# Solar Powered System

**Student Objectives**
The student:
- understands 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 explain factors that can increase the output of electricity from a photovoltaic system including cell size/area, reflective collection devices and intensifying devices

**Key Words:**
load
orientation
photovoltaic (PV)
system

,

**Time:**
1 class period

**Materials (1 per group):**
- small photovoltaic cell with wires and alligator clips
- motor
- propeller
- magnifying glass
- 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 cells (called PV or solar cells) are made of silicon (sand). The silicon is heated to extreme temperatures, then doped (coated/mixed) with chemicals, usually boron and phosphorous. This sets up an unstable environment within the photovoltaic cell. When light strikes the cell, electrons are dislodged and travel along wires placed within the cell. The electrons follow the wire and power whatever load is attached, in this case a motor. This flow of electrons is called electricity. PV cells use sunlight to directly produce electricity. Photovoltaic systems are quiet, clean, and non-polluting.

Because typical silicon solar cells produce only about ½ volt, cells are connected together to give more useful voltages. Usually 30 - 36 solar cells are connected in a circuit to give a final voltage of about 15-17 volts. To increase the power output further, modules are connected together to form an array.

**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 its 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 with alligator clips that they begin with in the activity. 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 in the beginning of the store activity.

1. Discuss what a photovoltaic (PV or "solar") cell is and how it works.
2. If you have played the Solar Cell Simulation game in *Solar Matters*, remind the students

of the "flow" of electrons in the system.

3. Give each team of students a photovoltaic cell, motor and propeller.
4. Demonstrate how to attach the propeller to the motor. Have the students attach theirs.
5. Demonstrate how to attach the cell wires to the motor wires: red to red, black to black. Have the students attach their wires.
6. Demonstrate the holding position of the system (i.e. face up, directed towards the Sun), making sure that the wire connections do not touch each other.
7. Take the "solar powered systems" outside and activate them in the sunlight. Carry the rest of the equipment for the activity outside with you.
8. While outside, discuss results and suggest things for the teams to try. Points to cover could include:
   - 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 to the motor 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 direction should the panel be facing to make the motor spin the fastest?
9. Gather the students together. Show them a milliamp meter and explain that it is a device that is used to measure how much electricity is produced by the photovoltaic panel.
10. Demonstrate how to attach the milliamp meter to a solar cell: remove the motor, attach the red wire to the positive prong in the back (the one with the plus sign), and attach the other wire to the other prong.
11. Pass out a milliamp meter to each group. Explain to the students that they are to measure how much electricity their solar cell is producing.
12. After they have learned how to use all of their equipment successfully, have the students return to their seats (retaining their equipment) and read them the following challenge:

***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.*

13. 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 the positive post of the milliamp meter, and all black leads on the negative post)*
    - one of the panels with alligator clips and 3 mirrors
    - one large 3V panel *(but they will have no money left over!)*
    - one medium-sized (2V) panel with one mirror
    - one of the panels with alligator clips and 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.*
14. Give the students ample time to try different solutions. You may want to remind them after a few minutes that there is only one movie theater. *(However, they may still not catch on. Don't tell them!)*
15. 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.
16. Questions you may wish to ask are:
    - Which devices increased the power output of the cell? *(mirror, magnifying glass)*
    - Why? *(They increased or focused the amount of sunlight hitting the solar cell.)*
    - What other variables affect the output of the photovoltaic cell? *(direction the cell is pointed, weather, time of day, time of year, latitude/position on the earth)*
17. Discussion questions for older students:
    - 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)*
18. 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.
19. Have students complete the Student Journal.

## Key Words and Definitions

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

## Further Research

1. Use the internet to help you find schools that have a photovoltaic system.
2. Can photovoltaics be used to power a vehicle? Research ways this can be done .
3. How are photovoltaics used in the space program? Collect photos and examples.

## Related Reading

- ***Catch the Wind, Harness the Sun: 22 Super-Charged Projects for Kids*** by Michael Caduto (Storey Publishing, 2011)
  Twenty-two projects plus stories, background information, cartoons and photos covering solar thermal, photovoltaics, solar cooking, climate change, energy production and energy conservation.
- ***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.
- ***The Kid's Solar Energy Book*** by Tilly Spetgang (Imagine, 2009)
  Cleverly intertwined with the science of solar thermal and photovoltaics are economics lessons about the cost advantages of energy efficient buildings and the production and price of solar cells. Illustrated with cartoon figures and set in a classroom, this book is appealing to students.
- ***Teaching Electricity: Yes, You Can: Grades 3 - 6*** by Steve Tomecek (Scholastic, 1999)
  Use balloons, paper clips and other easy-to-get stuff for super easy, super-cool activities that light up kids' science learning. Each lesson includes background information along with simple activities.

## Internet Sites

**http://www.solarpowersimulator.com/**

This 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.youtube.com/watch?v=NDZzAIcCQLQ**

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

# Solar Powered System

**Florida NGSS Standards & Related Common Core**

| | | | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Grade 3** | | | | | | | | | | |
| **The Role of Theories** | **Big Idea 3** | **SC.3.N.3** | X | X | X | | | | | |
| **Forms of Energy** | **Big Idea 10** | **SC.3.P.10** | X | X | | | | | | |
| **Grade 4** | | | | | | | | | | |
| **Forms of Energy** | **Big Idea 10** | **SC.4.P.10** | X | X | | | | | | |
| **Grade 5** | | | | | | | | | | |
| **Forms of Energy** | **Big Idea 10** | **SC.5.P.10** | X | X | X | | | | | |
| **Energy Transfer & Transformations** | **Big Idea 11** | **SC.5.P.11** | X | X | | | | | | |

**Third Grade Benchmarks**
**Science–Big Idea 3: The Role of Theories, Laws, Hypotheses, and Models**
- SC.3.N.3.1 - Recognize that words in science can have different or more specific meanings than their use in everyday language; for example, energy, cell, heat/cold, and evidence.
- SC.3.N.3.2 - Recognize that scientists use models to help understand and explain how things work.
- SC.3.N.3.3 - Recognize that all models are approximations of natural phenomena; as such, they do not perfectly account for all observations.

**Science–Big Idea 10: Forms of Energy**
- SC.3.P.10.1 - Identify some basic forms of energy such as light, heat, sound, electrical, and mechanical.
- SC.3.P.10.2 - Recognize that energy has the ability to cause motion or create change.

**Fourth Grade Benchmarks**
**Science–Big Idea 10: Forms of Energy**
- SC.4.P.10.1 - Observe and describe some basic forms of energy, including light, heat, sound, electrical, and the energy of motion.
- SC.4.P.10.2 - Investigate and describe that energy has the ability to cause motion or create change.

**Fifth Grade Benchmarks**
**Science–Big Idea 10: Forms of Energy**
- SC.5.P.10.1 - Investigate and describe some basic forms of energy, including light, heat,

sound, electrical, chemical, and mechanical.

- SC.5.P.10.2 - Investigate and explain that energy has the ability to cause motion or create change.
- SC.5.P.10.4 - Investigate and explain that electrical energy can be transformed into heat, light, and sound energy, as well as the energy of motion.

**Science–Big Idea 11: Energy Transfer and Transformations**

- SC.5.P.11.1 - Investigate and illustrate the fact that the flow of electricity requires a closed circuit (a complete loop).
- SC.5.P.11.2 - Identify and classify materials that conduct electricity and materials that do not.

**National Next Generation Science Standards**

**Third Grade Standards**

**Science–Engineering**

- 3-ETS1-1 - Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time or cost.
- 3-ETS1-2 - Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-ETS1-3 - Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

**Fourth Grade Standards**

**Science–Energy**

- 4-PS3-2 - Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- 4-PS3-4 - Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

**Science–Engineering**

- 4-ETS1-1 - Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time or cost.
- 4-ETS1-2 - Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 4-ETS1-3 - Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

**Fifth Grade Standards**

**Science–Engineering**

- 5-ETS1-1 - Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time or cost.
- 5-ETS1-2 - Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 5-ETS1-3 - Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

## Solar Powered System

1. In the space below, draw a diagram of a solar powered system that lights a lamp.

2. Make a list of things in your home and classroom that could be powered with photovoltaic energy (solar electricity). Circle any of the items in your list that you already power with photovoltaics.