

# SUN FUN

**Note:**

This activity can only be done if the sun is shining (a problem when dealing with solar energy). We suggest you choose an alternative activity in case of a cloudy day. However, a visit to Cooper ESC's photovoltaic system is always an option, sun or not.

**ACTIVITY:**

Students perform a number of simple experiments to demonstrate the sun's apparent movement across the sky, colors of light, solar energy and how we can harness this energy. The activity culminates with a visit to the photovoltaic setup that powers the office cabin.

**LOCATION:**

CESC staff will inform you of the location for this activity.

**EQUIPMENT AVAILABLE:**

Small sundial, white board and marker  
Compass  
4 prisms and 1 dark container for refraction  
Crayons  
White and black cans  
4 thermometers  
Radiometer  
Funnels with mylar (mock solar ovens)  
Solar oven (on request)  
A working solar energy operation (the office cabin runs on solar energy)



**EQUIPMENT BROUGHT FROM SCHOOL:**

Cookie dough to cook in solar oven (optional)  
Copies of the color spectrum (last page of this lesson) for students to color  
Envelope to take papers back to school

**ASSIGNMENT FOR GROUP LEADERS A FEW WEEKS PRIOR TO TRIP:**

The leader reads all the material about the lesson. The leader may wish to do additional research about solar energy.

**DIRECTIONS FOR GROUP LEADERS ON TRIP DAY:**

The kit containing the equipment listed above will be given to the leader by a Cooper staff member. The staff member will provide hints on using the center. If time allows, look over the materials in the kit.

## **THE LESSON:**

Note: Questions to pose to the group are printed in italics.

Background information for the leader is contained in a box.

Demonstration activities follow each box.

There may not be time for all of the activities listed below. Choose those you feel are most valuable for your group.

### **1. Introduction**

Explain to the students that they are going to learn about the sun...its make up and how we can use the energy it constantly produces.

*What is the sun made of? How does it give us heat and light?*

The sun is not a burning ball. It is a star composed of ultra high-temperature degenerate gases, mainly hydrogen and helium. Its mass is 99 % of the solar system. The sun's energy comes from thermonuclear reactions which convert hydrogen to helium. The surface temperature of the sun is 6000 degrees C.

### **2. The "movement" of the sun across the sky.**

*Does the sun really move across the sky?*

As the earth rotates on its axis, the sun appears to move across the sky from east to west. Because the earth is tilted on its axis the sun appears higher in the sky in the summer months when the sun is more directly overhead the northern half of the earth, and it appears lower in the sky during the winter months when our half of the earth is tilted away from the sun.

*How can we track the sun's movement across the sky?*

A sundial shows the movement of the sun by casting a shadow. When we mark the changes in the shadow we can see not only the rate of movement but the changes in the length of the shadow at different times of the year.

### **Demonstration:**

Equipment needed for demonstration:

- small sundial to show the movement of the sun's shadow
- white board and marking pen

Set the sundial on the white board. Use the compass to indicate north.

Each hour, mark the position of the shadow and the time.

### **3. The sun's light**

*If the sun's light appears white, why do we see colors?*

The sun's light is made up of different wave lengths. What appears to be white light is separated into its main colors by a prism. Each color of light is traveling as a wave, each with a different wavelength...only 10-thousandths of a millimeter different. When passing through a glass prism, the movement of the waves is hindered. They travel more slowly in glass than in air. Therefore, each color is bent or refracted. The color with the longest wavelength (red) is bent the least. The color with the shortest wavelength (violet) is bent most. This is because violet light waves travel more slowly through glass than red light waves. The more slowly the colored wave travels through the prism, the more it is bent (refracted).

Raindrops act as prisms. The inside of each raindrop acts like a mirror, reflecting sunlight back into your eyes. Different colors of light are refracted differently as they pass through the water of the raindrop, depending on the angle of the back surface of the raindrop.

Held in the sunlight, the prism will project a spectrum on a wall. The greater the distance from the prism to the reflecting surface, the larger the spectrum; moving the prism closer to the reflecting surface makes the spectrum smaller, but more intense.

The angle the spectrum is beamed from the prism is determined by the sun's position in the sky. The best time to see how far the spectrum can go is when the sun is at a 30 degree angle. At that angle the spectrum is transmitted horizontally from the prism and can be projected the greatest distance.

### **Demonstration:**

Equipment needed for demonstration:

- prisms
- black box with white projection backing or white board

Hand out the prisms to the students. Experimenting with the angle of the sun on the prism, students will quickly learn how to project the rainbow of refracted colors onto a light background. The white at the back of the black box will best show the colors.

*What colors do you see?*

red - orange - yellow - green - blue - indigo - violet

*Are the colors always in the same order? Is this the same as a rainbow?*

Yes, the colors are always in the same order because they are arranged according to the wavelength or angle they are bent as the light passes through the prism...whether it is glass or a raindrop.

Using the Spectrum diagram and crayons, each student may color in one of the Spectrum papers to illustrate the order and colors of sunlight.

### **4. Color affects the absorption of light energy.**

*How does color affect solar energy?*

White, which contains all colors of the spectrum, will reflect light energy and therefore will be cooler.

Black, which has no color, absorbs the light energy and will become warmer.

### **Demonstration:**

Equipment needed for demonstration:

- white and black painted cans
- 2 thermometers

Set both cans in the sun and ask two students to slip a thermometer in each can. Ask the group to guess what will happen. The thermometer in the white can should read a few degrees cooler than the thermometer in the black can.

After a few minutes ask other students to remove the thermometers and read the temperatures.

*What makes the vanes spin in a radiometer?*

The vanes (or wings) in the **radiometer** are colored dark on one side and white on the other side. When the light strikes the wings, heat is transferred to each wing, but not to the same extent. The light colored side reflects the rays. The dark side absorbs the rays.

When the freely moving particles of air inside the radiometer sphere strike the light reflective vanes, they take on very little energy and do not bounce off very fast. When the atoms strike the dark vanes, they take on a great deal of energy and "kick" away at a very fast speed.

The result is, the vane spins as the air particles continue to bounce off, and thereby push, the dark-sided vane. The stronger the light, the more energy there is available to heat up the dark wing, causing the air particles to bounce off of it at a faster and faster rate.

### **Demonstration:**

Equipment needed for demonstration:

- radiometer

Observe spinning vanes as the radiometer is placed in sun, partial shade, and shade.

**Caution:** Only the adult leader should handle this equipment. It is fragile.

## **5. Using the sun as another source of energy**

*What sources of energy do we use to light our lights, and power our machines?*

Wood, coal, oil, gas, water, wind, sun

*Which of these is not renewable (we can't make more)?*

Coal, oil, and gas are non-renewable. When these are used, no more will be produced.

*Which take a long time to be renewed?*

Wood, because trees must grow from seeds.

*Which energy sources are always available?*

Wind and sun energy are almost always available, but we must build equipment or machinery in order to harness the energy.

*The sun's energy hits the earth constantly. How can we put this source of energy to practical use?*

### **Mini-solar ovens:**

One simple way we can all use solar energy is by using solar ovens.

#### **Demonstration:**

Equipment needed for demonstration:

- mini-solar ovens made from funnels with mylar inserts
- thermometers

Aim the funnel towards the sun and insert the thermometer into the spout so the tip is at the base of the funnel. Students can read the temperatures on the thermometer dials. They may experiment with cones of different sizes, and different directions from the sun.

After a few minutes of experimentation, ask the group to share their findings.

### **Solar powered fan:**

#### **THIS DEMONSTRATION WILL BE DONE AT THE SOLAR TOUR AT THE OFFICE**

A more sophisticated piece of solar energy equipment is a solar collector, made of solar cells, which powers a small fan.

#### **Demonstration:**

Equipment needed for demonstration:

- solar powered fan

When the photovoltaic cell is aimed towards the sun, the fan spins. When a shadow (use your hand) falls on the cell, the fan stops. Remember this as we look at the solar installation at the office. How can we use solar energy at night or on a cloudy day? The answer is BATTERIES.

#### **HOW A SOLAR CELL WORKS:**

Solar cells generate electricity directly from sunlight. The basic solar cell consists of two layers of semiconductor materials (also used in computer chips and electronic circuitry). At the junction between the two layers in a cell a voltage is set up by excess negatively charged electrons from one layer fusing into the other electron-deficient material. When sunlight strikes the cell, electrons are knocked loose from atoms and are swept by the voltage onto an electrical contact. The "holes" left behind are positively charged and are swept onto the opposing contact. When a wire joins the two contacts, an electrical current is created.

Most solar cells are made of crystalline silicon that is made with impurities (boron, phosphorus), which create the different semiconductor layers. Many other materials are also used in cells. Cell designs also differ.

Some are thin films, which are low in efficiency, but cheap. Thin-film cells convert 5 - 15% of sunlight to energy. Thicker cells achieve up to 30%. Cells can also be stacked to capture more of the solar spectrum. The efficiency of solar cells will probably never be higher than 40% because some light is always lost through reflection, insufficient energy, and resistance and imperfections in the cell materials

## **6. A look at a real solar energy system**

### **Solar Hot Water Heater:**

On the roof of the kitchen cabin is a 40 gallon water tank. What color is the tank? (black)  
If there is time, go into the kitchen and test the temperature of the water coming from the hot water faucet. BE CAREFULL, IT'S HOT!

### **Photovoltaic System:**

The office cabin at Cooper ESC is solar powered. A photovoltaic system powers all electrical appliances: lights, evaporative cooler, computer, copy machine, etc. A Cooper staff member will be on hand to show the photovoltaic system to each group.

Upon completion of each session, collect all materials and place in the kit box.

### **CLEANUP:**

Upon completion of all sessions, collect all materials, arrange them in the kit box, and return the box to the table in Biznaga cabin.

# COOPER ENVIRONMENTAL SCIENCE CAMPUS TUCSON UNIFIED SCHOOL DISTRICT

## SOLAR ELECTRIC (PHOTOVOLTAIC) SYSTEM

The Cooper ESC office building was converted to photovoltaic power in April, 1995. Sunlight now provides power for the lights, electrical outlets, and an evaporative cooler. This demonstration facility will be used to educate TUSD students, teachers, and the community in the use of solar energy.

There was no cost to TUSD for the installation. The system, including materials and labor would have cost about \$9000 for the original installation, but Tucson Electric Power and the Arizona Department of Commerce Energy Office provided financial support. PhotoComm, Inc., and Roher Construction Co provided materials. Instructors and participants of the Solar Energy International workshop did training and installation. Each year additions are made to the system with the goal being to take Cooper ESC "off the grid" in the near future.

Four parts make up the system. **Solar cells** provide energy from sunlight and **batteries** store the energy made. A **controller** protects the batteries from overcharging or "running down" completely. The **inverter** changes the type of power coming from the solar array and batteries into the type of power we normally use for our lights and appliances.

### SOLAR CELLS

**Solar cells** produce the electricity in a photovoltaic system. When sunlight falls on a solar cell, a small electric current flows. To produce a larger electrical current, a number of solar cells are wired together on a **solar panel**. The panel also protects the solar cells and holds them in place. Experience with solar panels has shown them to be extremely reliable.

Solar panels are wired together to make a **solar array**. Panels are connected in different ways to provide the desired amount of electricity. This solar array has six 85 watt, 12 volt panels connected together in a "series-parallel" configuration. Two 12 volt panels are wired in *series* which doubles the voltage to 24 volts. Three of these 24 volt series pairs are connected in *parallel* which triples the amount of current available from a single panel. The mounting system faces the array toward the sun to collect as much energy as possible during the day. this system can produce 510 watts in full sunlight. In winter the array is tilted at a greater angle to take advantage of the rays of the sun when it is lower in the sky.

### BATTERIES

To have electricity when the sun is not shining, there must be a way to store the extra power produced while sunlight is available. This is what the **batteries** do. Electricity from the solar array is stored in the batteries and is drawn from them when needed. Battery life

depends on the number of times they are discharged and the amount of the discharge. The eight 6 volt batteries are also connected in series-parallel to provide 24 volts to match the rest of the system.

## **CONTROLLER**

The **controller** maximizes the battery life by preventing the batteries from overcharging and from becoming totally depleted. When the battery reaches a certain voltage, the controller disconnects the array from the batteries to prevent further charging and then reconnects them when voltage drops again. If the battery voltage drops too low, the controller disconnects the batteries from the lights and appliances.

## **INVERTER**

The **inverter** changes the direct current (DC) power of the solar array or batteries into alternating current (AC) power, which is the power typically used in our homes and offices. Without an inverter, special lights and appliances which use DC power would be necessary.

## **COOLING AND HEATING**

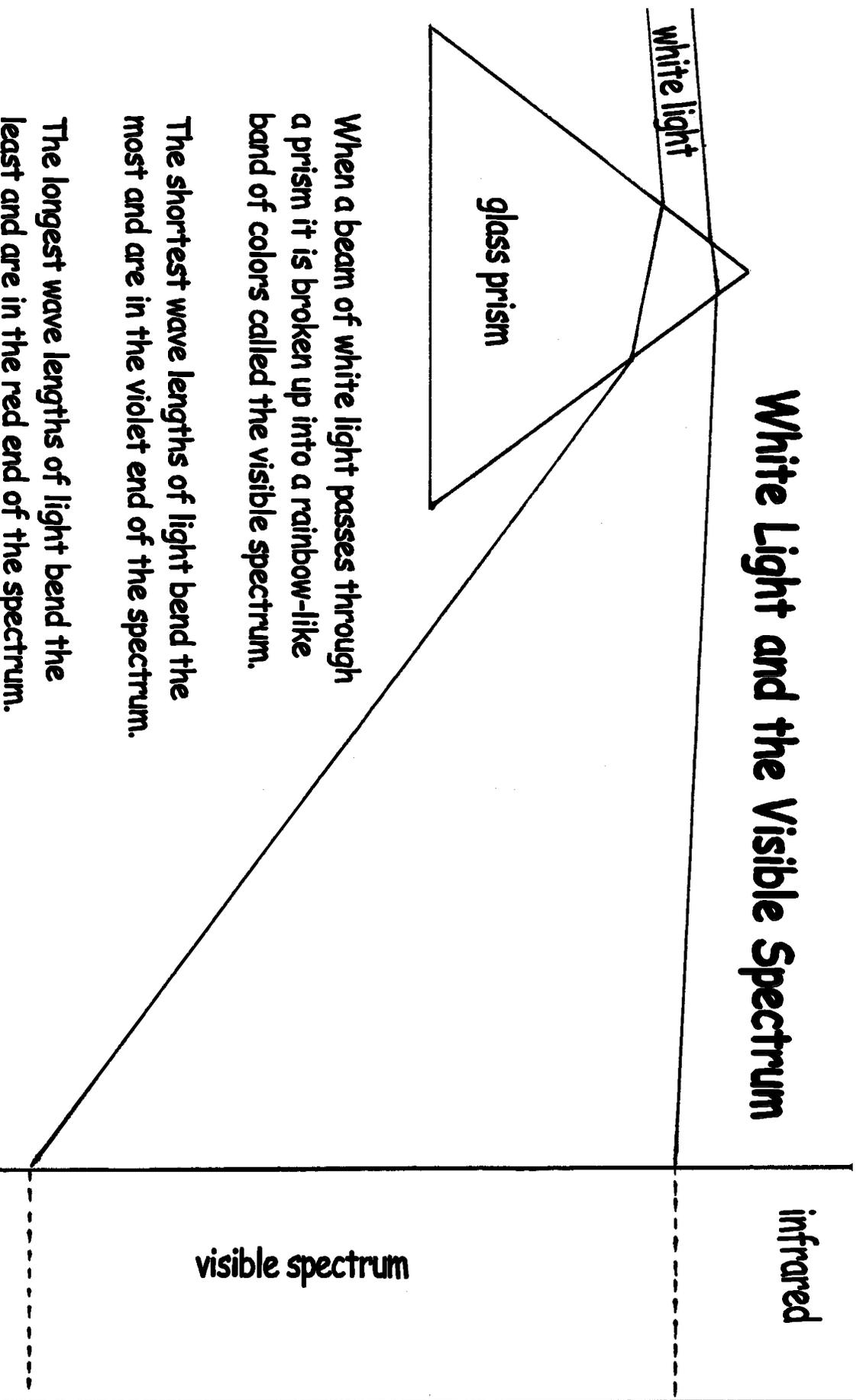
The evaporative cooler, which uses only 50 watts is not connected to the inverter. Its motor uses DC power and is connected directly to direct current.

## **SELLING EXCESS ENERGY**

The system is metered and linked to the Tucson Electric Power Company grid. That means we are able to "bank" excess power with TEP. The excess power is sold back to TEP.

*Cooper ESC received the Metropolitan Energy Commission's "Energy Education Award" in May 1997 in recognition of the photovoltaic and other energy saving installations and incorporating these into educational activities for student activity centers and teacher training workshops.*

# White Light and the Visible Spectrum



When a beam of white light passes through a prism it is broken up into a rainbow-like band of colors called the visible spectrum.

The shortest wave lengths of light bend the most and are in the violet end of the spectrum.

The longest wave lengths of light bend the least and are in the red end of the spectrum.

All the other colors lie in between and blend into one another.

All the colors in the spectrum mix together to form white light.