# YOU'RE GETTING WARMER... (1 HOUR)

*In this activity, students investigate the effect that a material can have on the absorption of solar energy. Students create model houses and place different materials on the roof. They then measure the effects of these materials on the temperature inside the house.*

## Overview

**Topic: Solar Energy**

**Real World Science Topics:**

- An exploration of how different materials absorb sunlight differently.
- An exploration of how sunlight can be used to heat a house.
- An exploration of the effects of construction materials on home energy efficiency.

**Objective**

Students will gain an understanding of performing a controlled experiment and how properties of materials can affect the amount of sunlight they absorb.

**Materials Needed for Each Team of 2-4 students:**

shoebox with no lid
thermometer
aluminum foil
pieces of cloth (white, black, gray)
scissors
tape or thumbtacks
heat lamp (if performing the activity outside is not an option)

**Standards Met**

National Science Standards Addressed
Content Standard A: Science as Inquiry
Students:

- Use data to construct a reasonable explanation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Thing critically and logically to make the relationships between evidence and explanations.

National Math Standards Addressed
Data Analysis and Probability: Collect data using observations, surveys, and experiments.
Find, use, and interpret measures of center and spread, including mean.
National Technology Standards Addressed
Use models and simulations to explore complex systems and issues.

**Sources:**

**National Science Teachers Association**
http://books.nap.edu/html/nses/overview.html#content
**National Council of Teachers of Mathematics**
http://standards.nctm.org/document/chapter5/index.html
**National Educational Technology Standards**
http://cnets.iste.org/currstands/cstands-netss.html

# STEPS FOR *YOU'RE GETTING WARMER...*

**1. Warm-Up Activity:**
Ask the students the following question: "If you could collect all of the energy from the Sun that hits Earth in one day, how long could that energy be used to power all the things that people use in the world?" They will probably not know that the answer is about one year. There is more than 300 times as much solar energy hitting Earth in one day than the entire amount of energy used by all of the people in the world over the course of a day. The idea is to show them the immense amount of energy that is continuously transmitted from the Sun to Earth.

2. Ask students to give examples of things that use the Sun's energy. If necessary, explain to them that most living things on Earth rely on the Sun for energy. Plants use energy from the Sun to make food from water and gases in the air. Animals get energy by eating plants or other animals. Humans also use energy that is derived from the Sun. Fossil fuels such as oil, natural gas, and coal are actually plant material that has been trapped underground and compressed. Therefore, when we use these materials, we are really using *solar energy* that has been trapped underground for millions of years. We can also make energy from wind and waves. Explain to students that the wind is caused when the Sun heats one area of the Earth more than another, and that waves are caused by wind. So, the energy in wind and waves ultimately comes from the Sun.

3. Ask students whether they feel warmer in the Sun when they are wearing a black shirt or a white shirt. Explain to them that the color of a material, as well as the type of material, can affect how much sunlight that material absorbs. Explain that one of the big challenges for scientists and engineers is to develop materials that can absorb sunlight more efficiently.

4. Make copies and distribute the *You're Getting Warmer*... Student Handout. Students can use this handout to record the results of their trials.

5. Divide students into groups of two to four. Give each group a shoebox, scissors, a thermometer, and the materials that they will use for the roof. Take the students outside to a sunny spot. If a sunny spot is not available, set up heat lamps around the room for students to use to simulate the Sun. The heat lamps should be at least 30 cm away from the surface of the table that the shoeboxes will rest on.

6. Explain to students that they will use the materials they have to construct a "roof" for the shoebox "house." They will then allow the house to sit in the sun (or under a heat lamp). During the trials the thermometer should be placed inside the shoebox, then the roof materials should be taped onto the top of the box in place of the lid. They will record the temperature inside the house. Have students make predictions about which roofing material will lead to the highest temperature inside the box, and which will lead to the lowest. Have them record their responses on the handout.

7. Next, students should carry out their trials. For the experiment to be controlled, the location of the thermometer, the location of the box, the location of the heat lamp (if one is being used), and the amount of time the thermometer is inside the box should be the same during each trial. Before each trial, students should place the box in a shady spot and allow its temperature to decrease. They should then place the thermometer in the box and allow it to sit in the box until the temperature reading has stabilized. They should then read and record this initial temperature inside the box in the table on the handout. Then, the material being tested should be draped over the top of the box and secured with tape or tacks so that it does not sag. Students should then place the box in a sunny spot or under a heat lamp for 5-10 minutes. Students should make sure each trial has the same duration.

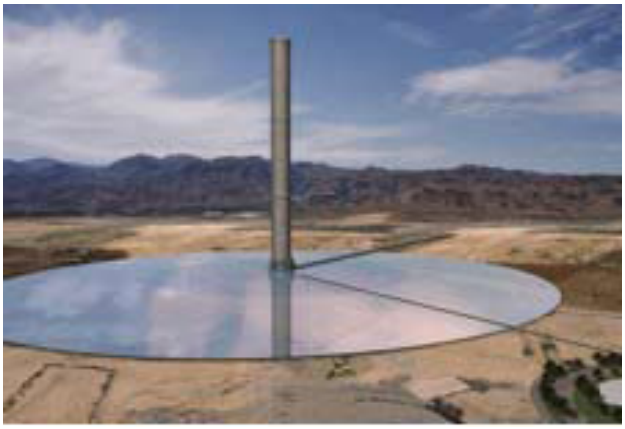
8. After each trial, students should remove the roof from the box and immediately read and record the temperature reading on the thermometer. They should place the thermometer in a shaded area and allow its temperature to decrease back to the original starting temperature. They should also calculate the change in temperature inside the box during the trial.

9. Students will have some downtime during each trial, and after each trial while they wait for the thermometer's temperature to decrease. If it is appropriate, lead the class in a discussion of solar power. Ask students what they know about solar power. Most students will probably have heard of solar panels, which convert light into electricity. Show them a picture of a *photovoltaic cell* that you would normally find on a roof, such as the one in the picture below.

(source: http://www.eie.gov.tr/english/solar/photovolt_e.html)

This solar cell is dark because it is designed to absorb much of the visible light from the Sun.

Remind students that, in this experiment, the Sun's energy is converted into heat. Explain that this method of energy conversion can also be used to harness the Sun's power. A common way to use the Sun's energy in this way is to use passive solar heating in buildings. A building that uses passive solar heating has large windows and light-absorbing flooring on the side of the building that gets the most sunlight. This allows the sunlight to help heat the building, reducing the amount of fossil-fuel-based energy required to keep it warm. Air heated by the Sun's energy can also be used to generate electricity. Large *solar towers*, such as the one that is shown in the picture below, have a large, clear canopy at the base. The air under the canopy gets warmer as the Sun shines on it. The warm air rises through the tower. This rising column of air can be used to turn a turbine and create electricity.



Source: (http://www.unenergy.org/Gallery/enviro006.jpg)

The canopy at the bottom of the tower acts like a car's windshield. Sunlight passes through it, but the heat that is generated by the ground below cannot. As a result, the air below the canopy absorbs the heat and becomes warmer.

Ask students to think of some advantages and disadvantages of solar energy. The main advantage is that heat and electricity generated from sunlight do not result in the emission of greenhouse gases or other pollutants. The main disadvantages are that, with today's technology, solar power is generally more expensive to produce than are other kinds of power. In addition, solar power is not practical in all areas. Areas that receive little direct sunlight generally cannot use solar power effectively.

**10. Wrap-Up Activity:** When the class is finished with the activity, lead a discussion of the results. Start by asking each group to write their results on the board. Then, as a class, calculate the average temperature change produced by each material. Explain that scientists try to replicate experiments so that they can tell if their results are reasonable. When you are done averaging, examine the results. Ask students to explain each result. For example, they should now realize that aluminum foil is a bad choice for collecting solar electricity because it reflects a lot of the sunlight. Black cloth, on the other hand, absorbs much of the sunlight.

# *YOU'RE GETTING WARMER...*
# EXTENSION ACTIVITY

Interested students could attempt this activity with materials not specified above. For example, students could try using several sheets of material to see if the thickness of the material has any effect on the heating of the box. The students should start at one sheet, then add one or two sheets and track the results.

# *YOU'RE GETTING WARMER...* BACKGROUND INFORMATION

## Where does solar energy come from?

Solar energy is actually electromagnetic radiation that is produced by nuclear reactions in the Sun's core. The pressure inside the Sun's core is very high. The high pressure causes hydrogen atoms to fuse and form atoms of other elements, such as helium. This releases a lot of energy, which eventually makes its way to the surface of the Sun. Only about a billionth of the energy that the Sun emits reaches Earth, but this is still a large amount. Of the solar energy that reaches Earth, about 25% is reflected by clouds and the atmosphere, and 20% more is absorbed by the atmosphere. That leaves about 55% that actually makes it to Earth's surface. Most of this is absorbed by the surface, heating the atmosphere and making the planet livable.

## What is electromagnetic radiation?

Electromagnetic radiation has rightfully gotten a reputation for being a tricky thing to explain. It exists as both a wave and a particle at the same time. Since we have more experience with objects that behave like particles (balls, for example), it is easier to think of electromagnetic radiation as a stream of particles called photons. Each photon travels near the speed of light and has a certain amount of energy, which is related to what type of radiation it is. X-rays, ultraviolet radiation, microwaves, and the visible light that we see as the colors of the rainbow are all forms of electromagnetic radiation with different energies

## How can electromagnetic radiation interact with matter?

Electromagnetic radiation can interact with matter in one of three ways: transmission, reflection, or absorption. Transmission occurs when the radiation passes through an object. Sunlight passing through a clear window is an example of transmission. Reflection occurs when photons hit matter and bounce off of it in another direction. Light bouncing off a mirror is an example of reflection. Absorption occurs when a photon hits a particle of matter and transfers its energy to the particle. The particle can then emit the energy as a different wavelength of energy. When light hits a black shirt, much of it is absorbed. The energy is the converted into infrared energy, which we feel as heat.

## How do these interactions affect the collection of solar energy in the real world?

The Sun is an important source of energy for people, and will become more important in the future. Photovoltaic solar cells absorb photons and convert them directly into an electric current. Scientists are constantly looking for materials or combinations of materials that can perform this absorption and conversion efficiently. Solar energy can also be converted into electricity using the solar heating tower model. In this model, a large tower is constructed. A large, clear canopy is built around the bottom of the tower. Sunlight passes through the canopy. The ground below absorbs the sunlight and gets warmer. The air absorbs heat from the ground and gets warmer. The rising air turns turbines, which generate electricity.

**Key Vocabulary:**
**solar energy:** electromagnetic radiation transmitted form the Sun to Earth
**photovoltaic cell:** a system for converting sunlight into electricity
**solar tower:** a system that uses sunlight to heat air, which spins a turbine, which creates electricity

# TEACHER HANDOUT FOR *YOU'RE GETTING WARMER...*

**Name** _____ **Date** _____

Which material do you think will cause the inside of the box to get hottest? Which do you think will heat the box the least?

[Sample answer: I think that the black material will cause the inside of the box to get hottest because black material absorbs a lot of light. I think that the white material will heat the box the least because white materials reflect light.]

| Roof Material | Initial temperature inside the box | Final temperature inside the box | Temperature change | Class average temperature change |
|---|---|---|---|---|
| Black cloth | | | | |
| Gray cloth | | | | |
| White cloth | | | | |
| Aluminum foil | | | | |

Which material produced the largest average temperature change? Which produced the smallest average temperature change? Do these results agree with your predictions?

[Sample answer: The black cloth produced the largest average temperature change. The white cloth produced the smallest average temperature change. My predictions were correct.]

Why is it important for scientists to repeat their experiments if possible?

[Repeating experiments makes the results more reliable because there is less of a chance that the results were caused by random events or errors.]

How is solar energy used to produce electricity?

[Solar energy can be used to create electricity in two ways. A photovoltaic cell can be used to collect sun light and convert it directly into electricity. Or, sunlight can be used to heat air, which creates a wind current, which can turn a turbine and generate electricity.]

# STUDENT HANDOUT FOR *YOU'RE GETTING WARMER...*

**Name** _____ **Date** _____

Which material do you think will cause the inside of the box to get hottest?
Which do you think will heat the box the least?

| Roof Material | Initial temperature inside the box | Final temperature inside the box | Temperature change | Class average temperature change |
|---|---|---|---|---|
| Black cloth | | | | |
| Gray cloth | | | | |
| White cloth | | | | |
| Aluminum foil | | | | |

Which material produced the largest average temperature change?
Which produced the smallest average temperature change? Do these results agree with your predictions?

Why is it important for scientists to repeat their experiments if possible?

How is solar energy used to produce electricity?