


SOLAR ENERGY

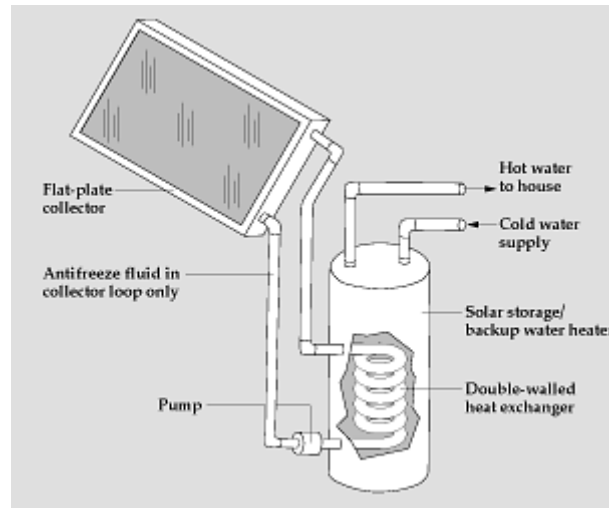
PASSIVE SOLAR WATER HEATER

Time Frame:	Standards:
45 minutes or longer	Idaho Standards PS1.1.2, PS1.6.2, E1.2.1
Objectives:	
To demonstrate solar energy on a small scale water heater. Students should understand how radiant energy is transformed into thermal energy, and that the thermal energy could be used by people in their homes. This is a scale model to show proof of concept.	
Background Information:	
<p>U.S. Department of Energy - Energy Efficiency and Renewable Energy Distributed Energy Program</p> <p>Solar Hot Water Solar hot water systems use the sun's energy to heat water and are almost always used along with conventional water heaters.</p> <p>How It Works Solar hot water systems use the sun's energy either to heat water directly or to heat a fluid such as antifreeze that indirectly heats the water through a heat exchanger. Solar-heated water is then stored for use as needed. A conventional water heater provides any additional heating that might be necessary.</p> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>A heat exchanger keeps two different liquids physically separated but allows heat energy to pass between them. In a solar hot water system, tubes carry hot antifreeze in and out of a reservoir filled with water.</p> <p>Solar hot water systems are always mounted on a south-facing roof, a south-facing outside wall, or on the ground facing south, to take greatest advantage of the sun's rays.</p> <p>Solar hot water systems can be either active or passive.</p> <p>Active Systems Active solar water heaters use electrically powered pumps, valves, and other equipment to help circulate water or a heat-transfer fluid through the system.</p> <p>There are three types of active systems:</p> <ol style="list-style-type: none"> 1. Direct systems — use pumps to circulate water through special solar heat collectors. These systems are best suited for mild climates. 2. Indirect system — instead of pumping water through the solar collectors, they pump heat-transfer fluids, such as antifreeze. Heat exchangers then transfer the </div> <div style="width: 45%; text-align: center;">  <p>This house in Golden, Colorado, is equipped with solar water heating panels.</p> </div> </div>	

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pump heat-transfer fluids, such as antifreeze. Heat exchangers then transfer the heat from the fluid to the water.



An indirect solar hot water system.

- 3.
4. Drainback systems — also use electric pumps to circulate water through the solar heat collectors. In this type of indirect heating system, the heated water drains into a holding tank when the pumps stop.

Both the indirect and the drainback systems work well in colder climates because they minimize the chance that frozen water in some part of the system could damage the solar water heater.

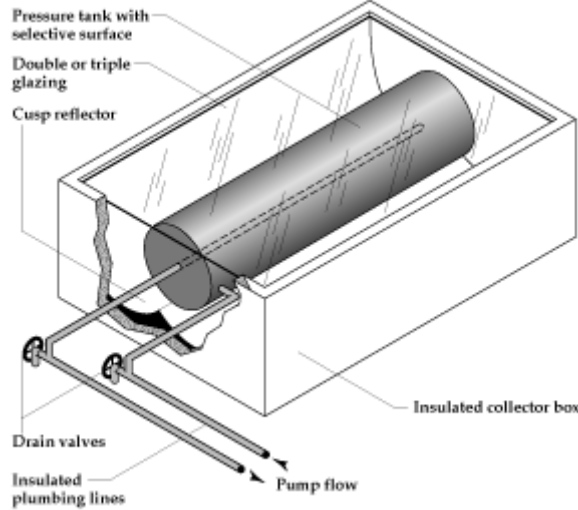
Passive Systems

Passive solar water heaters circulate water or a heat-transfer fluid without electric pumps and other devices. They come in two varieties:

1. Batch heaters — are very simple. They consist of one or more storage tanks placed in insulated boxes with their glazed, heat-absorbing sides facing the sun. Batch heaters must be drained or otherwise protected from freezing in cold climates.

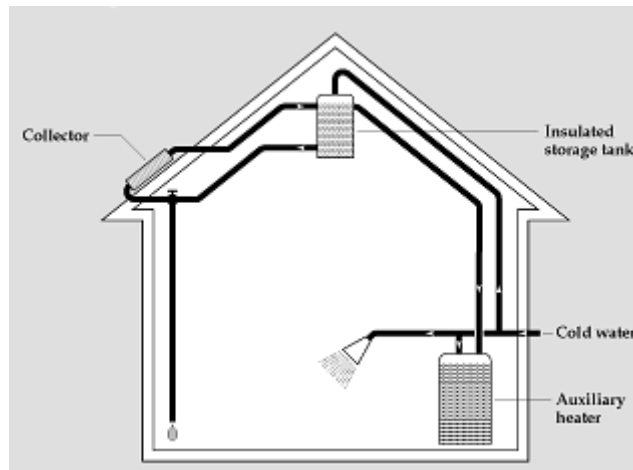
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A batch solar collector.

- 2.
3. Thermosiphon systems — rely on the natural process that causes warm water to rise. The system circulates water through solar heat collectors and then into a holding tank, which is located above the collector.



A thermosiphon solar hot water system.

Because passive solar water heaters don't have electrically powered components, they are generally more reliable, easier to maintain and sometimes last longer than active systems.

Advantages

Solar hot water systems have many advantages. First, they are nonpolluting. Solar water heaters are fueled by the sun, a renewable energy source that emits none of the greenhouse gases that contribute to global warming.



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Second, solar water heaters save energy. In fact, by cutting down on conventional water heating, some estimates show solar water heating systems can reduce the use of electricity to heat water by as much as 80%. Using the sun instead of conventional fuels to heat water also conserves non-renewable energy sources like oil, coal and natural gas for other uses.

Third, solar water heaters save consumers money. Research shows that an average household with an electric water heater spends about 25% of its home energy costs on heating water. Using solar water heaters, which use free solar energy, can save hundreds of dollars a year. When electricity rates increase, the savings increase. The average solar water heating system pays for itself over the long run, usually in four to eight years. Adding a solar water heater to an existing home can also raise its resale value.

Depending on where you live, installing a solar hot water heater may allow you to take advantage of state and local government tax incentives and rebates. Some electric utilities also offer rebates.

Disadvantages

Depending on where you live and what kind of system you choose, solar hot water systems can present some challenges. For example, to take advantage of solar water heating, an unshaded, south-facing location is necessary.

Areas with hard or acidic water are not prime locations for some active solar water heating systems. Hard or acidic water tends to corrode systems that circulate water. Direct systems should never be installed in climates that experience freezing temperatures for long periods. And because they require parts that run on electricity, active solar hot water systems will not function during power outages.

Passive solar hot water systems also have some potential disadvantages. For example, simple batch heater systems that use storage tanks housed in insulated boxes to heat water need a roof or other structure strong enough to support them. Special building regulations in areas where there is earthquake or hurricane danger also may limit the weight or type of equipment that can be placed on a roof.

Even though solar hot water heating systems pay for themselves over time, the up-front purchase and installation costs, usually between \$1000 and \$3000, are higher than those of conventional electric or gas water heaters.

Applications

Using the sun to heat water is not a new idea. Solar energy has been used for years to heat water for homes and businesses. In some countries, such as Israel, solar hot water systems are mandatory for residential use. In the United States, as far back as the turn of the 20th century, solar hot water systems were common in southern California.

Today, solar heated water systems provide hot water for everything from park bathrooms and single-family homes to hospitals and prisons.

Large facilities generally require more complicated active solar hot water systems. Active systems require electric pumps, valves and other equipment. Some homes and smaller



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facilities in remote areas can use passive solar hot water systems, which don't require electricity to function. For example, the federal government uses solar systems to heat water in many buildings in its national parks.

Solar water heaters also can be used to heat swimming pools, hot tubs, and spas. More than a million solar pool heaters have been installed in the United States alone. Swimming-pool solar water-heaters are quite simple in design. The pool's existing filtration system pumps water through simple solar heat collectors, usually made of black plastic or rubber, and the heated water then goes directly into the pool.

DOE's Office of Energy Efficiency and Renewable Energy provides an organized list of links to hundreds of documents on [solar hot water](#) systems.

[Webmaster](#) | [Distributed Energy Program Home](#) | [OE Home](#) | [DOE Home](#) | [USA.gov](#)

Content Last Updated: 05/17/2006

Materials:

Black Tubing ~ About 15' per group
Aluminum Foil ~ One large box per class period
Boxes ~ Various sizes and shapes
Box Cutter ~ Teacher only
Styrofoam Cups ~ 50
Clips, Holders, Portable Light Source ~ One per group
Also consider, if available
Small water pumps, such as those used in bird bathes and small water features
Black Plastic Sheeting
Clear Plastic Sheeting
Styrofoam Buckets, such as minnow buckets
Mirrors
Almost anything else a student wants to bring

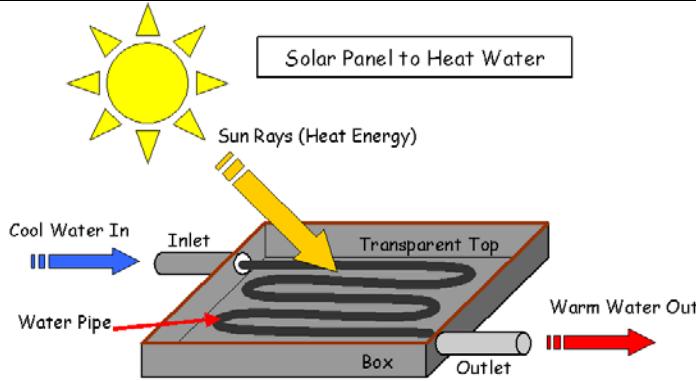
Very Simple Example of Product:

Energy for Educators

Bringing Energy to the Classroom

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Remarks:

This laboratory experiment is by its nature, very flexible in both depth and breadth. The solar water heater model can be as simple as a box with some black tubing with a funnel on one end, and a cup on the other. More advanced students or groups may want to extend the project and include a circulation system, water reservoir and enclosed collector plates.

A class project could be construction of a large assembly. The possibilities are limited by the creativity of the students and the instructor, and by the time constraints of the curriculum.

Assessment:

Assessment can be made in many different ways. The most basic would a calculation of the mass of the water, and to what temperature it was heated to.

Temperature MUST be made in Kelvin. To find Kelvin, take the Celsius temperature and add 273 degrees.

Mass of the water is equal to its volume. One mL of water has a mass of 1 gram. One liter of water has a mass of one kilogram.

If a student's water had a mass of 450 grams, and it rose in temperature from 300 Kelvin to 330 Kelvin, then the unit absorbed 1,350 Kelvin*grams of energy. This is also 1,350 Joules of energy.

Automatic Energy Calculator:

Amount of water in milliliters: _____
 Temperature of water in Fahrenheit _____
 Temperature of water in Celsius _____
 Total amount of energy absorbed: _____

Procedure:

If the students have been prepared with background information, and if students are motivated to complete an independent investigation, then this laboratory experiment is largely student driven.



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Students should be encouraged to design a solar hot water heater on paper before construction begins and they should be encouraged to try new designs that they feel may prove successful.

The procedures of this laboratory experiment should be meant to encourage creative problem solving, not to recreate a proven solar water heater model.

Assessment:

Additional Content:

References: