SunSmart Schools

Note: This lesson is included for students in SunSmart and other schools that have a photovoltaic system, to learn about their system's operation.

Student Objective
The student:
- given a photovoltaic system will name the component parts and describe their function in the PV system
- will access their school's system data (or data from a nearby school) and be able to explain its function.

Materials
- viewing access to school's photovoltaic system
- computer with internet access
- Science Journal pages

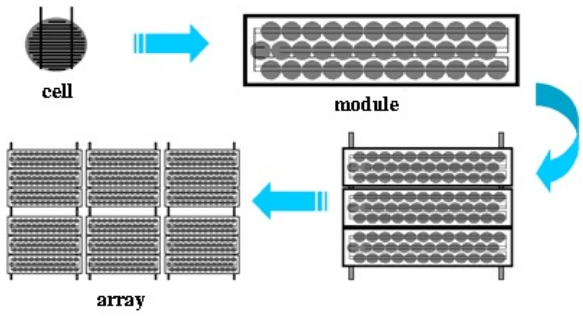
Key Words:
alternating current
data acquisition system
direct current electricity
distribution panel
electric meter
inverter
kilowatt hours
photovoltaic array
photovoltaic cell
photovoltaic module
semiconductor material
silicon

Time:
1 class period

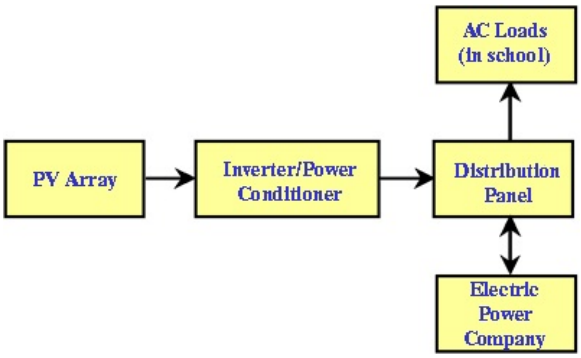
Background Information

Crystalline photovoltaic solar cells are made of the element silicon. When light shines on a solar cell, the energy of the light penetrates into the cell and 'knocks' negatively charged electrons loose from their silicon atoms. The freed electron has potential energy (voltage). These freed electrons flow through the internal electro-static field and out of the cell.

Because typical silicon solar cells produce only about ½ volt, cells are connected together to give more useful voltages. Within the module, cells are wired in parallel 'strings' to increase the amperage, then these 'strings' are wired together in series to increase the voltage; giving the module the desired output of amperage and voltage. To increase the power output further, modules are connected together to form an array.



Besides the solar panels, there are several other pieces of equipment that make up your photovoltaic system.



The **inverter**, or power conditioning unit, converts the DC power produced by the photovoltaic array into AC power of the same voltage and quality (kilohertz) as the utility grid, and automatically stops supplying power to the grid when the utility power is down (protecting anyone who is working on the lines). Your system has a bi-directional interface between the array and the electric utility network. This allows the AC power produced by the PV system to either supply the specified loads at your school (such as your emergency shelter), or to back-feed the electric grid when the output from your system is more than the shelter is using. Below are photos of three types of inverters–Trace, SMA (Sunny Island) and OutBack.

Many inverters have a display panel on the front that will show the amount of electricity being produced instantaneously, as well as the amount that has been produced that day. These read-outs can be interesting for the students once they understand the units referenced. They can also be useful when doing shading or cooling experiments on the actual array.

The **distribution panel**, commonly called a "breaker box", is the point where the photovoltaic system output is wired to load circuits (in this case, your school) and to the incoming power lines from the electric utility. This allows the AC power produced by the system to either supply part of the electrical demands of your school, or if the school does not need the power at that time, to feed it into the general electric power lines. This box is usually located in the school's electrical room next to the breaker box.

The **electric meter** keeps track of the amount of electrical energy produced by the photovoltaic system. Electrical energy over time is measured in **kilowatt-hours**.

The **data acquisition system** collects data from several different sensors and makes it available for diagnostic purposes. In most school PV systems the data is also sent to a webpoage that presents data on the internet in a user friendly way, where it can be monitored by students all over the world.

Your system may also include **batteries** to store the electricity for use during power outages. These solar batteries look similar to large car batteries, but are specifically designed to be charged and discharged thousands of times. The charging and discharging of the batteries is controlled by the **Charge Controller.**

Procedure

1. Divide students into groups for the data acquisition activities according to how many computers are available.
2. Discuss the school's photovoltaic system. Points to cover include:
   - Crystalline photovoltaic cells are made up of silicon, the main component of sand. Silicon is also commonly used in semiconductors.
   - Photovoltaic cells are wired together into panels called modules. The modules in a system are wired together into a photovoltaic array.
   - Photovoltaic cells generate direct current (DC) electricity. DC is the type of electricity used by battery operated devices. The circuits in homes, schools and businesses carry alternating current (AC) electricity. The DC electricity produced by photovoltaic cells has to be transformed into AC electricity before it can be used by the school. (Remind students of the "bricks"–actually small transformers–that they plug in to charge phones and other small DC devices.)
   - Electric meters measure how much electricity flows through them. This electricity is measured in kilowatt hours.
3. Escort students outside to look at the school system. If possible, let them also look at the system components that are housed inside. Students will then sketch the system in their Science Journal. Encourage them to be as complete as possible.
4. Write the website address on the board for your school's data. Help the students as needed to access the data.
5. Students may complete the remainder of the questions in groups if there are not enough computers for each student to work individually. Assist the students as necessary in locating the web page and interpreting the data contained there.

Key Words & Definitions

- **alternating current electricity (AC)** – an electric current that reverses its direction at regular intervals. This type of current in the United States is what is sent over electrical transmission lines, and typically used in homes, offices and schools.
- **data acquisition system** – collects data from several different sensors and sends them to the computer that posts the data on the internet where it can be monitored by students and scientists
- **direct current electricity (DC)** – an electric current flowing in one direction only. This type of electricity is typically used in battery operated devices, automobiles and boats

- **electric meter** – measures the amount of electrical energy flowing through the system
- **inverter** – changes DC electricity produced by the modules into alternating current (AC) which is the type of electricity used in most buildings
- **kilowatt hours** – basic unit of electrical usage over time
- **photovoltaic array** – complete unit of solar modules
- **photovoltaic cell** – the individual units in a photovoltaic module. Each cell is manufactured separately. These may then be wired together to make larger modules and produce more power.
- **photovoltaic module** – the term for a photovoltaic panel. Modules can be wired together to make a larger array.
- **semiconductor material** – a material such as silicon that is arranged in an even crystalline structure and is used in microchips and PV cells to facilitate the flow of electricity
- **silicon** – the element that is the main component of photovoltaic cells. Silicon is most commonly found on the Earth in sand.

Related Research

1. Is the system on your school large enough to power your home? Compare your home electrical usage as listed on your monthly statement with the output of your school system.
2. What percentage of your school's electrical usage does the array produce? Obtain a copy of your school's monthly electric statement to find the total electric usage of your school. Calculate what percentage is being supplied by the PV system. How could you increase this percentage? Include ways that would mean an investment of money as well as those that could be done without costing the school any additional funds.

Internet Sites:

http://www.energywhiz.com/
Florida Solar Energy Center's website for the SunSmart Schools data.

http://ed.ted.com/lessons/how-do-solar-panels-work-richard-komp
Ted Ed lesson, *How Do Solar Panels Work?*, describes how photovoltaics work, and the current limitations on large scale grid connected systems.

https://www.fsec.ucf.edu/go/solar_basics/
Florida Solar Energy Center, "Photovoltaic Fundamentals"

http://vimeo.com/album/1863654/video/38120404
Part of the SunSmart Facility Manager webinar produced by the Florida Solar Energy Center describing the SunSmart system components and how they operate.

http://www.solarschools.net/
Australia's solar school program. This site is a good source of photovoltaic system data from the southern hemisphere.

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Florida NGSS Standards & Related Subject Common Core

			.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	.11	.12
Grade 7														
Earth Structures	**# 6**	**SC.7.E.6**						**X**						
Energy Transfer & Transformations	**# 11**	**SC.7.P.11**		**X**										

Seventh Grade Benchmarks
Science–Big Idea 6: Earth Structures

- SC.7.E.6.6 - Identify the impact that humans have had on Earth, such as deforestation, urbanization, desertification, erosion, air and water quality, changing the flow of water.

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.

National Next Generation Science Standards - Sixth to Eight grade Standards
Science–Motion and Stability: Forces and Interactions

- MS-PS2-3 - Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

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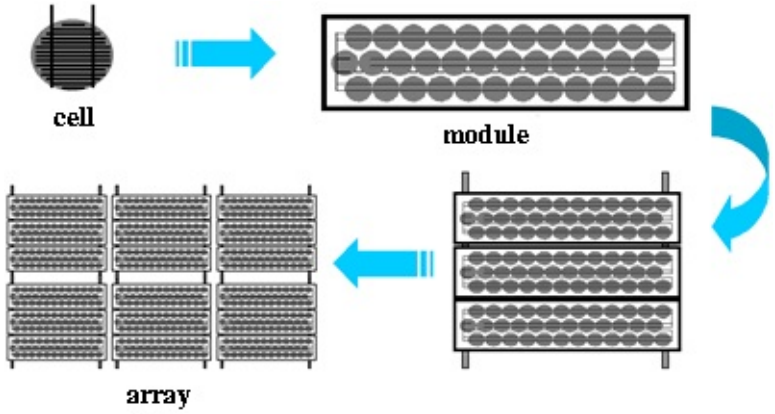
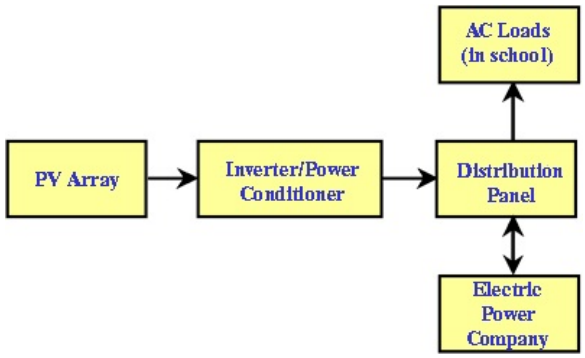
Parts of your Photovoltaic System



The **photovoltaic array** which is made up of several photovoltaic modules, converts sunlight directly into electric current. Like batteries, the current they produce is direct current (DC).



The **inverter** changes the DC electricity produced by the modules into alternating current (AC) which is the type of electricity used in your school and home.

The point where the photovoltaic system output is wired to load circuits (in this case, your school) and to the incoming power lines from the electric utility is the **distribution panel**. This allows the AC power produced by the system to either supply part of the electrical demands of your school or into the general electric power lines if the school does not need the power at that time.

The **electric meter** keeps track of the amount of electrical energy produced by the photovoltaic system. Electrical energy over time is measured in **kilowatt-hours**.

The **data acquisition system** collects data from several different sensors on the system that can be monitored by technicians and posted on the internet where it can be used by students.

Observations

1. With your class, observe the parts of your photovoltaic system that are on the ground (or visible from the ground). Draw a diagram of your system below and label the parts. Draw arrows to show the direction of energy flow.

2. How many photovoltaic modules make up your school's array?

3. If your array currently produces enough electricity to provide 5% of the power your school uses, how many more modules would you need to produce 25% of the school's electricity?

Data Acquisition System
On your computer, locate the page with your school's data.

4. What is the total capacity (in watts) of your photovoltaic system? (Note: The 'system size' is how many kilowatts of electricity your system is designed to produce.)

5. Calculate the electric output that each module adds to the total capacity of your system.

6. Study the graph/data of PV Array Temperature. Describe below what the graph tells you about the temperature for the last day listed and the two days prior. Make sure to include approximate high and low temperatures for each day and what time these temperatures occurred.

7. Look at the AC Power and the DC Current graphs. Why do you think they are similar?

8. Why are the AC Power and the DC Current graphs different?

9. Why would having both channels of data be useful to someone monitoring the system?