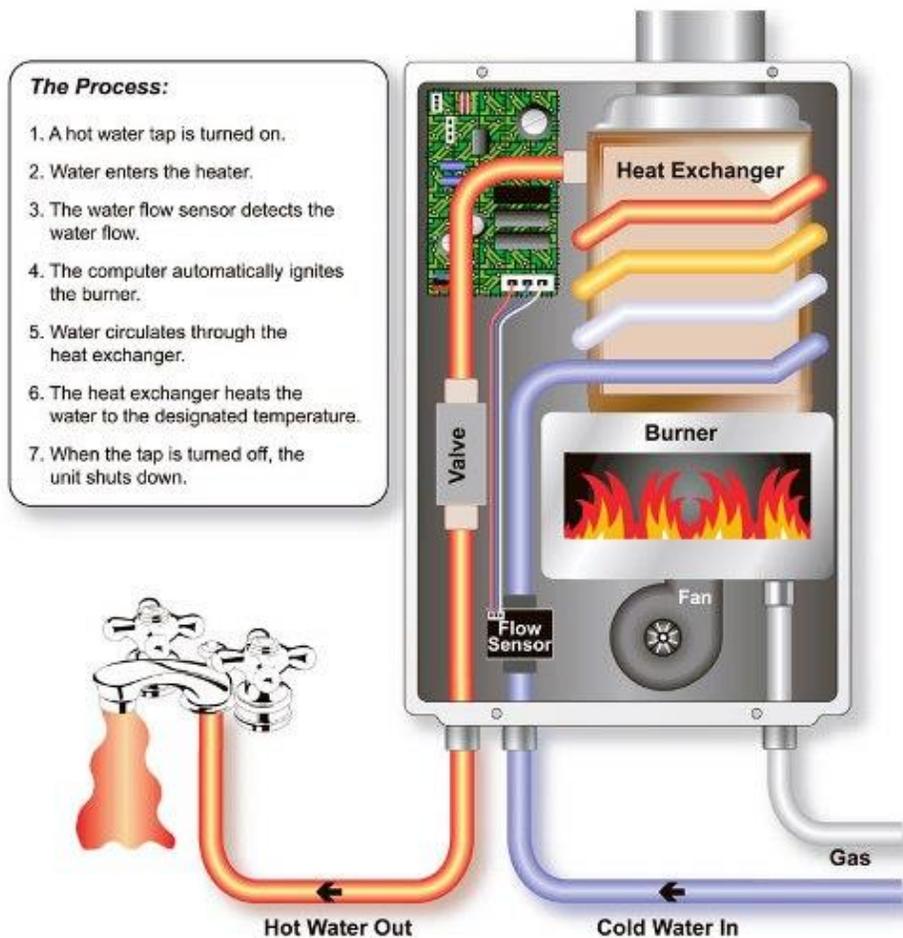
Source: http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13070

Tankless water heaters save energy by heating water only when needed

One of the drawbacks of a conventional water heater is that it maintains tens of gallons of water at high temperatures all day, even when heated water isn't needed. As heat is lost as the water sits, this represents an energy loss when water must be heated repeatedly to maintain it at the desired temperature. This is called **standby heat loss** and is influenced by the degree of tank insulation.

An alternative to conventional water heaters called "tankless" heaters are gaining popularity in the United States. True to their name, these heaters do not maintain a large tank of heated water, but rather heat water as needed. Hence, they are also sometimes called "on demand" water heaters. The operation of such a heater is shown in the figure below.

How Does a Tankless Water Heater Work?



Caption: Tankless water heaters heat water with electric coils or natural gas/propane burners as hot water is needed.

Source: <http://www.benfranklinplumbingcharlotte.com/service/tankless-water-heater.html>

As the water is heated on-demand, having multiple sources of hot water demand (running clothes washer while taking a shower, for example) operating at the same time can sometimes overload the heater's ability to provide adequate hot water. Determining demands for synchronous hot water needs is therefore a key consideration when evaluating whether or not a tankless heater is right for your home, or in determining the output of the tankless water heaters you are comparing.

Title: "How Tankless Water Heaters Work" (5 pp.)

Description: Learn more about the operation of tankless water heaters.

URL: <http://www.howstuffworks.com/tankless-water-heater.htm>

Tankless water heaters are ideal for some homes, but not for all

If you are building a new home or considering replacing/upgrading the water heater in your home, tankless water heaters are worth a look. There are many factors that influence whether or not tankless systems are a homeowner's best choice for their water heating needs.

Tankless water heaters (**Figure**) have a great many benefits. These heaters can reduce energy costs for hot water heating by up to 20% by only heating water when it is needed. Another benefit is that the supply of hot water is continuous, unlike a conventional water heater that takes a while to heat water once the tank is emptied. Larger tankless water heater models can provide hot water for an entire house, or smaller units can be installed near points of intensive hot water use. When the units are near the source of hot water need, this reduces the **lag time** (the amount of time needed for hot water to reach its site of use from its site of heating) and the energy loss associated with hot water traveling long distances in pipes through the home. Tankless heaters also last about twice as long as a conventional hot water heater, and there is no fear of in-home flooding from a corroded/ruptured hot water tank.



Caption: Tankless water heaters have a small area “footprint”, as there are no large tanks of water to store.

Source: <http://home.howstuffworks.com/tankless-water-heater3.htm>

One of the largest downsides of a tankless water heater is the up-front cost – about three times that of a conventional water heater. As savings on energy bills recoup this up-front cost over time, homes that use a lot of hot water (e.g., families with children, people that spend a great deal of time at home) will have shorter payback time on this investment than homes with minimal hot water use (such as single people or couples, or individuals that spend most of their time away from home). Tankless water heaters can also require changes to a home's venting system, natural gas lines, or electric circuits, which can limit their appropriateness for some existing homes.

Ultimately, careful consideration of all these factors will enable an educated decision on what's best for each home based on its unique characteristics and water use patterns.

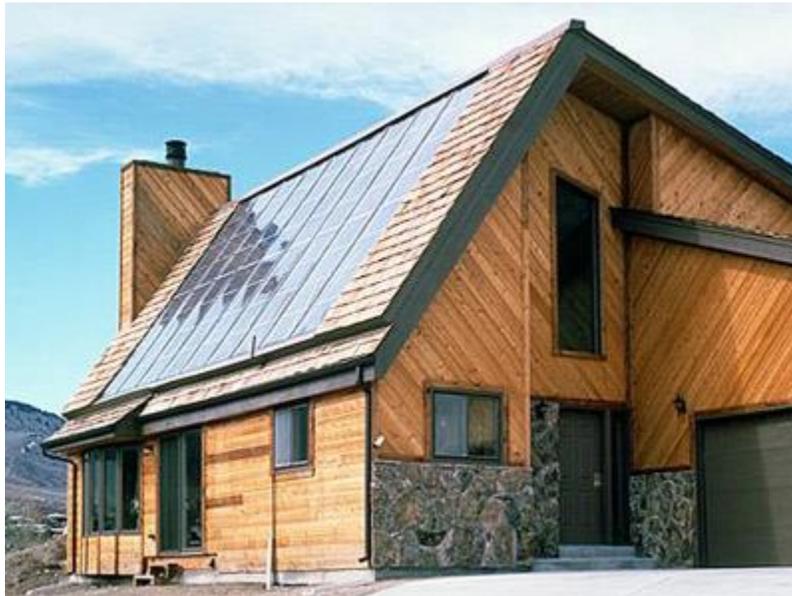
New technologies enable even greater energy savings in water heating

Buying a highly-efficient conventional hot water heater, insulating a conventional hot water heater, or investing in a tankless water heater will all reduce your energy use for home water heating. But there is yet another technology that can take those savings and put them into overdrive – solar hot water heating.

Using the sun's heat to warm water is nothing new. As shown in other modules in this project, humans have long used the sun's energy to heat their homes and warm the waters of public baths. But we now possess the technology to harness this free, sustainable energy source to greatly reduce our demands on fossil fuels for home water heating.

Solar hot water heaters (**Figure**) use the sun's energy to heat water for use inside the home. These systems are more expensive to install than a conventional hot water heater (usually about 2 – 7 times the cost), but provide savings of 50 – 80% on hot water heating expenses over a conventional water heater. And if you're using 50 – 80% fewer fossil fuels to heat your home's water, that translates to a similar reduction in your carbon contributions to climate change.

While this is a large up-front cost, the payback time on the investment is lowered by federal and/or state incentives for installing solar water heaters, the minimal costs of operating the system, and the lengthy lifespan of the system relative to a conventional hot water heater.



Caption: This home in Colorado uses solar energy to heat water for use inside the home. The black solar collectors on the roof capture and concentrate solar energy to heat water.

Source: <http://www.howstuffworks.com/environmental/green-tech/sustainable/solar-water-heater.htm>

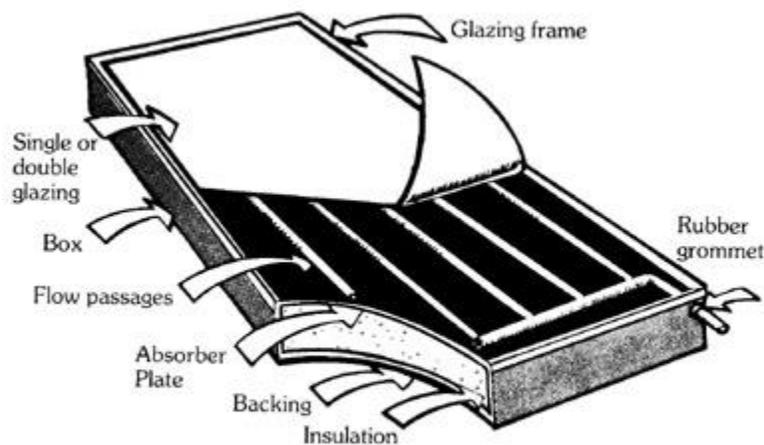
Title: "How Solar Heaters Work" (6 pp.)

Description: Learn more about the operation of solar water heaters.

URL: <http://science.howstuffworks.com/environmental/green-tech/sustainable/solar-water-heater.htm>

Solar hot water heaters use sunlight as a heat source

While there are many different types of solar hot water heaters, they all operate on the same basic principles. A solar collector uses dark-colored surfaces to collect solar energy, and concentrate it within an insulated box (**Figure**). The collector is designed to allow solar energy to enter the box with minimal interference to maximize heat gain in the dark surface at the collector's bottom. The heat produced is maintained in the collector with insulating materials. Temperatures within the collector rise substantially, and this heat is transferred to liquid circulating through the collector in a matrix of thin pipes. The pipe diameter is very thin, enabling efficient heat transfer to the liquid within. The circulating liquid varies by system. In some, water is used. In others, antifreeze or a similar heat-transferring liquid is used. The heated liquid is then used to meet the home's hot water demands. Solar heating aid efficiency by raising the temperature of the water in the tank, thereby decreasing or eliminating the supplemental heat needed to raise it to the thermostat setting.



Caption: Dissected view of a basic solar collector. The dark surface at the collector bottom absorbs solar energy, which concentrates heat in within the collector. The heat is then transferred to liquid that circulates through the box and enters the home.

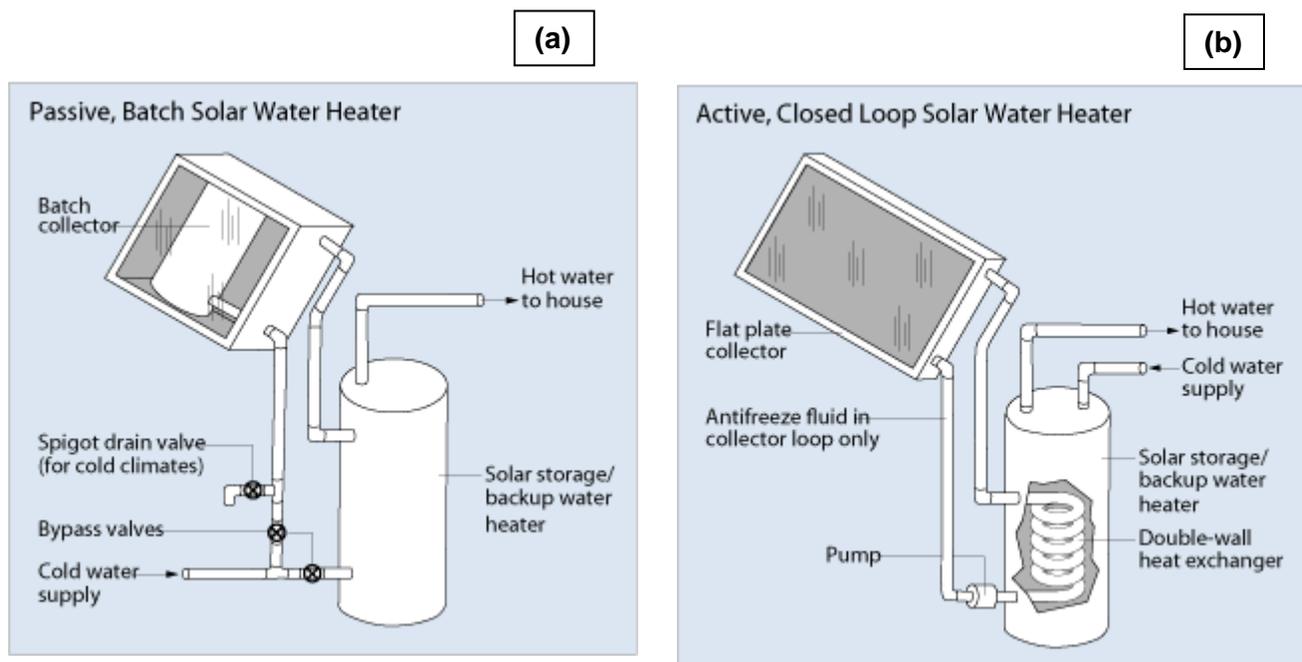
Source: <http://science.howstuffworks.com/environmental/green-tech/sustainable/solar-water-heater1.htm>

Let's take a closer look at the diversity of solar hot water systems in use today, and how they increase efficiency in hot water heating.

Solar hot water heaters use many different designs

The basic design of a solar hot water heater is pretty standard, but from there things can diverge quite a bit depending on the system being examined. There are a few generalities, though. The water heated by the solar collectors is shuttled, in nearly all cases, to a highly-insulated storage tank. From there, it circulates throughout the home. It is also common to supplement the solar collector with electric or natural gas heating to ensure ample hot water is available and at the proper temperature. A thermostat in the tank reports the water's temperature, and kicks on when needed to bring the water up to the desired temperature. This enables hot water to be available when solar energy levels are low (such as on cloudy days) or when hot water usage is unusually high and solar heating needs supplementing.

Passive systems use natural convection to pump hot water from the solar collector to a storage tank (**Figure a**). More common are **active systems**, which use pumps to circulate materials between the various components of the system. Systems that circulate water through the tubes are called **direct active systems**, while those that circulate antifreeze or some other liquid and then transfer the heat to water in the storage tank are called **indirect active systems** (**Figure b**).



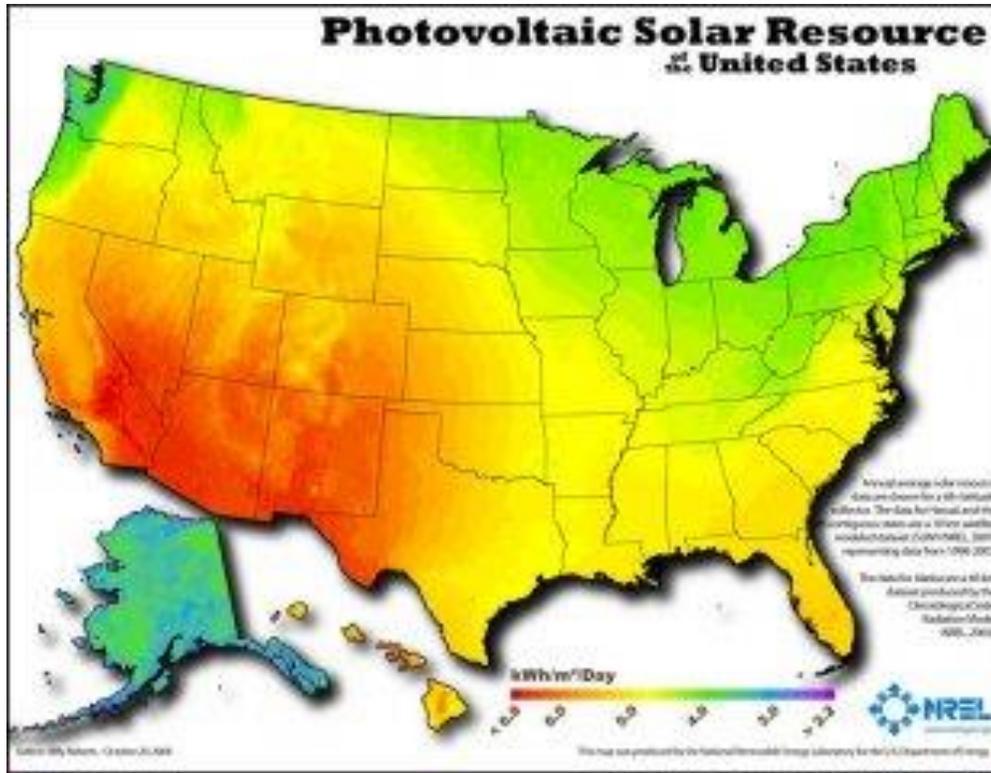
Caption: (a) Example of a passive system using a batch solar water heater. Water transfers from the collector to the tank without active pumping. (b) An indirect active system, in which antifreeze circulates through the collector and is then transferred to water in the storage tank through a heat exchanger.

Source: http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12850

Is solar hot water heating right for your home?

As was the case with tankless water heaters, there are a number of factors to consider when thinking about using solar hot water heating. Savings are seen with hot water usage, so financially such a system makes the most sense for homes that use a great deal of hot water. As with any such investment, the payback time shrinks as the savings accumulate at a more rapid rate.

There is also the issue of location, as that greatly influences solar energy levels. Geographically, a solar hot water system in the sunny U.S. southwest would payback quicker than one in the cloudier northwest, as solar heating would be much more prominent (**Figure**).



Caption: Solar energy levels differ across the United States, making solar hot water heaters more efficient in some areas than others.

Source: <http://solarenergy-usa.com/about-solar-energy-solutions/u-s-map-of-photovoltaic-solar-resource/>

The home must also have a suitable surface that receives good sunlight exposure. A home with south-facing surface unobstructed by trees or other buildings is ideal, although significant heating can still be attained in less-than-ideal locations. A direct active system also might not be suitable in very cold climates, as water could freeze in the tubes during winter and damage system components.

More-efficient approaches to water heating can aid sustainability

Making decisions about the best approach for your home and your lifestyle with respect to water heating can be difficult and sometimes complex. Luckily, analysis tools, such as the one at the link below from the U.S. Department of Energy, help homeowners with such decisions.

The web is overflowing with additional resources on all the topics in this module, including detailed examinations of sustainable water heating systems that will be helpful as your knowledge of these topics expands.

American homes offer many opportunities for increasing environmental sustainability by reducing energy use, and home water heating is a fantastic candidate given the diversity of technologies available for reducing our home use of fossil fuels, while still enjoying the comfortable lifestyle and amenities we have come to expect and cherish. And as the second link below shows, many improvements in efficiency can be seen with conventional water heaters by following a few simple steps.