Introduction to Photovoltaics (PVs)

OVERVIEW

Students learn the basics of solar cells and photovoltaic (PV) systems. A background reading is accompanied by a vocabulary worksheet to provide students with an introduction to the essential pieces of the PV systems at their schools.

PRIOR KNOWLEDGE

Students will be most successful with this activity if they are familiar with the concepts of energy, energy transformations, and energy forms and sources. A good general background to energy topics can be found in the NEED publication, *Intermediate Energy Infobook*. For additional background information about solar energy and photovoltaics, see the "Solar/PV Backgrounder" in the NEED publication, *Schools Going Solar Activities*.

TIME

One 45-minute class period. Note: This activity is appropriate to assign as a homework reading and worksheet.

MATERIALS

- Reading – "The Path to Solar Energy"
- Student vocabulary worksheet
- Miniature solar panel and motor
- 100-Watt bulb or bright sunny day

PREPARATION

- Review reading and procedures.
- Make copies of the reading and worksheets (one per student).

PROCEDURES

- Poll students to see how many are aware that the school has a solar panel that contributes to the school's electricity.
- Introduce the term "photovoltaic" – a device that makes electricity (volts) from light (photo). Demonstrate how a photovoltaic runs with the miniature panel and motor. (Connect the red wires and the black wires and hold the panel up to a 100W bulb or bright sunlight).

- Initiate a general discussion about solar energy, solar panels, and photovoltaics. Draw on prior knowledge from other energy activities and students' personal experiences. Point out that solar-powered calculators are powered by PVs.
- Explain that the class is about to start working with the school's PV system. The first step is to do a little background research to learn the basics of a PV array.
- Distribute reading and worksheets.
- After students complete reading and worksheets (either individually, for homework, or in small groups), go over worksheet answers.
- If time permits, start "Get to Know YOUR PV system" – a hands-on investigation of the schools PV system.

NOTES

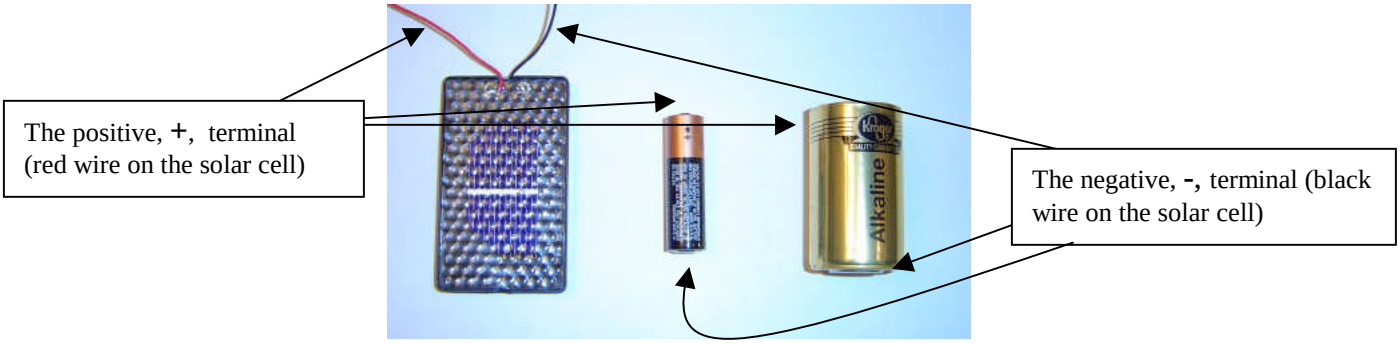
Throughout the reading are challenge questions that students can research to learn more about solar cells, the photoelectric effect, the importance of silicon, the electric grid, and other related topics.

The Path to Solar Energy

It starts with **silicon**, the 2nd most abundant element on earth (second only to oxygen). A common place to find silicon is beach sand and glass. However, we want it in a very pure form. Starting with a highly pure form, we sprinkle just a few impurities (sort of like salt and pepper for flavor) often in the form of Boron and Phosphorous. And out of that, we can create, TAA DAA!, a photovoltaic cell. A PV cell looks like a very thin, blue wafer, about 4 inches in diameter. *Challenge: Research how PV cells are manufactured.*

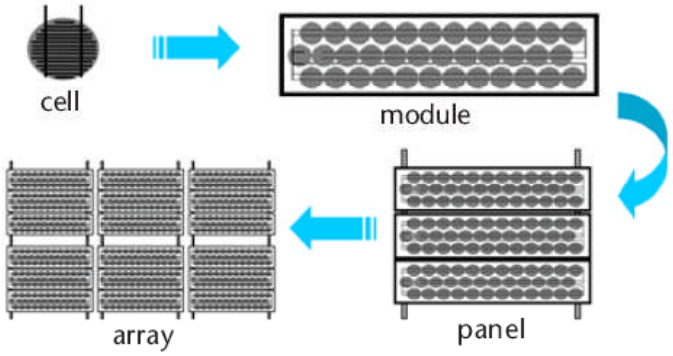
A photovoltaic (PV) cell, also called a solar cell.

PV cells are amazing! They are great examples of the conservation of energy in action. They take radiant energy and transform it directly into electricity through something called the photoelectric effect. You can look into more details of this fascinating process elsewhere, but for now, the main thing to understand is that **photovoltaic cells**, also referred to as **solar cells**, convert light into electricity. We can harness that electricity by attaching metal contacts to the top and bottom of the cell and connecting wires to the metal contacts. The top and bottom of the cell are very similar to the terminals of a battery. Like a battery's terminals, a PV cell has a positive (+) and negative (-) side. *Challenge: Learn about the photoelectric effect and how it works in PV cells.*



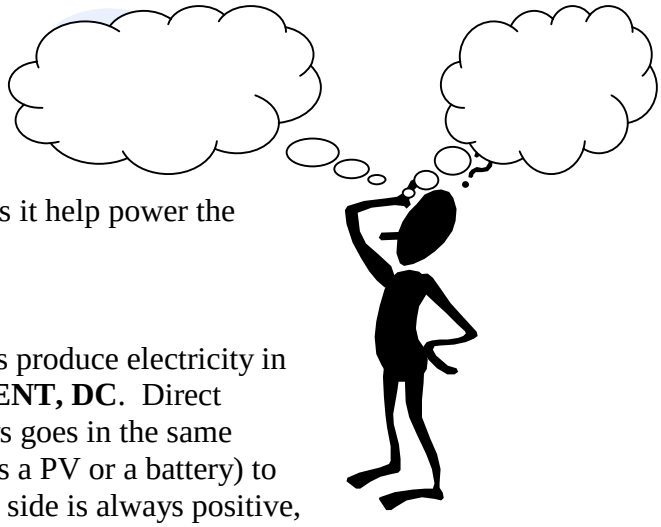
Solar cells have positive (+) and negative (–) terminals, like batteries.

The power produced from one cell is typically about 1.5 watts. That's not much! It would take one cell almost 1200 hours of producing 1.5 watts to supply the same amount of energy contained in one fast food meal (burger, fries, and drink at 1,500 calories/meal)! That's 50 days of constant work. If you consider that the sun doesn't shine for 24 hours a day, and think about cloudy days when the cell doesn't perform at its peak, it's even longer – it may take almost half a year to produce that amount of energy! Clearly, we need more than one cell to take advantage of solar power. And so, just as a cell is the building block of biological systems, a solar cell is the building block of PV systems.



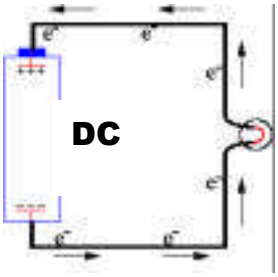
Solar cells are combined to make PV **modules**, which in turn are combined to create PV **panels**, which can be added together to create a **PV array**. In all these terms, the words "PV" and "solar" are often used interchangeably. Here's a diagram showing the relationship between all these terms.

The array on your school is most likely a 1 kW array. That means if all the cells are working well and the sun is shining brightly, it would take the array a little less than 2 hours to produce the amount of energy contained in that fast food meal. Wow! Talk about the power of teamwork! When you take a look at your solar array, spend some time seeing just how many cells, modules, and panels make up your school's system.

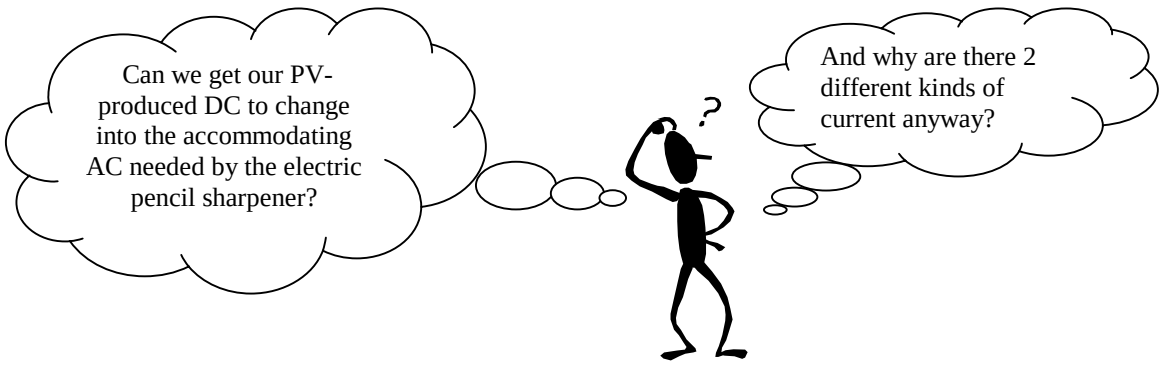


Imagine it's a beautiful sunny day. You know that there are solar panels somewhere in your school. You begin to wonder: How is the electricity produced by the solar panel getting to the school? How does it help power the electric pencil sharpener?

Well, let's find out! Like batteries, solar panels produce electricity in a form of **current** known as **DIRECT CURRENT, DC**. Direct current means that the flow of electricity always goes in the same direction from one terminal of a source (such as a PV or a battery) to the other terminal. In other words, the positive side is always positive, the negative, always negative. On the other hand, the electricity that comes out of the wall in most homes, schools, and businesses is in the form of **ALTERNATING CURRENT, AC**. AC means that the flow of electricity reverses the direction it goes between terminals in alternating cycles. In the US, the direction changes 60 times every second.



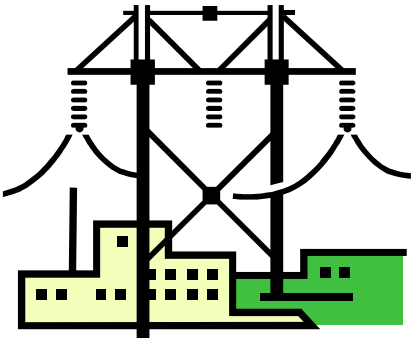
Solar panels produce direct current (DC), where electricity always flows in the same direction. But most household appliances require alternating current (AC).



Yes! We can change the DC into AC by using an inverter. An **inverter** is a device that changes DC into AC. When you check out your PV array, find the inverter. Most Ohio Solar Schools have either an Advanced Energy Systems (GC-1000) or a SMA Sunny Boy Inverter (in a red box). Secondly, great question! Power companies use AC electricity because it is a safer and more efficient way to transport electricity than DC. AC power allows them to transport energy economically at very high voltages. Then, using a device called a **transformer**, they can lower the voltage to the safer 120 V used in the USA when it enters your house. With your solar panel system, a transformer is inside the inverter adjusts the voltage of the power coming from the solar array to match the voltage of the power used in the school.

Are we there yet? Has the power of the sun been put to use to sharpen the pencil? Soon! A data logger measures the amount of electricity going into the school produced by the PV array. The electricity is measured before it joins the rest of the electricity from the **electric grid** that supplies your school.

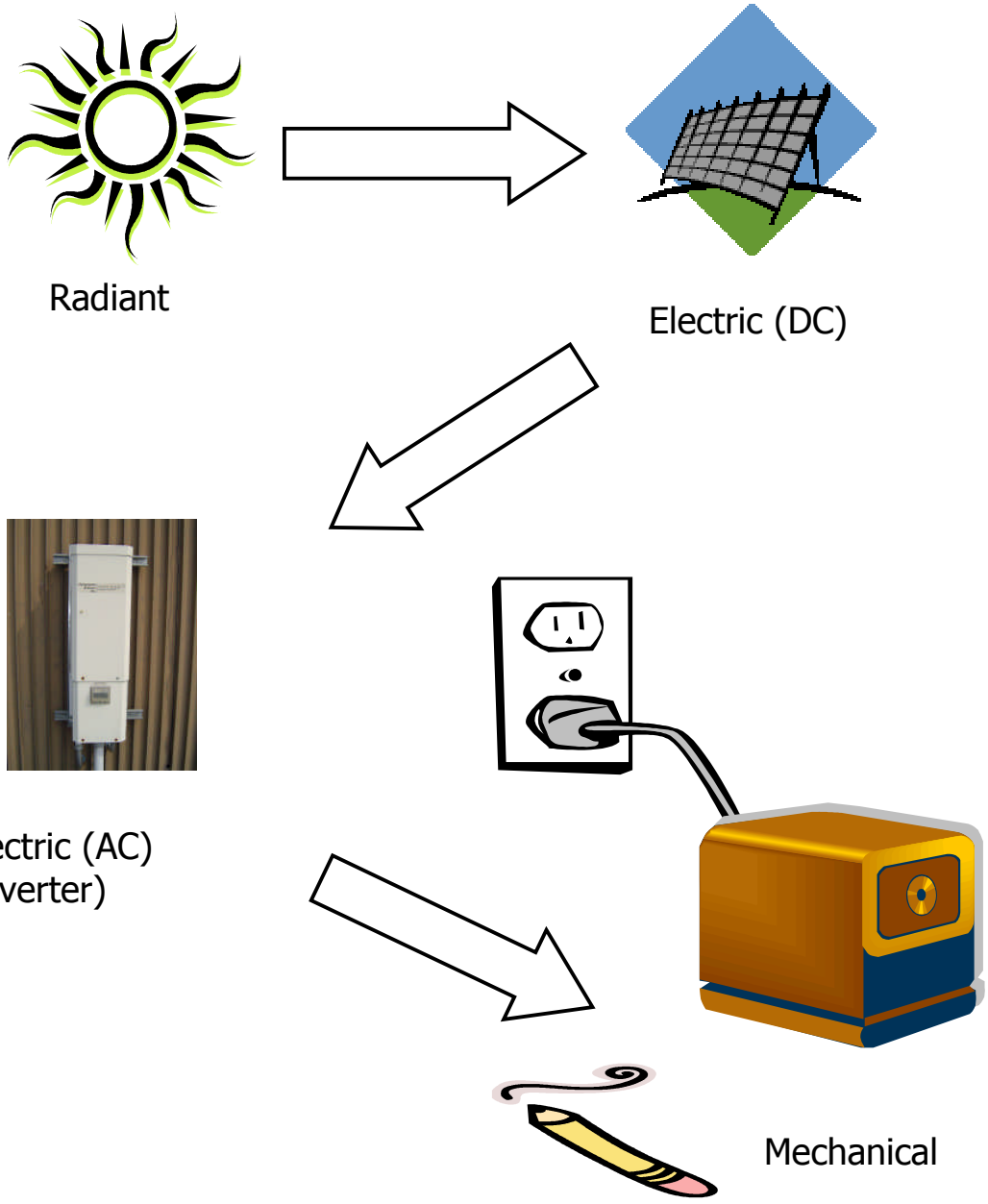
What is this grid? The grid is the network of cables through which electricity is transported from power plants to homes, schools, and businesses. A **grid-connected** solar system is connected to this network. In the case that the grid has a power outage or someone needs to work on the solar system, there are **safety disconnects** so that the solar system is protected. They are similar to circuit breakers. The safety disconnects take the solar system "off the grid" while work is done. Most of the first PV systems created were stand-alone systems. **Stand-alone** systems provide a separate electricity supply. Typically, these use a battery storage system and maintain DC electricity.



The Electric Grid is the network of cables through which electricity is transported from power plants to homes, schools, and businesses.

Phew! Have we made it? Are you ready to sharpen your pencil using sun power? Well, one thing is for sure – by learning all about photovoltaics and your school's PV system, you will be sharpening your mind to learn about the promises of a now and future energy technology!!

Let's look at the energy transformations from the sun to the pencil sharpener in this story.


Radiant
Electric (DC)
Electric (AC)
(inverter)
Mechanical

STUDENT WORKSHEET – READING GUIDE

Review the reading "The Path to Solar Energy." Using the word bank at the bottom of the page, fill in the following blanks.

1. _____is the basic material usually used in making photovoltaics, or solar cells.
2. A _____ is a device that converts light directly into electricity. It is also often called a _____.
3. A _____ is the smallest unit in a photovoltaic system. These are connected together to form _____, which are combined in objects referred to as _____. Lastly, a _____ refers to the entire grouping of PVs in a system.
4. _____ refers to the flow of electric energy.
5. When electricity flows in only one direction between the terminals of a source, such as a battery or a PV, it is referred to as _____.
6. The electricity that is used in most of our schools, homes, and businesses is called _____ because it reverses its direction each cycle.
7. An _____ changes DC electricity into AC electricity.
8. In order to ensure that the electricity coming from the PV system has the proper voltage needed by the appliances in the school, a _____ is used.
9. In a _____ system, the electricity produced by the PV joins the electricity provided by the grid for the school. On the other hand, in a _____ system, there is no connection between the electricity produced by the PV system and the grid.
10. A _____ is used to record how much power the PV is producing at any time and to keep track of the total amount of energy it has contributed to the school.
11. In order to ensure safety in a grid-connected PV system, there are _____ that will isolate the panels from the grid in the case of a power outage or a need for work on the panels.

Safety Disconnects	Stand-alone	Inverter	Direct Current, DC
Current	Panels	Silicon	Alternating Current, AC
Data Logger	Solar Cell	PV Array	
Transformer	Photovoltaic	Modules	Grid-Connected

STUDENT WORKSHEET – READING GUIDE (TEACHER KEY)

Review the reading "The Path to Solar Energy." Using the word bank at the bottom of the page, fill in the following blanks.

1. SILICON is the basic material usually used in making photovoltaics, or solar cells.
2. A PHOTOVOLTAIC is a device that converts light directly into electricity. It is also often called a SOLAR CELL.
3. A SOLAR CELL is the smallest unit in a photovoltaic system. These are connected together to form MODULES, which are combined in objects referred to as PANELS. Lastly, a
   PV ARRAY refers to the entire grouping of PVs in a system.
4. CURRENT refers to the flow of electric energy.
5. When electricity flows in only one direction between the terminals of a source, such as a battery or a PV, it is referred to as DIRECT CURRENT or DC.
6. The electricity that is used in most of our schools, homes, and businesses is called ALTERNATING CURRENT or AC because it reverses its direction each cycle.
7. An INVERTER changes DC electricity into AC electricity.
8. In order to ensure that the electricity coming from the PV system has the proper voltage needed by the appliances in the school, a TRANSFORMER is used.
9. In a GRID-CONNECTED system, the electricity produced by the PV joins the electricity provided by the grid for the school. On the other hand, in a STAND ALONE system, there is no connection between the electricity produced by the PV system and the grid.
10. A DATA LOGGER is used to record how much power the PV is producing at any time and to keep track of the total amount of energy it has contributed to the school.
11. In order to ensure safety in a grid-connected PV system, there are SAFETY DISCONNECTS that will isolate the panels from the grid in the case of a power outage or a need for work on the panels.

Safety Disconnects	Stand Alone	Inverter	Direct Current, DC
Current	Panels	Silicon	Alternating Current, AC
Data Logger		Solar Cell	PV Array
Transformer	Photovoltaic	Modules	Grid-Connected