Investigation 6:

Solar Energy

Key Question

Before you begin, first think about this key question.

What other energy sources are there?

Does all electricity come from burning of fossil fuels? Aside from electricity, what other kinds of energy do you use or need?

Write down your ideas in your journal. Share them with your group and the class.

Investigate

Part A: Modeling the Absorption of Solar Energy

1. Select three containers.

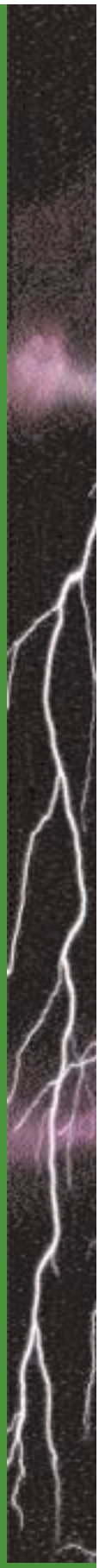
   Using your supplies, make one container black, another container white, and the final container shiny. (Your teacher may choose to have each group investigate only one of the containers.)

   Using a graduated cylinder, place exactly the same volume of water in each of these three containers.

Materials Needed

For this part of the investigation your group will need:

- three cylindrical metal containers, all alike
- black paint
- white paint or paper
- aluminum foil
- masking tape
- graduated cylinder
- water
- stirrer
- three alcohol thermometers
- heat lamp



a) Record the room temperature, in degrees Celsius, before beginning.

Place a thermometer in each of your containers. Measure the temperature in each container.

b) Record these temperatures in a data table similar to the one shown.

Time (min.)	Black Temperature (°C)	White Temperature (°C)	Shiny Temperature (°C)
Before test			
After 4 min.			
After 8 min.			
After 12 min.			
After 16 min.			
After 20 min.			
After 24 min.			

2. Think about what may happen if you heat the water using solar energy (or a heat lamp). Now make predictions about the effect that the color of the container is likely to have on:
   - how warm the water gets;
   - how quickly the water is heated.

   a) Write your predictions down, together with your reasons for them.

3. Place each of the three containers under a heat lamp or in a sunny place. If you use a heat lamp, be sure to place each container exactly the same distance from the bulb.

   Every four minutes, stir the water vigorously and measure the temperature in each container.

   Repeat this procedure for 24 min.

   a) Record these measurements on your data table.

Be careful not to stir with the thermometer as it can break. Be careful of the lamp—it will get hot and can cause burns.

4. After 24 minutes of temperature measurements have been recorded (or longer if necessary), review your data.

   a) How can the data you gathered be used to test the prediction you made in **Step 2?**

   b) Which container got the hottest?

   c) Which container heated the quickest?

   d) Were your predictions correct?

   e) Do the reasons you gave for your prediction seem sound? If not, can you find an alternative explanation for what happened?

   f) What evidence do you have that shows a connection between color and the absorption of sunlight (or light from a heat lamp)?

   g) In your group, discuss your findings and what they show.

   h) Can you think of any other examples where color of materials and heat are involved?

   i) What variables did you control in this experiment?

   j) What variable did you manipulate or change?

Part B: Designing a Water Heater

1. As a group, you will design a device to heat water contained within rubber tubing. The goal is to produce the hottest water. You must use the equipment provided.

Inquiry

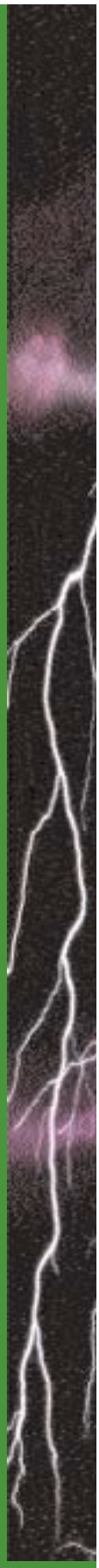
Variables

A variable is anything about an experiment that can be changed by the investigator or changes naturally. Usually in a scientific experiment, all variables are kept the same except for one—the variable that is being tested. Variables that are kept the same are said to be controlled.

Materials Needed

For this part of the investigation your group will need:

- tubing
- funnel
- insulated container like a small Styrofoam® cooler for collecting water
- cardboard lid or box trimmed to a 3-cm height
- masking tape
- black construction paper
- scissors
- school glue
- plastic wrap
- tubing clamping
- newspaper
- ring stand



Here are some guidelines you need to follow:

Guidelines for Designing the Water Heater

(1) Water must be added to your device using a funnel and must leave your device and flow into an insulated collecting container.

(2) The "official" temperature of the water will be measured in the insulated collecting container.

(3) In your design, the funnel must be placed at the top so that water flows through the device.

(4) The container to collect the water, once it has run through your device, must be placed at the bottom.

(5) The tubing must pass through a box.

(6) You may put holes or openings in your box.

(7) You may leave the box lid on, or take it off.

NOTE: You may need to use chairs, books, or other appropriate items to prop up the device.

When you are sure you understand the guidelines, discuss your ideas on how to make the device in your group.

a) Make a design drawing and have it checked by your teacher before beginning.

2. Once your design has been approved, build your water-heating device.
3. After each group has built a device, place the device on a flat, horizontal surface in the sunlight (or beside heat lamps).
4. First run 500 mL of cool water through each device to cool it off.

   Collect another 500 mL of cool water.

   a) Measure and record the initial temperature.

   Run the water through the device.

   b) When all of the water has reached the container at the bottom, immediately measure its temperature.

   c) How did the temperature change?

Be sure your teacher checks and approves your design. Only light should be used as the heat source.

5. Now tilt your box (using chairs or books for support) so that your device faces the Sun or the lamp.

   Repeat **Step 4.**

   a) Record all your temperatures.

   b) Did your device change the temperature?

   c) If the water became heated, by how many degrees, or fractions of a degree, did it warm up?

6. Repeat **Step 5,** but this time use the tube clamp to keep the water inside your device for five minutes. Then, release the water and measure its temperature.

   a) Record all the temperatures.

   b) What change in temperature do you have?

   c) How could you improve the design of your solar water heater so that it heats water more effectively?

   d) How could you adapt the design to heat water in a home?

   e) For what would you use this water?

   f) Explain why the energy resource used here is either renewable or nonrenewable.

Part C: Researching Renewable Forms of Energy

1. Now that you have had a chance to experiment with one form of renewable energy, think about what other forms are available.

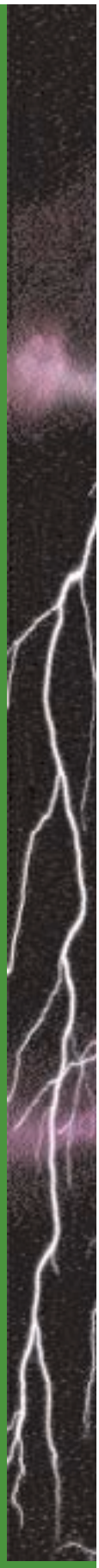
   As a class, make a list of all the renewable forms of energy that you can think of. Your teacher may contribute some new ones as well.

   Choose one form of energy to research. Your teacher may assign a form of energy to you.

   Use the following, or any other resources available to you, to find out all you can about your renewable energy source:

   - library reference books;
   - telephone book Yellow Pages for suppliers of alternative energy equipment (in some cases);
   - literature from agencies like the Department of Energy (DOE) and specialist energy companies;

Do not make any telephone calls without a teacher or other responsible adult present.



- any people with specialist knowledge you can find;
- CD-ROMs;
- *IES* web site.

2. Answer the following questions:
   a) How is your energy source environmentally friendly? How is it not?
   b) What hazards or risks does your energy source pose, and why?
   c) How cost-effective is your energy source compared to fossil fuels?
   d) For what part of the country is your energy source best suited, and why?
   e) Are there any other questions that you would like to include in your research?
3. When you have researched and answered these questions, think of the best way to present your findings to others.
4. In a class session, compare all these different forms of energy.
   - What are the advantages and disadvantages of each energy source?
   - How might these forms of renewable energy sources develop in the future?
   - Why are renewable energy sources being researched and developed?

   a) List all your ideas in your journal.

Digging Deeper

SOLAR ENERGY

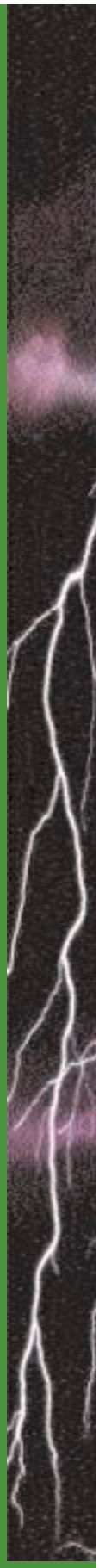
Direct and Indirect Uses of Solar Energy

All matter radiates energy from its surface. This energy is in the form of electromagnetic waves. These waves travel at the speed of light. The hot surface of the Sun radiates energy mostly in the form of visible light. You can detect the energy of sunlight when it shines on you and is changed into heat energy. Only a very small part of the Sun's energy reaches the Earth. That is because the Earth is small and very far away from the Sun. The energy received from the Sun is far more than enough, however, to provide all of your energy needs. The problem is to harness it in a practical way. Solar energy is spread out over such a very large area. Therefore, in any small area it is not very intense. As a result, capturing the Sun's energy must be planned. To obtain large amounts of solar energy, large areas of the Earth's surface have to be covered by collectors.

As you read in **Investigation 2**, sunlight can be used as an energy source both directly and indirectly. The most direct way is to use sunlight for heating of buildings or

As You Read...
Think about:

1. ***Explain the two kinds of solar-heating systems.***
2. ***What are some ways that sunlight can be used as an energy source?***
3. ***What is the most common way to use solar energy to generate electricity?***



water. Another direct way is to use sunlight to generate electricity. This is done using devices called photovoltaic cells. The most important indirect use of solar energy is to generate electricity with hydroelectric dams and windmills. As you found out in **Investigation 2,** the wind that blows the windmills and the rain that falls to form rivers are both due to the effects of solar heating. The Sun's energy is therefore the basis for both hydroelectric power and wind power. Another indirect form of solar energy is the energy stored by plant growth. The energy stored in wood and other plant materials comes from storage of solar energy as the plants grow. The plant material can be used for fuel. It can also be used for making many kinds of products.

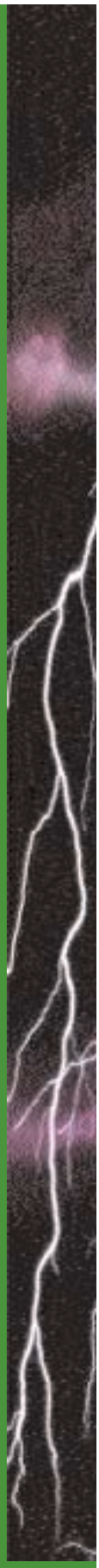
Solar Heating

Home heating is one of the main uses of solar energy. There are two kinds of solar heating systems: active and passive. Active systems use a special collector to capture the Sun's energy. The collector is usually a large, flat panel. The panel is mounted on the roof, facing the Sun. While the Sun is shining, air or a liquid is pumped through the collector panel to a storage tank. The building is then heated from the storage tank. Collectors for water heating are similar, but they are not as expensive. In sunny regions they can provide most or all of the hot water in homes or swimming pools.

In a passive system, the building is designed to let in large amounts of sunlight. The heat produced from the light is trapped inside. Passive systems do not rely on special mechanical equipment. Buildings designed for passive solar heating usually have large, south-facing windows with overhangs. In winter, the sunlight shines directly through the large windows. The floors and walls heat up during the day and release the heat slowly at night. In summer, the high Sun is blocked by the overhang from shining directly into the building.

Photovoltaic Cells

Solar energy is also used to generate electricity. The most familiar way is to use photovoltaic cells. These are also called solar cells. Solar cells use special materials that change sunlight directly into electricity. The simplest solar cells power many of the small calculators and wrist watches used every day. Solar cells are especially useful in places far from power lines. Have you ever seen emergency call boxes along highways? They are usually powered by solar panels. Often, solar power is the cheapest form of electricity for tasks like that. The efficiency of solar cells is not high.



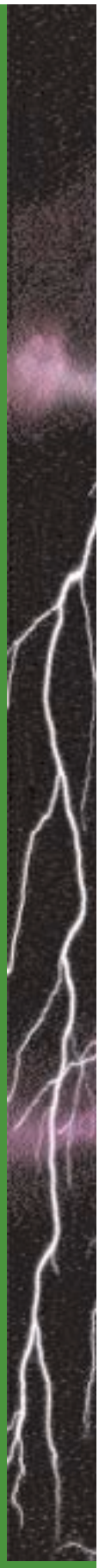
It is increasing, however, as research develops new materials for converting sunlight to electricity. Solar cells are already an important part of your lives, and their use is growing rapidly.

Hydroelectric Power

In early times, the energy of falling water was used to turn machinery in factories. Nowadays it is used to generate electricity. The water level behind a dam is higher than the river below. The water pressure behind a hydroelectric dam turns large turbines attached to electrical generators. In 1998 hydropower accounted for nearly 9% of electricity generated in the United States. In Canada, where they use much less electricity than in the United States, nearly 60% of the electricity generated came from hydropower! Advantages of hydropower are that it is nonpolluting, and the energy source is free. The disadvantage is that a dam alters the natural environment of a river. Most of the good hydropower sites in the United States are already in use.

Wind Power

People have been using wind power for hundreds of years to pump water from wells. Only recently, however, has wind power been used on a large scale to generate electricity. "Wind farms" consist of large numbers of special windmills, called wind turbines, that are built in a windy area. Each windmill consists of a tower with a very large propeller at the top. The propeller turns an electrical generator behind the propeller. The propeller blades can be as long as 30 m! The electricity is then supplied to a power grid, the same as with other kinds of power plants. California now leads the country in wind power. Many other areas of the United States have a high potential for wind power as well. The cost of electricity from wind is gradually dropping. This is due mainly to innovations in design of the windmills. The present cost of wind power is not much greater than the cost from standard power plants.



Review and Reflect

Review

1. In the investigation, which container absorbed the most heat?
2. Did your findings confirm what you predicted? Explain.

Reflect

3. What are the advantages and disadvantages to solar power as an energy source?
4. Which renewable energy source do you think has the most promise for the future? Explain your answer.

Thinking about the Earth System

5. How is solar energy connected to the atmosphere?
6. What is the original source of the energy derived from burning wood and other plant material?
7. What connections can you make between the use of solar energy and the hydrosphere?

Thinking about Scientific Inquiry

8. What were the variables in your experiment?
9. How were conditions controlled?