Solar Powered System

Student Objectives
The student:
- can explain that light energy from the Sun can be turned into electricity with a photovoltaic (solar) cell
- can list variables such as clouds, shading and direction of panel tilt, that can affect the amount of power that the photovoltaic cell produces
- can list the factors that can increase the amperage output of a photovoltaic system including cell area, collection devices and intensifying devices..

Key Words:
load
orientation
photovoltaic (PV)
system

Time:
1 class period

Materials (per group):
- small photovoltaic cell with wires and alligator clips
- motor
- propeller
- milliamp meter
- Science Journal

Items for solar store:
- additional small and medium sized (2V) pv cells, including if possible small cells rated > 400 mA
- 3V photovoltaic panel (Junior Solar Sprint size)
- acrylic mirrors and/or reflective foil
- colored paddles/film or filters
- magnifying glasses
- wires with alligator clips
- any other available light related lab equipment (i.e. prisms, fresnel lens, convex & concave lenses, etc)
- price labels for store items
- play money ($5, $10, and $20s)

Background Information

Photovoltaic refers to the process of turning the energy of the Sun directly into electrical current through the use of photovoltaic cells. These cells (commonly called solar cells) are manufactured in several different ways, however the most common method uses silicon that undergoes a chemical process to add electrons and increase its instability. The silicon mixture is allowed to form crystals from which the photovoltaic cells are made. Electricity is produced when a photon of light energy strikes the solar cell, exciting the electrons. This action causes the electrons to "flow", starting an electric current. The conversion of sunlight to electricity happens silently and instantly with no moving parts to wear out, no emissions and without a depletion of resources.

Photovoltaic technology is relatively new; as a viable energy source, it is a little over 60 years old. However, it has great potential for the future. As a source of energy, sunlight is free, its supplies are unlimited and it is available in the majority of areas of the world. However, at this time the relatively high cost of photovoltaic cells and systems is limiting its use. This is expected to change as our supplies of fossil fuels diminish, new methods of producing photovoltaic cells are discovered, and the increase in demand for the technology brings the price down.

Procedure (prior to class)

The "solar store" can be set up ahead of time in a few plastic bins or a shallow cardboard box. This makes it easy to carry outside and quickly get started. Your store should have items ranging from $5 pieces of aluminum foil, or mirrors, to additional small panels ($10.). It is also fun if you can have something like a large fresnel lens, that is priced higher than what they think they can afford ($50 or $60). At the start of the challenge, the teams will already have a panel that is worth something (usually $10), that they can also cash in at the store. The challenge should be tough for them to attain with their $20 but not impossible.

Some possible store items and prices:

Mirrors, pieces of aluminum foil	$5.
Pairs of wires with alligator clips	$5.
Magnifying glass* and other lenses	$5.
Color filters*	$5.
Hand warmers*	$5.
Black construction paper*	$5.
Small PV cells	$10.
Medium sized PV cells	$20.
3V PV panels (Junior Solar Sprint size)	$30.
Fresnel lens	$50.

* these are "confounding" items–they don't increase the output of the photovoltaics, and can actually decrease the output

Procedure (during class)

Note: It is best to do this activity on a clear, sunny day, or when the intensity of the sunlight will give a reading of at least 150 mA on the small panel they begin with. However, if this is not possible, you can adjust the activity to require less sunlight by giving them a larger panel, an extra panel, or extra money at the beginning of the store activity.

1. Show the video, *Solar 101*, produced by the Department of Energy (link to the video is in the Internet Sites section).
2. After the video have the students tell you what they now know about the production of photovoltaic cells and how they work (help them "remember" as necessary).
3. Divide the class into lab groups. Give each group a photovoltaic cell, motor, and propeller.
4. Take the students to a sunny area. Tell them that they are to get their motor to spin.
5. As the students investigate their "solar powered systems", ask questions to guide their investigation. Suggested questions are:
    - What happens when the panel is turned over away from the light?
    - What happens when part of the panel is shaded with your hand? How much of the panel can you shade before the motor stops?
    - Observe the rotation of the propeller blades, which way are they turning? What happens when the wires are attached the opposite way--red to black? *(The flow of electricity is reversed, so the motor reverses direction.)*
    - Does the angle of the cell in relation to the Sun make a difference in how fast the propeller turns?
    - What happens when the two alligator clips touch*? (The motor stops because the electrons circle through the shortest way–through the wires and clips instead of the motor)*
6. Give the groups each a milliamp meter and have them replace the motor with the milliamp meter. Have the students see how much amperage (electric current) their cell is producing.
7. Read the following challenge to the students:

Power Up and $ave

"You are all members of a small community in Florida named Sun Town. Sun Town has one movie theater that serves the entire population. The movie theater has huge electric bills especially in the summer when people like to escape from the heat. Unfortunately, the movie theater may have to close if they can't find a solution to their high electricity bill.

You have been grouped into teams based on the neighborhoods in Sun Town. Each neighborhood (team) has been asked to come up with ideas on how to power the movie theater using solar energy. Each of the neighborhood teams will be given $20 to use towards testing and implementing their plan of action. The goal is to create 500 milliamps of sustained reliable renewable power. By producing 500 milliamps you have successfully powered the movie theater. Because you are responsible citizens, you are trying to spend the least amount of the $20 as possible, while accomplishing the goal of 500 sustained milliamps. There are no rules except, no cheating or stealing.

A store has been set up with additional materials that you can use to help you put together your system. Additionally, any item can be returned or exchanged, so you can continue to try out different combinations to find the best *solution. Remember, you want to have as much money left over as possible while still getting your milliamp meter to read 500 mA."*

8. Turn the groups loose and help with the store as necessary. *(Don't tell them, but since there is only one movie theater that they are all trying to power, the most effective way to power it and have the most money left over would be for all the teams to pool their money and use it for the least expensive solution they can find.)*
   Some possible ways groups could reach 500 mA (depending on the sun/weather conditions of course):
   - 3 or 4 of the panels with alligator clips wired in parallel *(all red leads together on one prong of the milliamp meter, and all black leads together on the other prong)*
   - one of the panels with alligator clips and 3 mirrors
   - one large 3V panel *(but they will have no money left over!)*
   - medium-sized (2V) panel with one mirror
   - one of the panels with alligator clips and a fresnel lens *(too much money spent!)*
   - one panel rated > 400 mA *(this PV panel is wired differently to maximize amperage)*

   Note; The "best" solution for one movie theater would be to pool their money and buy the least expensive system. If you are using a high amperage (> 400 mA) panel priced at $10., this would be their best choice, as it will reach 500 mA on a clear, sunny, Florida day.
9. Give the students ample time to try different solutions. When a group uses the 3V panel and declares themselves the winner, tell them "they can do better" (have more money left over). Additionally, if you see groups trying out several new items (variables) at the same time, you may want to remind them "to think like a scientist". After a few minutes, you may want to remind them that there is only one movie theater. *(However, they may still not catch on. Don't tell them!)*
10. After returning to the classroom, ask the groups to tell you the different ways they were able to attain 500 mA, and how much money they had left over.
11. If the students did not think to team up, ask them what would have happened if they would have all worked together to solve the problem of their shared movie theater. (This is a great time to discuss how our future energy problems will require cooperation between groups!)
12. Discuss variables that will affect the output of a photovoltaic cell such as:
    - time of day
    - weather conditions
    - time of year
    - location (latitude) on earth
13. Questions for further discussion:
    - How could you use a solar powered system for a flashlight which you want to use at night when the Sun isn't shining?
      Hint: You need a device to store the electricity. *(A battery)*
    - What could we do to produce more electricity on a cloudy day? *(Use more cells in the system)*
14. Have students complete the Student Journal.

Key Words & Definitions

- **load** – a device to which power is delivered, such as a motor, a light, or a household appliance
- **orientation** – set in a definite position with reference to the points of the compass
- **photovoltaic** (PV) – the effect of producing electric current using light
  "photo": light
  "voltaic": relating to electricity (volt)
- **system** – a group or combination of things or parts forming a compex or unified whole

Related Research

1. How are photovoltaics used in the space program? In telecommunications? Use the internet to collect data and pictures of these applications. Are the photovoltaic cells different or the same as those used in terrestrial applications?
2. How are photovoltaic cells made? Research the difference between single crystal, poly crystal and thin film cells. Which is the cheapest to produce? Which has the highest efficiency?

Related Reading

- ***Electrical Wizard: How Nikola Tesla Lit Up the World*** by Elizabeth Rusch (Candlewick Biographies, 2015)
  This is a lively introduction to the life of an important figure in technology, someone whose ideas are still at the center of today's world. An engaging book that will encourage both budding scientists and anyone intrigued by the creative process.
- ***Harnessing Power From the Sun*** by Niki Walker (Crabtree Publications, 2007)
  This book explains why solar power is becoming a very real replacement for our current energy sources. Detailed images feature different types of solar collectors, solar thermal to electricity plants, and solar cells.
- ***Real-World STEM: Develop Economical Solar Power*** by Stuart Kallen (Referencepoint Pr Inc, 2017)
  Examines the need to harness efficient and affordable solar power, covering its history, current status, challenges, and the innovative ways scientists are working to bring solar energy to people around the world.
- ***Solar Energy Projects for the Evil Genius*** by Gavin Harper (McGraw-Hill, 2007)
  This book includes more than 50 solar energy projects with plans, diagrams and schematics.

Internet Sites

http://www.eia.gov/kids/energy.cfm?page=solar_home-basics

Department of Energy, Energy Kids photovoltaics page.

http://energy.gov/eere/energybasics/articles/photovoltaic-technology-basics

Department of Energy page explains how photovoltaics work and includes a brief animation.

https://www.youtube.com/watch?v=NDZzAIcCQLQ

Energy 101: Solar Power, an animated video that discusses, photosynthesis, photovoltaics and solar thermal technology.

https://www.fsec.ucf.edu/go/solar_basics/

Florida Solar Energy Center's photovoltaic fundamentals page explains the basics of photovoltaic cells including their manufacture, the components of systems, as well as the pros and cons of photovoltaic power. This site is suitable for teachers, mentors and advanced students.

http://www.solarpowersimulator.com/

Solar Power simulator lets you control the input (amount of sunlight) and load (appliances) and see how much electricity is being generated, how much is being sent to the batteries, and how much electricity is going out to the loads.

https://www.bbc.co.uk/programmes/p00kjq6d

Shock and Awe: The Story of Electricity, BBC miniseries on electricity, includes three episodes: *Spark*, the history of our understanding of electricity and the harnessing of its power; *The Age of Invention*, the link between electricity and magnetism; and *Revelations and Revolutions*, modern day electrical history and achievements.

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Florida NGSS Standards & Related Subject Common Core

			.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	.11	.12
Grade 6														
Practice of Science	**# 1**	**SC.6.N.1**				**X**								
Grade 7														
Energy Transfer & Transformations	**# 11**	**SC.7.P.11**		**X**										

Sixth Grade Benchmarks
Science–Big Idea 1: The Practice of Science

- SC.6.N.1.4 - Discuss, compare, and negotiate methods used, results obtained, and explanations among groups of students conducting the same investigation.

Seventh Grade Benchmarks
Science–Big Idea 11: Energy Transfer and Transformations

- SC.7.P.11.2 - Investigate and describe the transformation of energy from one form to another.

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1. In the space below, draw a diagram of a solar powered system that powers a water pump that only needs to pump water during the day, and label its parts.

2. Many of the things we would like to power with photovoltaics need to store some of the electricity to be used at night (with a storage device like a battery). Below, list at least five things that could be powered with photovoltaics without a battery in the system, and at least five things that would require a battery to be in the system to work effectively.