How Solar Cells and Solar Panels Work

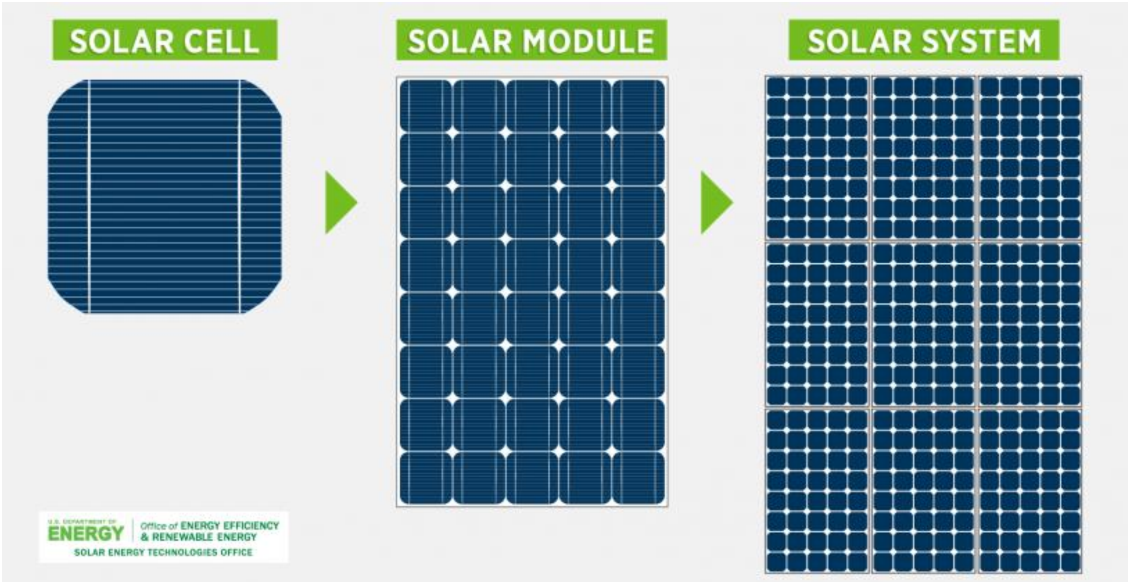

Diagram courtesy of the U.S. DOE Office of Energy Efficiency and Renewable Energy

Summary

A solar cell is a small electrical device that changes light energy into electrical energy. Solar cells are also known as photovoltaic (often abbreviated as PV) cells because they utilize the photovoltaic effect. A single solar cell usually does not produce enough electricity to be useful. To produce more electrical energy, it is common to connect many solar cells together to make a solar module. Solar modules are also referred to as PV modules or solar panels. To produce enough electrical energy for a home or for the electrical grid, many solar modules can be connected together to create a solar system also known as a solar array.

Objectives

- Students will be able to explain how sunlight is converted to electricity in a solar cell and solar panel.
- Students will be able to demonstrate that a solar cell can be used to make electricity to power a circuit board, LED light, motor or other electrical device.

Standards

4.PS3.2	4.ESS3.1	MS.PS1.4	MS.ESS3.3
4.PS3.4	5.ESS3.1	MS.PS3.3	

Vocabulary

- Electron
- Electricity
- Solar Cell
- Solar Panel
- Electrical Circuit
- Silicon (Si, #14)
- Boron (B, #5)
- Phosphorus (P, #15)

Materials List (*To check out a kit go to OREEP.org and fill out a form.)

- Solar Energy Exploration Kit
- Multimeter (Multimeter Tutorial Available on **OREEP.org**)
- Light Source (the sun or an electrical lamp, 75-100 watt equivalent recommended)

Worksheets and Attachments

- Lesson Document (pdf)
- Student Activity Worksheets (pdf)
- Vocabulary Sheet
- Connections Pictures & Video

Teacher Information / Background Information

How do solar cells work?
https://www.youtube.com/watch?v=UJ8XW9AgUrw&ab_channel=SciToons

How do solar panels work? - Richard Komp
https://www.youtube.com/watch?v=xKxrkht7CpY

EIA Energy Kids, see diagram of a photovoltaic cell
https://www.eia.gov/kids/energy-sources/solar/

The basic mechanism by which solar cells and solar panels produce electricity is known as the Photovoltaic Effect. The Photovoltaic Effect was discovered by French physicist A. E. Becquerel in 1839 using a liquid photochemical cell. In 1884 Charles Fritts made the first solid solar cell. Unfortunately, the solar cell Fritts made was not efficient enough to make usable amounts of electricity. Then in the 1950s scientists and engineers at Bell Laboratories made solar cells they called “solar batteries” which had higher efficiencies and could be used to power communications equipment. Soon after initial development of solar cells in Bell Laboratories, solar panels composed of many solar cells were used to power satellites and then many other spacecrafts.

Most of the solar cells and solar panels currently being manufactured are primarily composed of the element silicon. Silicon is a plentiful natural resource that makes up more than one fourth of the earth's crust and is the main component of ordinary sand. The silicon used in the production of solar cells must be purified to a very high degree. Much of the cost of producing solar cells and solar panels results from the processes needed to remove unwanted impurities in order to produce the highest quality silicon.

Silicon solar cells and solar panels consist primarily of a slab or thin wafer of crystalline silicon. During manufacture, small amounts of different elements are introduced into the slab to cause the formation of two different layers of crystalline materials on opposite sides of the slab. The first type of crystalline material is created by adding a small amount of the element boron to one side of the crystalline silicon slab. Addition of the boron results in the presence of spaces or holes in the crystalline material which can accept additional electrons. This type of crystalline material is commonly referred to as "P-type" silicon material and forms the bottom layer of a solar cell or solar panel.

The second type of crystalline material is created by adding a small amount of the element phosphorus to the other side of the crystalline silicon slab. Addition of phosphorus to the silicon results in the presence of free electrons in the crystalline material. This type of crystalline material is commonly referred to as "N-type" silicon and is used to form the top layer of a solar cell or solar panel. The P-type and N-type silicon crystalline materials in solar cells and solar panels are like the crystalline materials used to make computer chips, transistors and other electrical components.

After the two different types of crystalline materials are formed, some of the electrons in the N-type material move into the P-type material. Movement of the electrons creates an electric field in a region near the two different types of crystalline materials called the p-n junction. (See the diagram on the following page.)

When light penetrates into a solar cell or solar panel and reaches the area near the p-n junction it transfers energy to electrons in the crystalline materials. Electrons which have acquired energy from light move in the crystalline materials creating a flow of electrons. The flow of electrons is then collected by thin wires on the top of the solar cell or solar panel and can move through wires connected to the solar cell or solar panel.

Inside a photovoltaic cell

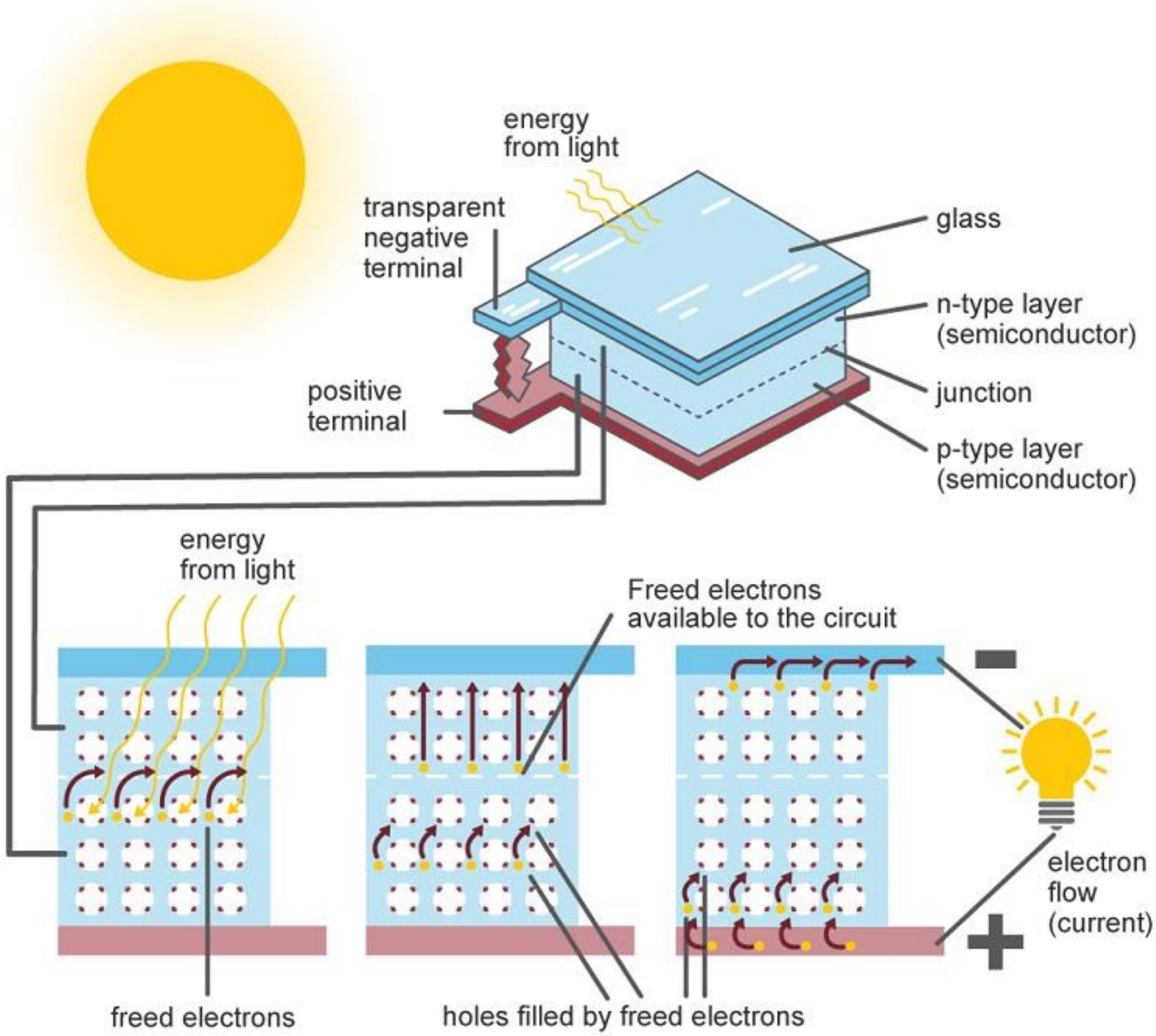

Diagram courtesy of U.S. Energy Information Administration

The type of electricity solar cells and solar panels produce is the same type as produced by batteries which is known as direct current. Like batteries, solar cells and solar panels have two electrical terminals with different polarities. One terminal has a positive electrical polarity denoted by a plus sign (+) and a second terminal has a negative electrical polarity denoted by a minus sign (-). Like batteries, solar cells and solar panels can be used to provide electricity needed to operate electrical devices that require direct current electricity. Many types of light bulbs, motors and electrical circuits can be powered using direct current electricity if the voltage and current are at the proper levels.

Some types of electrical devices such as incandescent light bulbs do not require that the terminals are connected to the terminals of a source of electricity with the same polarity. However, other types of electrical devices such as light emitting diodes (LEDs) require that the device's terminals be connected with battery, solar cell or solar panel terminals having the same polarity. Polarity is often indicated by wire color; red wire indicates positive polarity and black wire indicates negative polarity. Both the circuit board and LED lights require that the terminals from the device be connected to the same polarity from a battery, solar cell or solar panel. So red wire to red wire and black wire to black wire.

Sound and Light Circuit Board connections.

Photo by Doug Weirick

LED connections.

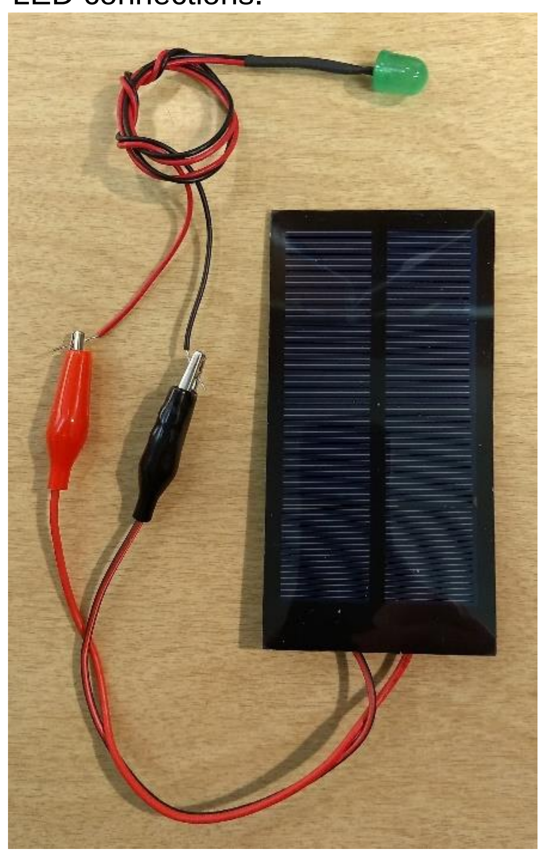

Photo by Doug Weirick

How Solar Cells and Solar Panels Work
Student Activity Sheets - Exploration

Engagement

1. Watch videos:

Solar Energy Basics - National Renewable Energy Laboratory
https://www.nrel.gov/research/re-solar.html

How do solar cells work?
https://www.youtube.com/watch?v=UJ8XW9AgUrw&ab_channel=SciToons

How do solar panels work? - Richard Komp
https://www.youtube.com/watch?v=xKxrkht7CpY

2. From EIA Energy Kids look at the diagram of the photovoltaic cell.
https://www.eia.gov/kids/energy-sources/solar/

Exploration

Part 1. Read the paragraphs below about how solar cells and solar panels are made and how they make electricity.

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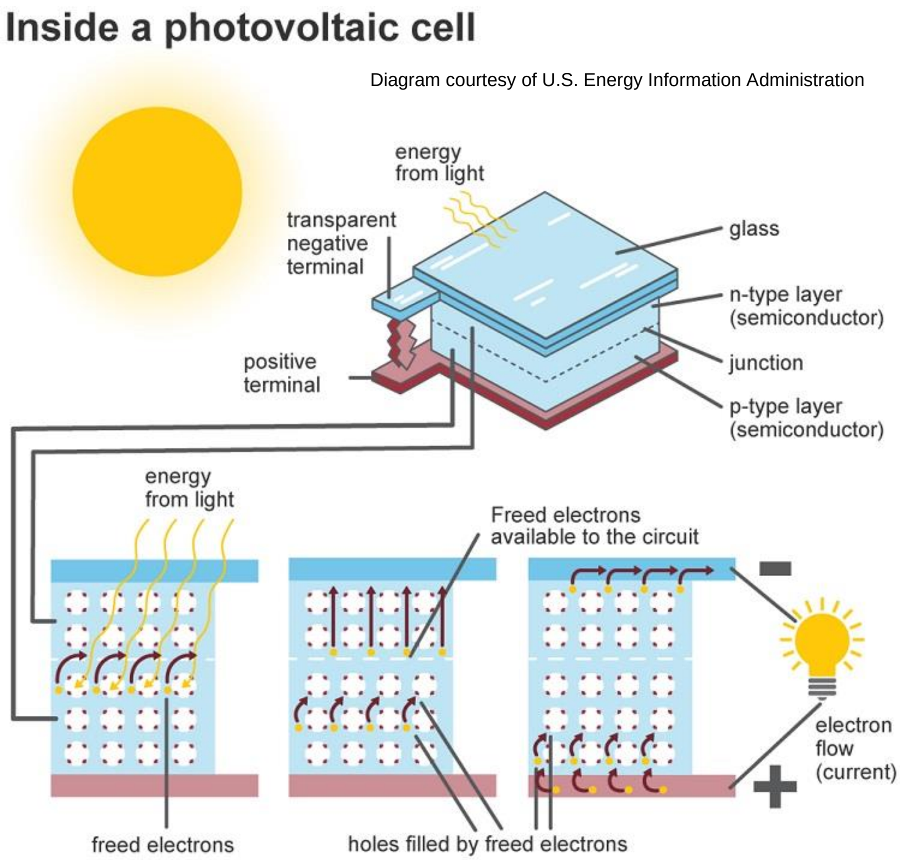
Silicon solar cells and solar panels consist primarily of a slab or thin wafer of crystalline silicon. During manufacture, small amounts of different elements are introduced into the slab to cause the formation of two different layers of crystalline materials on opposite sides of the slab. The first type of crystalline material is created by adding a small amount of the element boron to one side of the crystalline silicon slab. Addition of the boron results in the presence of spaces or holes in the crystalline material which can accept additional electrons. This type of crystalline material is commonly referred to as "P-type" silicon material and it is used to form the bottom layer of a solar cell or solar panel.

The second type of crystalline material is created by adding a small amount of the element phosphorus to the other side of the crystalline silicon slab. Addition of phosphorus to the silicon results in the presence of free electrons in the crystalline material. This type of crystalline material is commonly referred to as “N-type" silicon and is used to form the top layer of a solar cell or solar panel. The P-type and N-type silicon crystalline materials in solar cells and solar panels are similar to the crystalline materials used to make computer chips, transistors and other electrical components.

After the two different types of crystalline materials are formed, some of the electrons in the N-type material move into the P-type material. Movement of the electrons creates an electric field in a region near the two different types of crystalline materials called the p-n junction.



When light penetrates into a solar cell or solar panel and reaches the area near the p-n junction it transfers energy to electrons in the crystalline materials. Electrons which have acquired energy from light move in the crystalline materials creating a flow of electrons. The flow of electrons is then collected by thin wires on the top of the solar cell or solar panel and can move through wires connected to the solar cell or solar panel.

1. Have students draw their own diagrams that show how solar cells are constructed.

2. Have students use their diagrams to explain how solar cells and solar panels change energy in the form of light into electrical energy.

Part 2. Construct electrical circuits to demonstrate that a solar cell or solar panel can produce the electricity needed to make an LED light turn on and a circuit board operate.

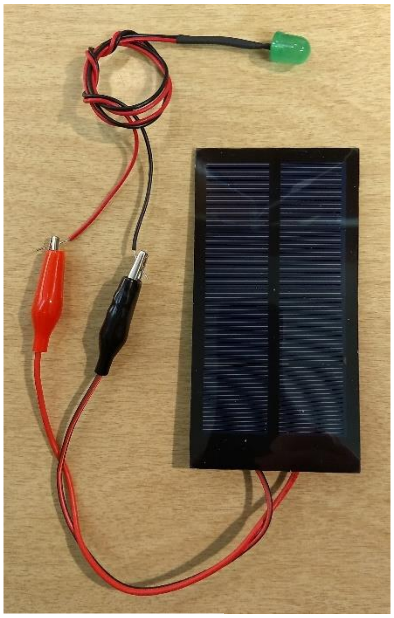


Photo by Doug Weirick

a. Use the alligator clip to connect the positive (red) wire on the LED light to the positive (red) wire of a small solar panel. Make sure the alligator clip attaches to metal in the wire where the insulation has been removed.

b. Use the alligator clip to connect the negative (black) wire on the LED to the negative (black) wire of the small solar panel. Make sure the alligator clip attaches to metal in the wire where the insulation has been removed.

c. Illuminate the small solar panel by placing it under a bright electric lamp (75-100 watts or equivalent) or in a location where full sun light shines on the solar panel.

d. Did the LED light turn on? Yes / No

e. Try completely covering the small solar panel using your hands or a book so that it is fully shaded and no light shines on the solar panel. Is the LED light still on or did it turn off? On / Off

f. Start with the small solar panel completely covered and fully shaded from the electric lamp and sun. Make a prediction about what might happen to the LED light if the small solar panel was slowly uncovered so that increasing amounts of it (1/4, 1/2, 3/4) received light from the electric lamp or the sun until the whole solar panel was uncovered and receiving light.

g. Test your prediction by observing the LED light while slowly uncovering increasing portions of the small solar panel a little more at a time until it is fully uncovered and not shaded. What happened when the solar panel was 1/4, 1/2, 3/4 and fully uncovered? The LED should have been off when the small solar panel was fully covered and then the LED light should turn on but be dim when the solar panel is partially uncovered. The LED light should be bright when the solar panel was completely uncovered.

h. As the small solar panel was being slowly uncovered and larger portions received more light, what do you think was happening to the amount of electricity produced and that was available for the LED light? Uncovering larger portions of the solar panel caused more electricity to be produced and to be available for the LED light.

i. Use the alligator clip to connect the positive (red) wire on the small solar panel to the positive (red) wire of the Sound and Light Board. Attach the clip to the metal in the wire where the insulation has been removed.

Photo by Doug Weirick

j. Use the alligator clip to connect the negative (black) wire on the small solar panel to the negative (black) wire of the Sound and Light Board. Attach the clip to the metal in the wire.

k. Illuminate the small solar panel by placing it under a bright electric lamp (75-100 watts or equivalent) or where full sun light shines on it.

l. Move the switch marked SW on the Sound and Light Board to the Torch setting. If the Torch LED does not light up, move the small solar panel closer to the electric lamp or in brighter sunlight. Did the Torch LED light up? Yes / No

m. Move the switch on the Sound and Light Board to the music setting. Do you hear any sound coming from the board? Yes / No

n. Start with the small solar panel completely covered and fully shaded from the electric lamp and sun. Make a prediction about what might happen to the sound if the small solar panel was slowly uncovered so that increasing amounts of it (1/4, 1/2, 3/4) received light from the electric lamp or the sun until the whole solar panel was uncovered and receiving light.

o. Test your prediction by listening to the sound while slowly uncovering increasing portions of the small solar panel a little more at a time until it is fully uncovered and not shaded. What happened when the solar panel was 1/4, 1/2, 3/4 and fully uncovered? There should be no sound when the small solar panel is fully covered and then some sound but not music when the solar panel is partially uncovered. The Sound and Light Board should play music when the small solar panel is completely uncovered.

p. As the small solar panel was being slowly uncovered and larger portions received more light, what do you think was happening to the amount of electricity produced and available for the Sound and Light Board? Uncovering larger portions of the solar panel caused more electricity to be produced and to be available for the Sound and Light Board.

Explanation

1. Give a detailed explanation of what you observed which provides evidence that the small solar panel was making electricity.

2. Give a detailed explanation of what you observed which provides evidence that the amount of shading of the small solar panel affects the amount of electricity produced.

3. Draw a diagram of the sun, solar cell, and Sound and Light Board. Draw arrows to show the path that energy followed to make the Torch LED light up.

Extension

Give an example of a location that you think would be a good place to put solar panels. Give an example of a location that you think would not be a good place to put solar panels. Why did you choose the examples for a good and a bad location?
Solar panels make the greatest amounts of electricity when they are tilted and facing south with no shading from trees or other objects.

Evaluation

1. What happens when the energy from the sun hits a solar cell or solar panel?
The sun's energy is transferred to electrons which allows electrons to flow as electricity.

2. Give at least two advantages of using solar energy to produce electricity instead of fossil fuels ? Answers could include doesn't create greenhouse gases, not as much environmental damage as result of production and refining, will not be depleted, now less expensive to use solar technology than fossil fuels to produce electricity.

References

How Does Solar Work? Solar Energies Office, U.S. Department of Energy, https://www.energy.gov/eere/solar/how-does-solar-work

Exploring Photovoltaics Teachers Guide, National Energy Education Development Project (The NEED Project), Manassas, VA, 2017

Secondary Energy Infobook, National Energy Education Development Project (The NEED Project), Manassas, VA, 2017