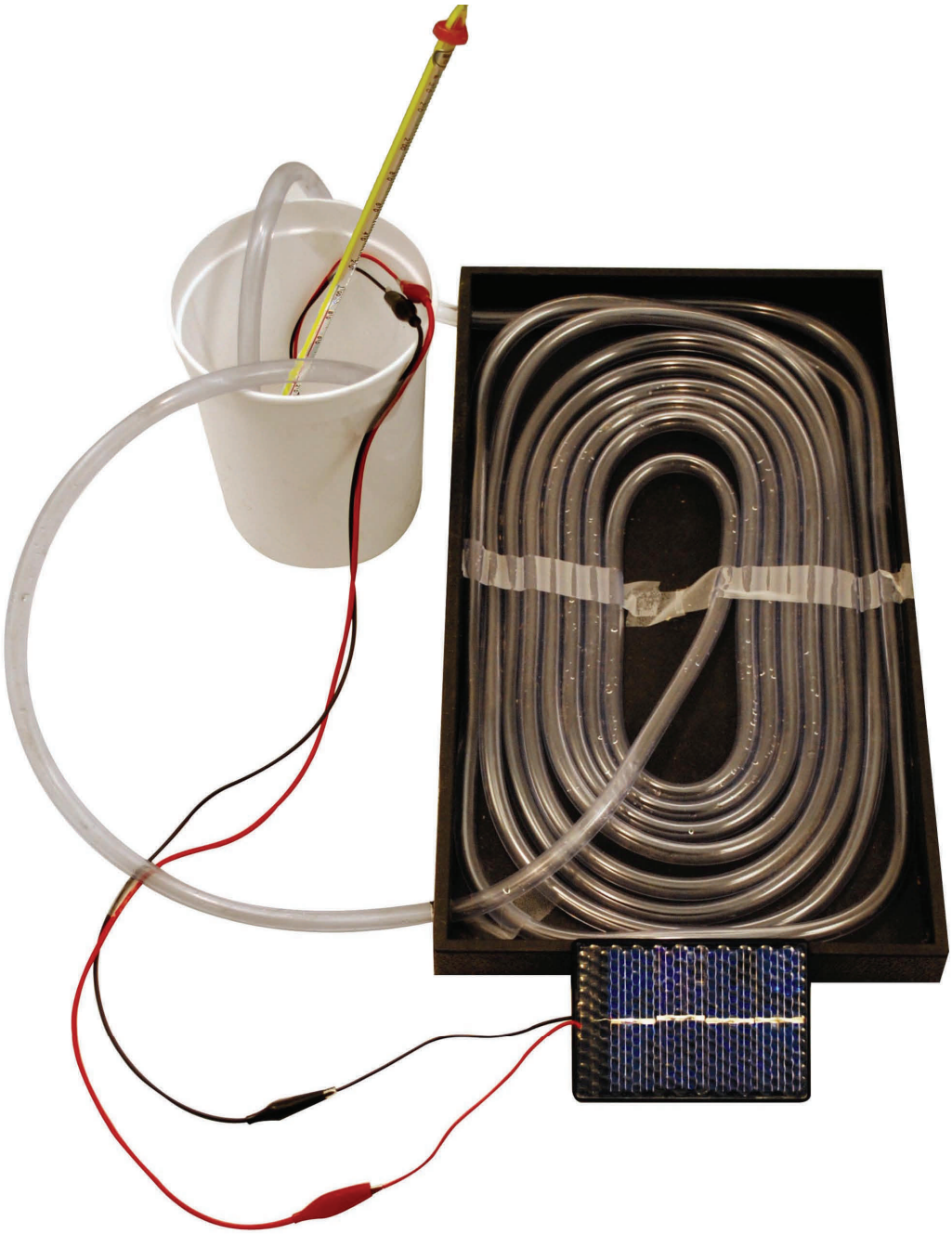


# KidWind Solar Thermal Kit



Kidwind Project
2093 Sargent Avenue
Saint Paul, MN 55105
http://www.kidwind.org

The production of the kits and other materials related to wind energy have been generously supported by these agencies.

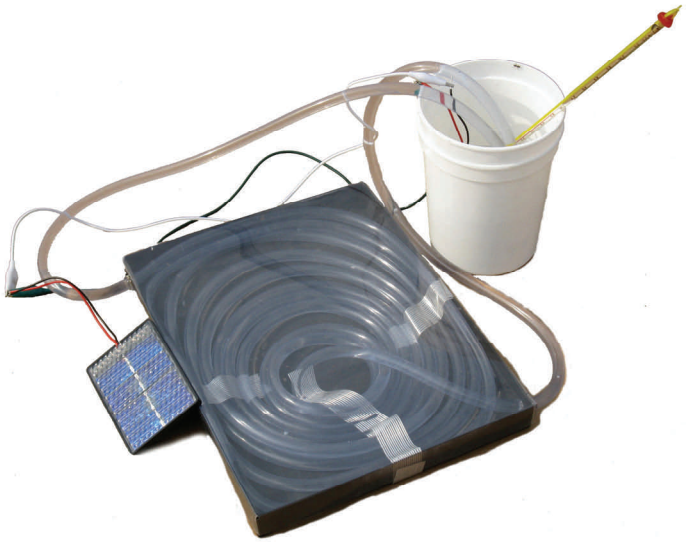

We would like to thank the *Wright Center for Science Education* at Tufts University for giving us the time and space to develop a nugget of an idea into a useful project for hundreds of teachers.

We would also like to thank Trudy Forsyth at *National Wind Technology Center* and Richard Michaud at the *Boston Office of the Department of Energy* for having the vision and foresight to help keep the KidWind Project going! Lastly we would like to thank all the teachers for their keen insights and feedback on making these wind turbine kits and materials first rate!

# KidWind Solar Thermal Kit

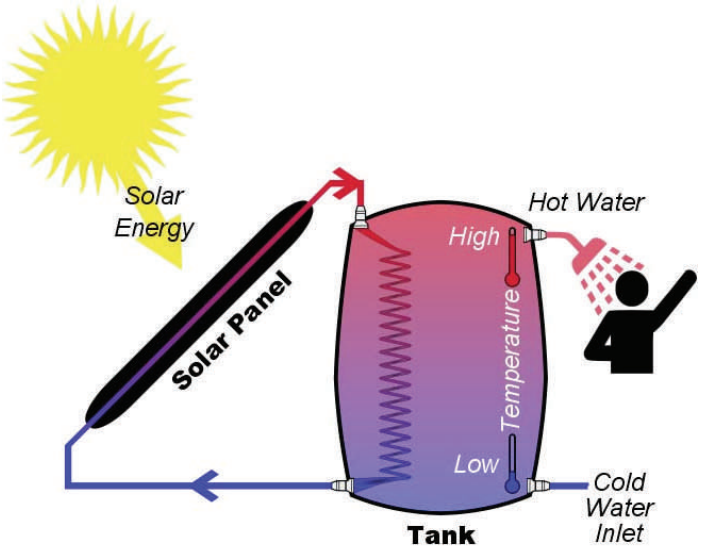
Parts Included:

- 25 ft. Tubing
- 1 Black Plastic Box
- 2 Paper boxes with plastic lids
- 1 Plexiglas lid for plastic box
- 2 Containers for water
- 2V Solar Panel
- Electric Water Pump
- 2 Thermometers
- Alligator clip wires
- Copper Tube
- Aluminum Tube
- Black rubber tube
- Supercapacitor



Other Useful Materials (Not Included)

- Tape (Clear, Duct, etc..)
- Hot Glue
- Flood Light
- Tin foil/reflective materials
- Insulating Material
- Glitter to visualize water flow
- Black paint

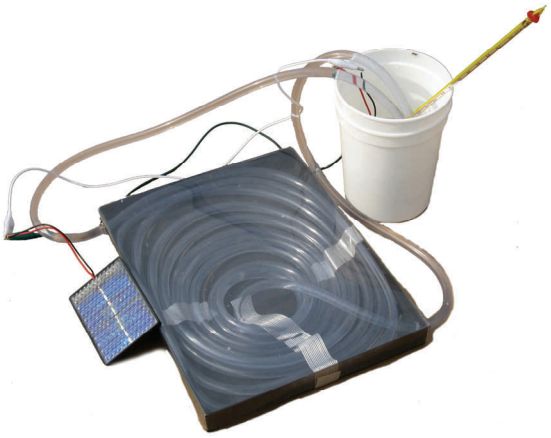



Challenge:

- How much can you heat up water in a given amount of time?
- What is your maximum temperature?
- What materials are best for this energy transformation (light -> heat)?

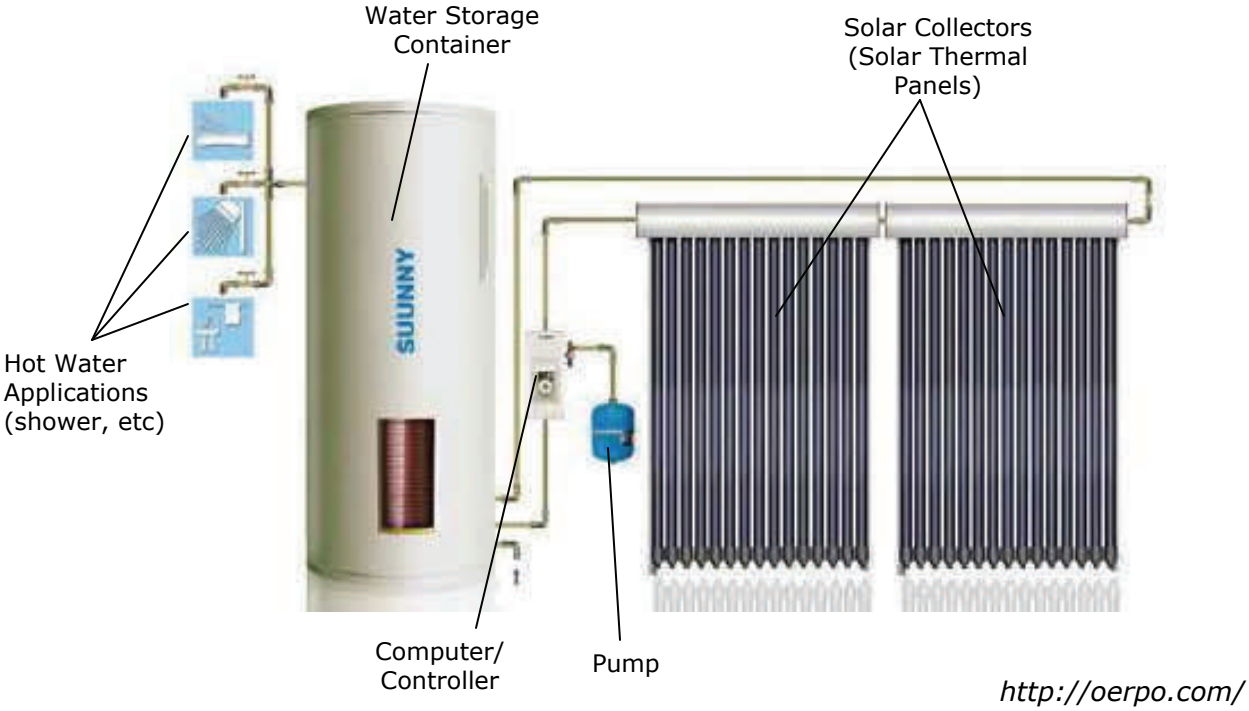
# KidWind Solar Thermal Kit

These instructions will show you how to build the KidWind solar water heater. This kit allows you to experiment with a number of variables as you try to increase the water temperature. How you design your solar heating system will dramatically affect how fast you can heat the water and the maximum temperature it will reach.



*http://www.reuk.co.uk*

This document also includes some basic information on solar water heating systems and how they work. You will also find some ideas for experiments to conduct with your model solar water heater.

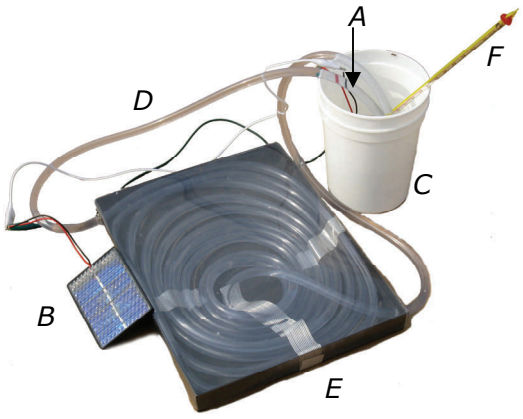



*http://oerpo.com/*

# Building the Solar Water Heater

This kit allows for a great deal of variability in design. You will face many choices as you assemble your solar collector, and each design decision you make will affect the efficiency of your system. Here are the general features that your solar water heater must utilize:

*(A)* Electric Water Pump to circulate water
*(B)* Photovoltaic Solar Panel (powers the water pump)
*(C)* Water Storage Container
*(D)* Tubing for water to circulate
*(E)* Enclosed Box with Clear Lid to house the tubing
*(F)* Thermometer to measure temperature change




## Step 1: Arrange Tubing in the Box

Your first design choice will be which box to use. Your kit comes with 2 paper boxes, 1 white plastic box, and 1 black plastic box. The plastic boxes have holes drilled in the side. These holes allow the tubing to enter the box from the water pump and exit the box to the storage container.

Push one end of the tubing out of the drilled hole from the inside of the box. Make sure you push enough tubing out of the box to reach the water pump in the water container.

Now you face a very important design choice—arranging the tubing. Remember, the more surface area you expose to the sun, the more efficient your system will be. Take your time to coil, wrap, or loop the tubing to try to maximize the amount of tubing being hit by the sunlight. You may need to use some tape to hold the tubing in place. Clear tape will do the job and also allows light to pass through.

Next run the other end of the tubing out of another hole in the box. The water will go through this tubing and out to the external storage container. Leave enough tubing to get to the container, but remember that having more tubing exposed outside of the solar collector may reduce efficiency. You might try *insulating* this outer tubing.

*This arrangement used about 20 feet of tubing.*

You should cover the tubing in the box with a clear lid. If you used one of the smaller paper boxes, the plastic lids fit over them well. The clear Plexiglas sheet fits perfectly over the black plastic box. You can tape one edge of the Plexiglas onto the box to make a hinge, or tape all the edges for a tight seal.

**Step 2: Set up the Water Storage Container**

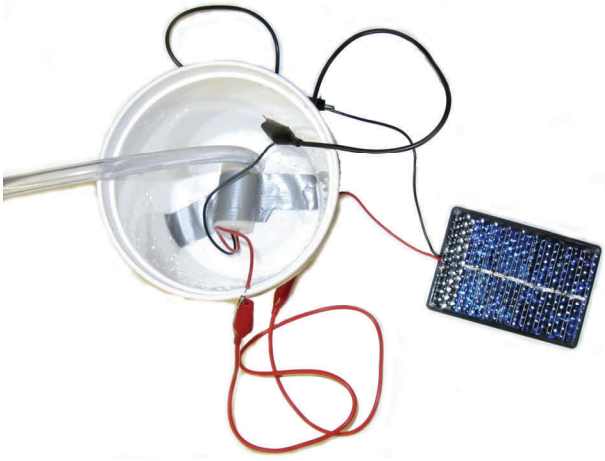
This kit comes with two bins to use for water storage. The electric water pump will pump water out of the storage container, through the solar collector, and back into the container. This way, the entire system is a contained, circulating loop.

Connect one end of the tubing to the water pump and place it at the bottom of the storage container, making sure that the two wires from the pump are facing up. These wires will be connected to your photovoltaic panel.

It is a good idea to insulate the storage container. Since the bins are made of thin plastic, it is easy for heat to escape through the walls of the container. There are many different ways to insulate the container. Since there are two bins, you can put some insulating material at the bottom of one, then slide the other bin inside the one with insulation at the bottom. Then you can wrap the outside of the container with tin foil, newspaper, cloth, etc… Experiment with different insulation.

Now you can pour some water into the container. Use cold or room temperature water so that you can measure a temperature change as the system operates. The water pump should be fully submersed, but ***remember to keep the wires sticking up out of the water***. Insert the thermometer into the storage container and record the initial water temperature.

**Step 3: Connect the Photovoltaic Panel to the Water Pump**



Use the alligator clip wires to connect the solar electric panel to the water pump. You may need to strip the leads of the solar panel or the water pump to expose enough metal to clip the wires to. It should still work if the water pump wires are under water, but be sure you have a secure connection.

If the photovoltaic panel is in sunlight, the pump will begin pumping as soon as this circuit is connected. Since the pumping will start right away, be sure that your tubing is all set up before you connect the pump. Double check that the tubing coming from the solar collector goes back into the storage container.

If you want to stop the pumping, all you have to do is shade the solar panel. The panel will stop producing electricity if sunlight is not hitting it, and the pump will stop when this electricity stops.

# Solar Water Heating Background

Using the sun to heat water is not a new concept. Humans have been harnessing the thermal energy of the sun for centuries. In fact, people have been designing commercial solar water heaters since the 1800's!

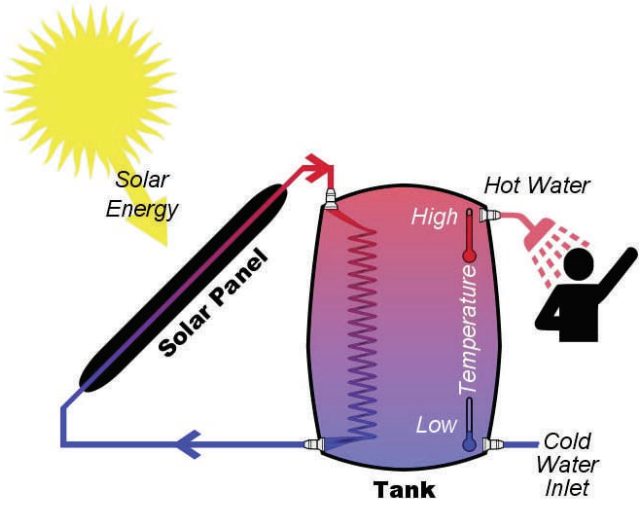
According to the American Council for an Energy-Efficient Economy (ACEEE), water heating uses more household energy than any activity except home heating and cooling. We use hot water all the time—washing clothes and dishes, taking a shower, and sometimes even heating our homes. With a solar water heater, you'll get the hot water your household needs while saving money and energy and reducing your environmental impact.

In most homes, water is heated using electricity, natural gas, or oil. Since most of our electricity comes from fossil fuels today, it is safe to say that most water is heated using fossil fuels. The burning of fossil fuels releases a lot of pollution into the environment and contributes to global warming.

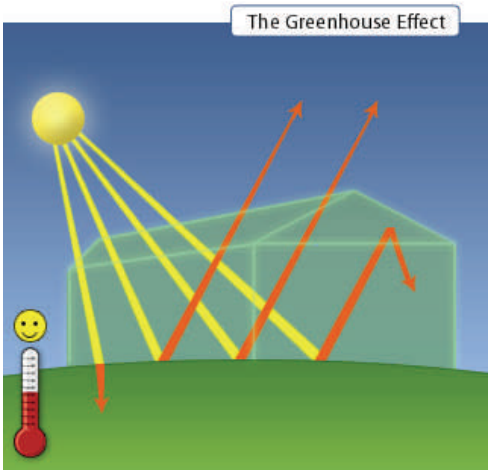
Since water heating is one of the biggest uses of energy, it can be a significant ratio of our energy bills. Therefore, replacing a traditional water heater with free energy from the sun is good for the environment and a good way to save money on your energy bill.

There are many varieties of solar thermal systems. Generally, a solar water heater consists of a hot water storage tank, a solar collector that absorbs solar energy, and a back-up energy source (electric or natural gas). Some systems use a pump and controls to move the water through the system.

This KidWind model solar thermal kit resembles an "active" or "forced circulation" system. This type of solar water heater requires a pump to move water from the storage tank to the collector. Most solar water heaters in the United States are forced circulation systems because this type of system works well even when temperatures drop below freezing. Passive systems that do not use an electric pump are also common, but are not practical for colder climates where the water may freeze.



# How Does it Work?




*http://www.stopglobalwarming.com.au*

The sunlight that shines down on earth is full of energy. In photovoltaic panels, that energy is converted into electricity. In a solar water heating system, sunlight is converted into heat in the solar collector.

An efficient solar collector will take advantage of the greenhouse effect. Have you ever noticed how the inside of a car that has been parked in the sun is surprisingly warm? Sunlight easily passes through the glass windows and is converted into heat when it hits the interior of the car. Some of that heat can pass back through the glass, but a lot of it gets trapped inside. A greenhouse works the same way to keep plants warm enough to grow.

It is important to have a clear lid on your solar collector that forms a tight seal over the tubing. This will give your collector the same advantage that a greenhouse has. Sunlight will pass through the clear lid and turn into heat. Some of that heat will be trapped inside the collector to heat up the water.

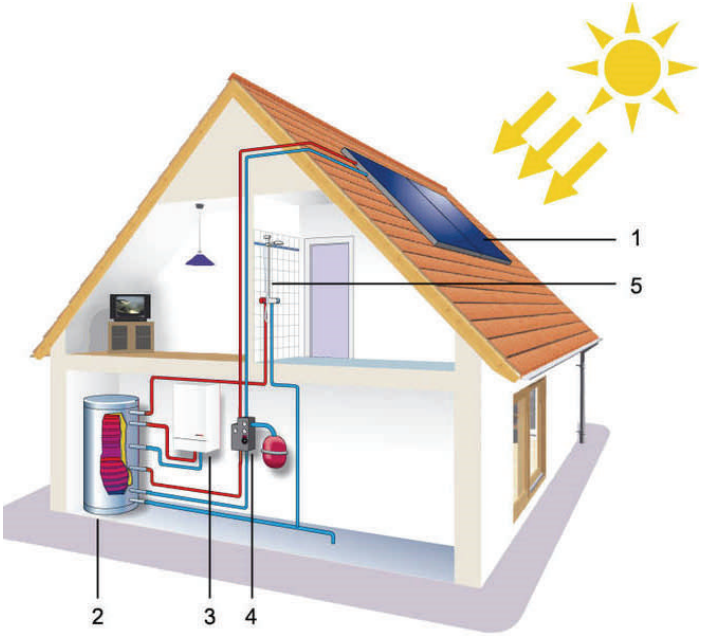
Most solar collectors use dark colors like dark blue or black. Dark colors reflect less light than lighter colors like white or silver. The light that is not reflected is converted into heat. In other words, darker colors are better absorbers of light and better radiators of heat.

As water circulates through the tubing, it gets hotter and hotter. The longer the water is exposed to the sun, the hotter it will become. That is why the water is usually pumped through the tubing at a slow rate.

**The Basics:**

A solar collector plate is positioned facing the sun, and heat from sunlight is collected.

- A flat plate absorber catches and absorbs the sun's light.
- A transparent cover is made of glass or Plexiglas.
- A fluid, either water or anti-freeze, flows through the collector, usually in tubes.
- A heat insulating backing is usually made of black plastic.
- The heated water is collected in an insulated tank.




***Solar Water Heating System***

*1) Collector*
*2) Solar storage tank*
*3) Boiler*
*4) Solar station*
*5) Hot water consumer (e.g. shower)*

# Experiments:

By changing different variables with this solar thermal kit, you can learn a lot about what makes a solar water heating system more or less efficient. You can design a number of experiments by isolating one variable at a time and examining how this variable affects the performance of your system.

Variables to explore:

- Box color
- Light intensity
    - use of reflective materials
    - time of day of experiment and/or angle of collector
    - cloud cover
- Insulation of box and storage container
- Use of the greenhouse effect
- Tube design
    - Pattern
    - Length of tubing
- Rate of water pumping
- Amount of time
- Use of capacitor to sustain water flow if solar panel stops working
- Material and color of tubing
    - Aluminum tube vs. copper tube vs. clear plastic vs. black rubber

## Sample Experiments:

Experiment 1: Color of the Solar Collector

By conducting this experiment, you will be able to quantify the difference between 2 colors of a solar collector (preferably black and white). Leaving all other variables constant, you will only change the color of the box that houses the tubing. Which system will be more efficient?
If you have a second water pump, you can compare the two boxes simultaneously. These instructions will show you how to do it separately.

1. Fill two bins with water. Leave them out for an hour or two so that they will both be at room temperature.
2. Your kit came with two white cardboard boxes with clear plastic lids. Paint one of the boxes black or another dark color. Leave the other box white.
3. Start with the white box. Arrange the tubing in a simple pattern that will be easy to repeat.
4. Record your initial water temperature.
5. Set up the solar collector in a sunny place. Connect the tubing to the water pump and the wires to the solar panel. Make sure that water is pumping through the system and flowing back into the water storage container.
6. Leave the system in the sun for 20 minutes then record the final water temperature. Also record the temperature change (final temp. - initial temp.).

Now repeat the experiment using the black box. Make sure you arrange the tubing exactly the same way as you did in the white box. Try to clear all the water from the first trial out of the tubing before you begin this second trial. Remember to set up the collector in a sunny place. You should try to keep all the variables constant except for the color of the box.

Measure the initial water temperature, then let the black box system run for 20 minutes. Record the final temperature and calculate the temperature change from start to finish.

Is there a noticeable difference between the two collectors? If so, which system had a greater temperature change in the 20 minute time period? Is this result what you would have predicted? Why is this system better than the other?

If you have time, running the experiment for longer than 20 minutes will give you better results. Eventually, the temperature will stop rising. How hot does it get after an hour?

Experiment 2: Length of Tubing in the Collector

In this experiment you will examine how well the solar collector works with different lengths of tubing.

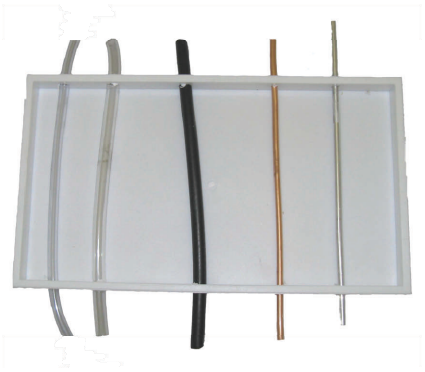
1. Set up 3 different bins of water and allow them to reach room temperature.
2. Start with the full 25 feet of clear plastic tubing. Coil it up to fit as much as possible in the plastic collector box.
3. Place the Plexiglas lid over the collector, connect the tubing to the water pump, and the solar panel wires to the water pump wires. Record the initial water temperature.
4. Place the collector in a sunny place and let the system run for 20 minutes.
5. Record the final temperature and calculate the temperature change.
6. Cut the tubing down to 15 feet and repeat the experiment.
7. Cut the tubing down to 7 feet and repeat the experiment.

Is there a noticeable difference in the efficiency of each tubing length? Which length allowed the water to heat up the most? Is this a result you would have predicted? Why did this length of tubing work the best?

Experiment 3: Different Tubing Materials

Does the type of tubing you use affect the efficiency of your solar thermal system? In this experiment, you will compare how well different tubing materials heat water. Your kit came with a few different tubes that you can compare: clear plastic, black rubber, copper, and aluminum.

1. Set up 4 different bins of water and allow them to reach room temperature.
2. Cut each of the 4 different materials to the same length. It is hard to cut the metal tubes, so we recommend leaving those and cutting the plastic tubes to match the metal ones.
3. If you have 4 water pumps, you can try all 4 tubes at the same time (you will have to drill more holes). Otherwise, just try one at a time. Put the tube through the pre-drilled holes in the plastic box. Set up the water pump to circulate water through the tube and back into the container.
4. Record the initial water temperature. Move the collector into the sun and let the system run for 20 minutes.
5. Repeat this process for each different material of tubing. Try to leave all the other variables constant (initial water temp., light intensity, flow rate of water, length of tubing, etc.).
6. Record the final temperature of the water for each tube and calculate the temperature change.



Is there a noticeable difference in the temperature reached from each tube? If so, which tube was the most efficient (greatest temperature change)? Would you have predicted this result? Why do you suppose this tube was the best?

NOTE* In this experiment, you are also using tubing of different diameters. This is another variable that affects the efficiency of the system. What do you think is the relationship between tubing diameter and water heating efficiency? Do you think this skewed your result?

Imagine that the copper tube increased the water by 22 degrees (F) and the clear plastic tube increased the water by 6 degrees (F). Copper tubing is about 5 times more expensive than the clear plastic tubing. Do you think the copper tubing is worth the extra expense for the increased efficiency?

## Real World Applications

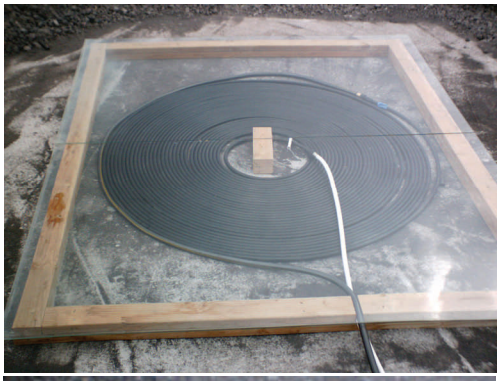
The model solar water heater you construct will very closely resemble this model that a hobbyist made in Hawaii.

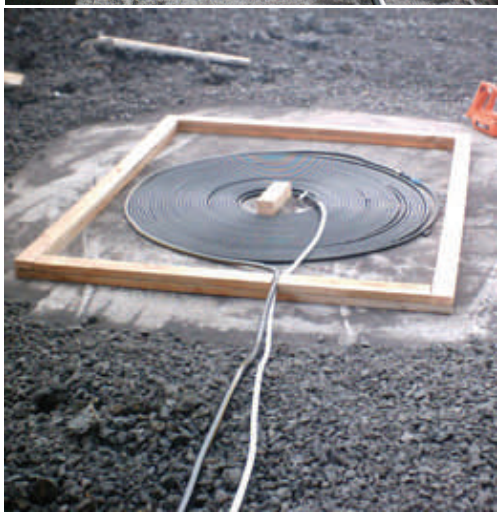
This system uses a water pump to push water through the coiled tubing. With 100 feet of tubing, he is able to store about 5 gallons of VERY hot water without the use of a storage tank. Notice the sheet of glass pane on top.

This entire system was constructed for about $30 and stores enough hot water for a good shower! The system paid for itself in energy savings in less than a month.

Read more about this project here:

http://www.thesietch.org/projects/solarthermalpanel3/index.htm





Here is another simple design for a real, functional solar water heater. This design uses all recycled materials and cost about $5 to construct!

After a couple hours in the sun, this system heated 5 gallons of water from 70 degrees (F) to 110 degrees (F). The outside temperature was 76 degrees (F). Apparently, if water is allowed to sit still in the collector, it can reach temperatures of 170 degrees (F)!

You can read more about this project here:

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

## For More Information…

**Check out these websites for more on Solar Thermal Systems**

- http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12850
- http://www.solarroofs.com/goingsolar.html
- http://www.southface.org/solar/solar-roadmap/solar_how-to/solar-how_solar_works.htm
- http://www.thesolarguide.com/solar-thermal/
- http://www.nrel.gov/learning/re_solar_hot_water.html
- http://en.wikipedia.org/wiki/Solar_hot_water
- Plans for a residential scale system:
  http://www.jc-solarhomes.com/how_to.htm
- Solar Hot Water Simplified (from *Homepower* Magazine) (pdf)
  http://www.homepower.com/view/?file=HP107_pg18_Patterson