Solar Schools
for British Columbia

A collection of lessons to assist teachers and students with their exploration of solar energy

SolarBC
Join the Solar Revolution

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The magic of solar thermal

How the sun can be used to heat water

What will happen

Students are introduced to using the sun to heat water.

Students will

- Understand that sunlight can be? collected and converted into heat energy;
- Distinguish the different types of solar water heating, active or passive;
- Construct a simple solar hot water heater;
- Demonstrate how a passive solar hot water heater works;
- Calculate solar hot water heater energy savings.

Total Time 1/2 - 1 1/2 hours	Establish what students know	Activity Part A	Activity Part B	Debrief what students learned
	5-20 minutes	20-30 minutes	60-120 minutes	10 minutes

What you need to know

- Solar heating systems capture the sun's heat and turn it into hot water or space heating using solar panels. The panels absorb the sun's energy from sunrise to sunset and heat liquid that runs through insulated piping to connect with an array of collectors. Water flows through collectors mounted on a roof, the side of a building, or on the ground. The water is pumped to a heat exchanger, where the heat is transferred to a hot water supply. The heated water is kept in an insulated tank until it's used. Solar thermal is also used for space heating and can heat houses or other buildings.
- ***Passive solar*** heating is when solar energy is used to heat something without requiring electrical or mechanical components. Active solar methods use temperature controls and electrical or mechanical pumps to make fluids flow through collectors. Active solar water heaters are more efficient than passive solar water heaters, but they require more equipment and engineering expertise to build and install, and are more expensive to run.
- Solar water heaters provide several benefits over conventional water heaters: (a) a reduction in hot water heating costs and (b) a reduction in greenhouse gas emissions (carbon dioxide,CO2, released into the atmosphere), thereby contributing to a healthier environment.
- The energy you can expect to save by switching to a solar water heater depends on several factors such as the size of the collectors and storage tank, appliance efficiency, amount of sunlight in your region and, most importantly, the amount of water you use. A typical solar hot water system will reduce annual energy costs by 40 to 50 percent and provide you with 1500to 3000 kWh of energy per year, depending on your hot water usage and regional climate. The map on the Student worksheet shows approximate energy savings for various places in Canada.

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What might surprise you

The build-up of greenhouse gases in the atmosphere is the primary cause for concern for climate change now and into the immediate future. While greenhouse gas emissions can be from both natural and human activities, the one causing the most concern is the build-up of atmospheric carbon dioxidewhich is released through the combustion of fossil fuels. In Canada, 80 percent of total national greenhouse gas emissions are associated with the production or consumption of fossil fuels for energy purposes such as electricity generation, space heating, manufacturing, construction, and mining. According to Natural Resources Canada, 70% of the energy used in the residential and commercial/institutional building sector is used for heating1 and domestic water heating contributes approximately 6 million tonnes of CO2 each year toward Canada's greenhouse gas emissions[2].

1. http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/renewables/solar_thermal.html
2. Solar Water Heating Systems, A Buyer's Guide. Natural Resources Canada. Cat. No.: M92-179/2000E ISBN 0-662-28486-0, page 3

Establish what students know

- List the different energy sources that are used to heat homes.
- Ask the students how to use solar energy to heat water.

Main Activity Part A

This activity has three parts: Part A is a Passive Solar Hot Water Heater demonstration, in Part B students construct their own Solar Hot Water Heater, and in Part C students calculate potential energy savings for implementing solar hot water heating in their geographic region.

Part A Demo: The Passive Solar Hot Water Heater

What you do

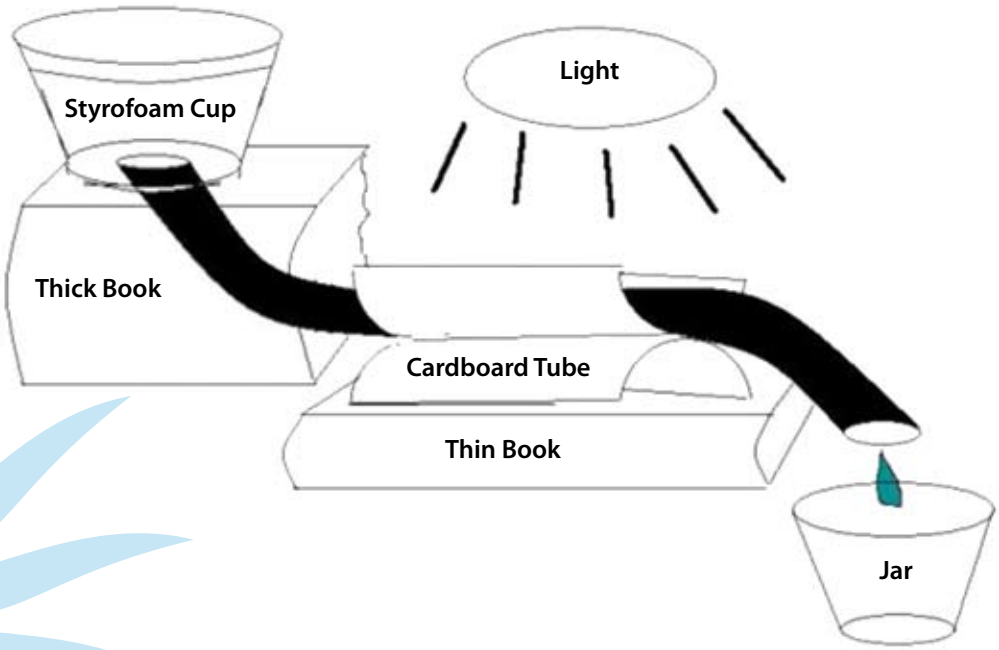
- Set-up the Demo for Part A in advance.
- Prep materials by cutting the aquarium tubing into 30 cm lengths and painting black for each student hot water heater demo.
- If performing the activity indoors, prepare a few light stations and associated supplies (see material lists).

What you need (for each demo)

- 30 cm of aquarium tubing, painted black;
- a cardboard paper towel roll;
- 1 small sheet of aluminum foil;
- 1 pair scissors;
- 2 Brass fasteners, glue or stapler to join two halves of the paper towel rolls;
- lamp to represent the sun or access to strong, direct sunlight;
- 1 Styrofoam cup;
- plasticine;
- 1 collecting jar or small beaker.

The Demo Set-up

1. Cut the paper towel roll in half lengthwise.
2. Place the roll halves together so their convex sides are touching (back to back).
3. Join the two roll halves together with brass fasteners, glue or staples at both ends of the rolls. If gluing find something that can go through the roll that will hold the tube in place without blocking too much of the tube eg twist tie or string.
4. Line the inside of one paper towel roll with the aluminum foil, shiny side of foil facing up towards the sun, gluing it to the paper towel. This now is your parabolic collector or heater.
5. Place the black tubing on top leaving equal amounts of tubing on each end of your parabolic collector.
6. Poke a hole approximately 1 cm from the bottom of the Styrofoam cup to allow the aquarium tubing to fit snuggly through it, no bigger.
7. Insert one end of the aquarium tubing into the hole and seal it with a small amount of plasticine. Place the parabolic collector on a raised object such as a book.
8. Place the cup on an object raised approximately 1-2.5 cm higher than the collector such as 2 books. The cup is on one level and the parabolic collector is a half step lower than the cup.
9. Place a water collector (a small jar or beaker) on the tabletop and place the other end of the tube in it. The top of the water collector should be approximately even with the platform that the parabolic collector is on. Now there are three levels. The cup is the highest, the parabolic solar collector is second highest and the jar or beaker is on the lowest level. adapted from www.InfinitePower.org



The Demo

1. Measure 100 ml of water in a beaker or graduated cylinder. Record the temperature.
2. Add the 100 ml of water to the Styrofoam cup (on the top level of your set up) You may have to hold the cup so that it sits flat on the books and table.
3. * Immediately raise or lower the position of the collection jar (on the lowest level), so that the water flows through the black tubing of the shiny parabolic collector *at the slowest rate possible*.
4. Record the temperature of the collected water during the process, recording the temperature every 30 seconds. Mark the reading when all of the water has flowed through the collector and the Styrofoam cup is empty.
5. Keep recording the temperature readings after all of the water has flowed through the solar collector for another 2 - 3 minutes.

Main Activity Part B

Part B Students Make a Solar Hot Water Heater
(illustrations and instructions on student worksheet)

In this experiment students will observe how solar water heaters take advantage of the fact that hot water rises.

1. Students will build a simple solar water heater to demonstrate the concept of heating water with light.
2. In small groups students construct their hot water heater.
3. Set up the model solar water heater and place it in a sunny position or use a lamp.
4. Fill the bottle and the plastic tubing with water.
5. Record the temperature of the water in the solar water heater while sitting in sunlight for 20-30 minutes.
6. Create a graph to indicate the temperature readings taken every 5 minutes. Interpret the results of your graph citing what happens to the temperature during the flow of water and what happens after it has stopped flowing.
7. Conclude with a class discussion comparing results and graphs. What happened to the temperature as additional rounds were completed? (Answer: The water temperature increased.) How would this relate to solar water heaters? (Answer: As the water moves through the solar heater it continues to warm.)

Main Activity Part C

Part C Calculate Your Energy Savings

Things You Need

- Utility bill-gas, oil, electric or propane;
- Copies of Student worksheet;
- Diagram of Hot Water Heating Systems on student worksheet;
- Table on Solar Hot Water Heating Systems on student worksheet.

Step 1

Estimate your annual energy requirement for hot water heating from the table on the student worksheet. Locate/identify? the energy requirement of electricity, litres of oil or propane, or cubic metres of natural gas, depending on the fuel you use for heating your water. Record this value in Box 1.

Step 2

Find your location (or one with a similar climate) or the nearest location to you on the map of Canada on the student worksheet. Write the percentage that corresponds to the potential portion of water heating energy saved in Box 2.

Step 3

Multiply Box 1 by Box 2. Write this figure in Box 3, which is your estimated energy saving in kWh, litres or cubic metres.

Step 4

On a recent electricity, gas, oil or propane utility bill find the amount you paid and the amount of kWh, litres, or cubic metres of fuel used. Write the amount you paid in Box 4 and amount of fuel used in Box 5.

Step 5

Multiply Box 3 x Box 4 and divide by Box 5

This is your estimated annual dollar savings from your solar hot water heater.

Debrief what students learned

- What are some limitations of a solar hot water heater?
- List some benefits of using solar hot water heat.

Assessment

- Describe how a passive solar water heater system works. Why does the water tank need to be painted black?
- What is one major difference between a passive solar system and an active solar system?
- What is the purpose of a storage tank?

Extensions

- Test for the effect on the temperature of altering variables (eg, clear plastic versus glass covering the box; various insulating materials around the bottle; the colour of the bottom of the cardboard box; the angle at which the box is tilted).

Check Out

Links

- Hot Water Heating http://chuck-wright.com/calculators/hotwater.html
- http://nrcan.gc.ca/eneene/renren/index-eng.php#solar
- http://www.digtheheat.com/Solar/solar_energy_index.html

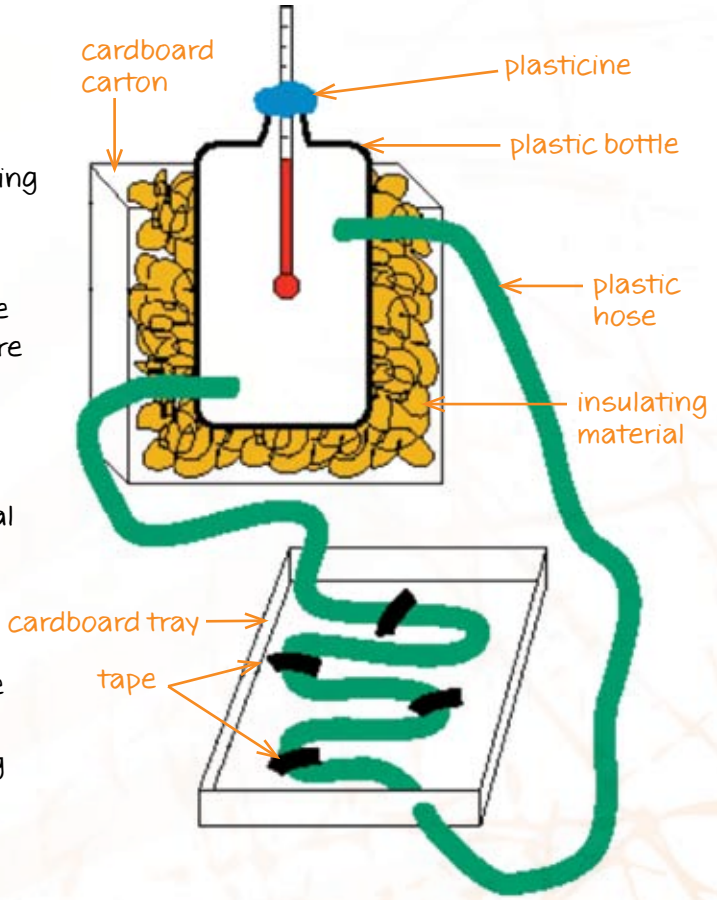
student worksheet

Making a Solar Hot Water Heater

Materials

- ❑ large cardboard tray, approximately 60 × 30 × 15 × centimetres (made by cutting down a cardboard carton)
- ❑ 6 metres of plastic tubing painted black, or garden hose
- ❑ 2-litre plastic bottle
- ❑ cardboard carton (big enough to hold the plastic bottle)
- ❑ thermometer
- ❑ scissors with pointed ends
- ❑ plasticine, hot glue or caulking
- ❑ electrical or duct tape
- ❑ water
- ❑ black and white poster paints
- ❑ sheet of clear plastic or glass, larger than 60 × 30 centimetres
- ❑ a variety of insulating materials (eg, old clothing, sawdust, plastic foam, crumpled newspapers)

1. Tubing should be painted black.
2. Prepare the plastic bottle with two holes to allow the aquarium tubing or hose to fit snugly. One of the holes should be at the top of the bottle and the other at the bottom to ensure that circulation and mixing occurs as the water is heated.
3. In the bottom of the cardboard carton place a layer of insulation and position the pop bottle inside. Mark on the carton where the top and bottom tubing will need to go through and carefully cut out the holes.
4. Place plastic bottle inside carton. Insert tubing through carton and into bottle. Seal with hot glue, caulking or plasticine so it won't leak. Add remaining insulating materials to the inside of the carton.
5. Position as much of the tubing as possible across the bottom of the cardboard tray, ensuring that the maximum area of tubing is exposed to the sun.
6. Fasten the tubing with tape.
7. Cover cardboard tray and tubing with clear plastic or glass.
8. Fill pop bottle with water to the top.
9. Insert the thermometer and hold in place with plasticine.



Calculate your energy savings

Follow steps 1-5 to translate these energy contributions into dollar savings

Step 1

Estimate your annual energy requirement for hot water heating from the table on the next page. Read off the energy requirement of electricity, litres of oil or propane, or cubic metres of natural gas, depending on the fuel you use for heating your water. Write this value in Box 1.

Step 2

Find your (or one with a similar climate) location or the nearest location to you on the map of Canada above. Write the percentage that corresponds to the potential portion of water heating energy saved in Box 2.

Step 3

Multiply Box 1 by Box 2. Write this figure in Box 3, which is your estimated energy saving in KWh, litres, or cubic metres.

Step 4

On a recent electricity, gas, oil or propane utility bill find the amount you paid and the amount of KWh, litres, or cubic metres of fuel used. If you are paying a fixed monthly rate, call your utility company for this information. Write the amount you paid in Box 4 and the amount of fuel used in Box 5.

Step 5

Multiply Box 3 by Box 4 and divide by Box 5. This is your estimated annual dollar savings from your solar water heating system.

Calculate your energy savings

Table of Yearly Energy Requirement for Water Heating			
Household Size (in persons)	2	3-4	More than 5
Average Hot Water Usage	150 litres/day	225 litres/day	300 litres/day
Suggested Solar Water Heater System Size	Small • no pre-heat tank • about 3 m^2	Medium • pre-heat tank • 5-6 m^2	Large • pre-heat tank • greater than 6 m^2
Equivalent? Existing Water Heater Tank Size	180 litres (40 gallon)	270 litres (60 gallon)	270 litres high power output (60 gallon)
Estimated Annual Energy Required by Fuel Type			
Electricity KWh	3400	5000	6600
Natural Gas (m^3)	500	740	1000
Oil (litres)	480	720	960

Box 1		Box 2		Box 3		Box 4		Box 5		Answer
Yearly energy requirement for water heating in KWh, m^3, or litres		Portion of energy met by a solar water heating system in your region (see map on previous page)		Potential energy savings by a solar water heating system in KWh, m^3, or litres		Dollars paid for energy used (from a recent utility bill)		Amount of energy used in KWh, m3, or litres (from a recent utility bill)		Estimated annual savings from a solar water heating system
Example: 5000 KWh		Example: 47/100		Example: 2350 KWh		Example: $55		Example: 600		Example: $215
Your figure	x	Your figure	=	Your figure	x	Your figure	÷	Your figure	=	Your figure