Solar Energy

Examining How Angle and Temperature Affect Solar Panels

Description

This activity transitions students into thinking about solutions to the problem created by the phenomenon under investigation in this module. Students play the role of solar engineers as they test two factors that can affect solar panel efficiency: air temperature and angle of sunlight.

Problem

Due to human production and use of energy, Earth's climate is changing, creating social, economic, and environmental problems.

Design Challenge

Create an informational flier about the causes and effects of climate change which proposes solar energy as a solution to that problem.

Grade Level

5 – 8

Objectives

Students will:

- Investigate effects of angle and temperature on solar panel efficiency
- Understand the basics of solar electricity and recognize it as an alternative to fossil fuels

Time

1 Hour

Materials

- *Solar Energy* handout [1 per student]
- PowerPoint presentation
- Computer and projector*
- Station task cards [3 per station, 6 total]
- Angle and output station [materials for 3 stations]
    - Multimeter with cables [3]
    - Solar panel with leads [3]
    - Flashlight with Velcro [3]
    - Clear ruler with Velcro on top and bottom [3]
    - Protractor with Velcro [3]
- Temperature and output station [materials for 3 stations]
    - Multimeter with cables [3]
    - Solar panel with leads [3]
    - Flashlight [3]
    - 8 in. pie pans [2 stacked per station, 6 total]
    - Digital thermometer [3]
    - Clear plastic container with hole on top for leads and thermometer [3]
    - Bath towels [3]
    - 200 g weights [3]
    - Stopwatches [3]
    - Beakers [3]
    - Approximately 2 L of water warmed up to 55°C (approximately 130°F)*
- An assortment of drawing materials,* such as: paper, markers, and/or crayons.

* Not included in kit

Developed by the Asombro Institute for Science Education (www.asombro.org)

The previous four activities allowed students to make sense of the phenomenon of human behavior changing Earth's atmosphere and affecting the climate. As a result of these activities, students should recognize the role of energy production and consumption in global climate change. This activity introduces students to the problem created by the phenomenon above: Due to human production and use of energy, Earth's climate is changing, creating social, economic, and environmental problems. The remainder of NM Climate Champions focuses on solutions to this problem. This activity suggests solar energy as an alternative to fossil fuels that can increase the sustainability of energy production and decrease greenhouse gas emissions.

In New Mexico, solar energy is a growing industry. With an average of more than 275 days of sunshine a year, solar energy has become one of the most feasible options for alternative energy in our state. When photons (tiny particles of light) hit a solar panel, they dislodge electrons that then migrate to the surface of the solar panel. As these free, negatively charged electrons surface, an imbalance is created with the bottom of the panel, which is positively charged. This imbalance creates voltage potential. When a load is attached, these dislodged electrons flow through the circuit and power the load.

The efficiency of this process and the efficiency of the solar panel both depend on environmental factors. The angle at which the sunlight hits the solar panel and the air temperature surrounding the solar panel are two factors that affect voltage. Depending on the angle, more or fewer photons hit a solar panel. The number of photons that are exciting electrons within the solar panel is directly related to the amount of electricity it can produce. At illumination angles closer to 90°, more photons directly hit the solar panel. As the illumination angle moves away from 90°, the light becomes more spread out, and fewer photons directly hit the solar panel.

Additionally, temperature affects solar panel efficiency. As temperature increases, the electrons in the solar panel have more thermal energy. With more thermal energy in the electrons, there is less imbalance in the solar panel when the electrons are knocked loose. Less imbalance means less electricity produced.

The growth of the solar industry in New Mexico means that potential jobs in solar are becoming available. In this activity, students will take on the role of a solar engineer as they investigate these two factors that affect solar energy. After collecting data on solar panel efficiency related to angle and temperature, students will design an informational flier that synthesizes their knowledge of how these factors influence solar efficiency with global climate change and energy production.

Tips for Entire Class Participation

- There are supplies to set up three identical stations for both station activities (six stations total). Divide students into six groups when it is time to rotate through the stations. Larger groups work best, so a small class may need fewer sets of each station.
- When possible, we recommend setting up stations on tables where students can stand all around the set-up rather than on a table or lab bench against the wall. This allows more students to have a good view and easy access to the station.
- Students will need to work together to collect data at each station accurately.
    - At the angle and output station, students can each take a turn holding the flashlight to collect a data point. One person can be the multimeter reader, while another records the data on the handout.
    - At the temperature and output station, students can take specific roles.
        - One student can watch the stopwatch and call out every 30 seconds.
        - One student can read the thermometer.
        - One student can read the multimeter.

Preparation

1. Plan to divide students into six groups for the activity stations.
2. Heat approximately two liters of water to 50°C (approx. 120°F).
3. Set up three angle and output stations:
    a. Plug the cables into the multimeter (students will attach solar panel leads to the multimeter). Attach the red cable into the center plug (labeled VΩmA) and the black cable into the plug on the right (labeled COM).
    a. Remove the solar panel with leads from the envelope and place it near the multimeter.
    b. Place flashlight, clear plastic ruler, and protractor near the solar panel and multimeter.
    c. Set out station task card.
4. Set up three temperature and output stations (see photos on the task card):
    a. Spread out a towel at each station. Do all of the following on top of the towel.
    b. Plug the cables into the multimeter (students will attach solar panel leads to the multimeter). Attach the red cable into the center plug (labeled VΩmA) and the black cable into the plug on the right (labeled COM).
    c. Remove the solar panel with leads from the envelope and place the solar panel in the clear plastic container. Run the solar panel leads through the hole in the top of the container from the inside out.
    d. Place the weight in the bottom of the container and snap the lid closed.
    e. Place two stacked pie pans, a digital thermometer (sheath removed), a stopwatch, flashlight, and beaker on the towel at the station.
    f. Have the warm water accessible to students at these stations.
    g. Set out station task card.
5. Draw the Angle and Output: Whole Class and Temperature and Output: Whole Class data tables (page 2 of the handout) on the board.
6. Set up computer, projector, and PowerPoint.

Teaching Guide

Introduction: Identifying the Need for Solar (~10 minutes)

1. Slide 2: Review the four previous lessons and how they point to a need for renewable forms of energy that emit fewer greenhouse gases to the atmosphere. Remind students how these four lessons guided them to make sense of the phenomenon: Human behavior is changing Earth's atmosphere and affecting the climate.
    a. *Insulating You, Insulating Earth*: We learned about the change occurring in our atmosphere (increased greenhouse gases) causing global temperatures to increase and the global climate to change.
    b. *Energy Audit*: We identified the human behavior changing the composition of the Earth's atmosphere: energy production and use. We measured how much energy household appliances use and calculated how many kilograms of CO_2 we individually emit to the atmosphere through personal use of these appliances.
    c. *Energy Resources and* Use: We identified large-scale patterns in energy consumption in different countries as we modeled the difference between renewable and non-renewable energy. We determined that switching to renewable energy sources increases resource sustainability and emits fewer greenhouse gases to the atmosphere.
    d. *Energy Data* Jam: We looked at energy in New Mexico, where it comes from, and how it is used. We saw that in New Mexico, we rely heavily on non-renewable resources rather than renewable resources.
2. Slide 3: This human behavior is creating a problem: climate change. Due to human production and use of energy, Earth's climate is changing, creating social, economic, and environmental problems. The rest of NM Climate Champions focuses on possible solutions to this problem. This activity looks at one proposed solution to the energy and climate crisis, solar energy. Through this

activity, students learn more about solar engineering and how solar panels function. At the end, students will synthesize their knowledge in a solar energy informational flier.

3. Slide 4: Give an overview of the job of a solar engineer.
    a. Explain that students are playing the role of a solar engineer throughout today's lesson.
    b. A solar engineer plans, designs, and implements solar energy projects. They may manage anything from large-scale municipal projects to home rooftop installations.
    c. Solar engineering is one of many career options related to renewable energy sources.
    d. New Mexico hires an increasing number of solar engineers annually.
    e. Qualifications to be a solar engineer include:
        i. Bachelor's degree in mechanical or electrical engineering
        ii. Professional license
    f. Part of a solar engineer's job is to report on the efficiency of the solar panels that they are installing. To do this, solar engineers must conduct tests to determine the conditions under which solar panels produce the most electricity.
    g. This is what you will be doing today, conducting tests to determine when solar panels produce the most electricity.
    h. Before we do that, we must review how a solar panel works to create usable electricity.
4. Slide 5: Give a brief overview of how solar panels work.
    a. Sunlight is made up of photons, tiny particles of solar energy.
    b. Solar panels are comprised of photovoltaic cells, materials that have been designed specifically to convert sunlight into electricity.
    c. When enough sunlight is absorbed in the photovoltaic cell, electrons in the cell are dislodged by the photons.
    d. When the electrons are dislodged and leave their position, a hole is formed in that place.
    e. Due to special materials used in the solar panels, these freed electrons migrate towards the surface of the photovoltaic cell.
    f. When many freed electrons, each carrying a negative charge, migrate towards the front surface of the cell, an imbalance is created with the positively charged back surface. This imbalance creates a voltage potential (which doesn't mean that solar panels store the energy) like the negative and positive terminals of a battery.
    g. Electrical conductors are placed in the panel to absorb the electrons. When these conductors are placed in an electrical circuit, the electrons can flow through the circuit, powering an external load.
    h. Explain that students will determine how the angle of sunlight hitting the solar panel and how the air temperature surrounding the panel affect the voltage produced by the solar panel.

Activity Stations (~ 30 minutes)

1. Slide 6: Give an introduction to the angle and output station.
    a. Students will have 12 minutes at each station to complete the procedures on the task card.
    b. This station asks the question: What is the best angle for solar panel output?
    c. Be sure that you move through the procedures exactly as the task card states.
    d. Here are the instructions from the task card:

Station: Angle and Output

1. Turn to page 1 on your handout.
2. Connect the positive (red) and negative (black) wire leads from the solar panel to the red and black multimeter cables. Be sure that red is attached to red and black is attached to black.
3. Turn the multimeter knob to the left to select voltage range 20 V.
4. Attach the flashlight to the ruler using the Velcro. The flashlight should shine towards the center of the ruler.
5. Turn on your flashlight.
6. Place the protractor at the base of the solar panel, with the wires coming out of the top of the solar panel (see image). The Velcro on the protractor should be facing away from the solar panel.
7. Attach the ruler and flashlight to the protractor with the Velcro so you can read 90° on the protractor through the ruler. At this angle, the flashlight will illuminate the solar panel.
8. Record the voltage to the nearest 0.01V in *Angle and Output Data* for 90°.
9. Detach the ruler and pivot it to the left until you read 60° through the center of the ruler. Attach the small piece of Velcro on the ruler to the small piece of Velcro on the protractor. Keep the ruler and protractor flat against the table surface.
10. Be sure the flashlight illuminates the solar panel. Record the voltage for 60°.
11. Repeat steps 9 and 10 for 40° and 20°.
12. Turn off flashlight and multimeter, disconnect wire leads, and detach Velcro.
13. Graph your data on *Graph: Angle and Output*. Note: you will plot your data points from right to left.
14. Answer question 1 on the bottom of page 1.

2. Slide 7: Give an introduction to the temperature and output station.
    a. At this station, students will answer the question: What is the optimal temperature for solar panel output?
    b. Remind students once again to follow the procedures exactly as the task card states.
    c. Safety note: Practice caution when working with water. Follow directions carefully. Do not let wires come into contact with the water.
    d. Here are the instructions from the task card:

Station: Temperature and Output

1. Turn to page 2 on your handout.
2. Connect the positive (red) and negative (black) wire leads from the solar panel to the red and black multimeter cables. Be sure that red is attached to red and black is attached to black.
3. Turn the multimeter knob to the left to select voltage range 20 V.
4. Place the flashlight on top of the container with the solar panel (see image).
5. Insert the thermometer in the hole on top of the container. Turn on the thermometer and be sure it is reading in °C.
6. Turn on the flashlight. The flashlight should be illuminating some parts of the solar panel.
7. Record the temperature and voltage in *Temperature and Output Data* in the *"Room Temperature"* row.
8. Use the beaker to measure 300 mL of warm water and pour it into the pie pan that is sitting on the towel.
9. Carefully, place the container and solar panel with the flashlight into the pie pan, being sure that the wires do not go near the water.
10. Place the flashlight back on top of the container over the solar panel.
11. Using the stopwatch, record the temperature and voltage every 30 seconds for 4 minutes.
12. After 4 minutes, turn off thermometer, flashlight, and multimeter. Remove clear container from water and set on towel. Disconnect wire leads from multimeter and pour out water from pie pan. Remove thermometer from container. Open the lid of the container to air out for next group.

3. Slide 8: Have this slide up while students are completing the station activities.
4. Slide 9: Once students have completed both activity stations, have them share their group data with the whole class. As students share their data and you write them on the board, students should fill out their whole class data tables on their handout.
    a. For the angle and output whole class data, have each student group share the angle that produced the most voltage (20°, 40°, 60°, or 90°).
5. Slide 10: Have students share their groups' temperature and output data.
    a. Begin by having each group identify the value they are going to share.
    b. Have each group find the highest voltage they recorded during their temperature and output trial. Have students circle and write a "Max" next to the temperature associated with that voltage; this is their **temperature at maximum voltage.**
    c. Next, have each group find the lowest voltage they recorded during their trial. Have students circle and write a "Min" next to the temperature associated with that voltage; this is their **temperature at minimum voltage**.
    d. Students will share their "Max" temperature value in the first column and their "Min" temperature value in the second column.

Results and Conclusions (~20 minutes)

1. Slide 11: Design Challenge: create an informational flier about the causes and effects of climate change that proposes solar energy as a solution. Students can write this in the form of a promotional flier for solar energy written by a solar engineer. The flier should synthesize across the activities presented in the energy module and contain information about 1) the cause of climate change, 2) the effect of climate change, 3) how solar energy can mitigate climate change, and 4) an argument for when solar energy is most efficient in New Mexico (using data from the investigations above).
    a. Provide students with blank paper and drawing materials to create their informational fliers. Students could also design these electronically if technology is available.
    b. It may be helpful to walk through the storyline of the energy module with students (Slide 2) before making their fliers as a reminder of the phenomenon investigated and the problem that resulted.
    c. You may have students display or share their fliers with the class, school, and/or community.

Extensions

1. Run an additional trial of the temperature and output experiment with ice water rather than warm water to determine the effects of colder temperatures on solar panel output. Students can predict how the voltage will respond with cooler temperatures, or specifically, a temperature they think will produce the highest voltage.
2. Have students test angles that were not included in their task card for the angle and output experiment.

This lesson has been adapted for New Mexico Climate Champions from "Solar Cell Misconceptions" by Carolina. <http://www.carolina.com/teacher-resources/Interactive/solar-cell-misconceptions/tr29719.tr>