

Solar Powered System - 2

Student Objective

The student:

- given a photovoltaic system will be able to name the component parts and describe their function in the PV system
- will be able to access their systems data and be able to explain its function.

Materials:

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

Key Words:

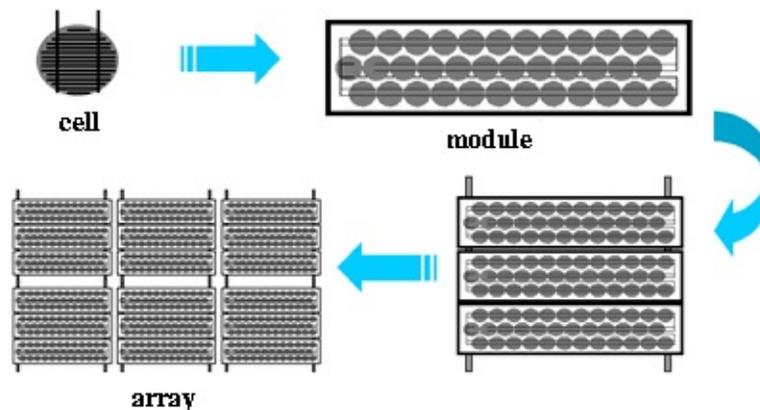
alternating current (AC)
 data acquisition system
 direct current electricity (DC)
 distribution panel
 electric meter
 inverter
 kilowatt hours
 photovoltaic array
 photovoltaic cell
 photovoltaic module
 semiconductor material
 silicon
 voltage

Time: 1 class period

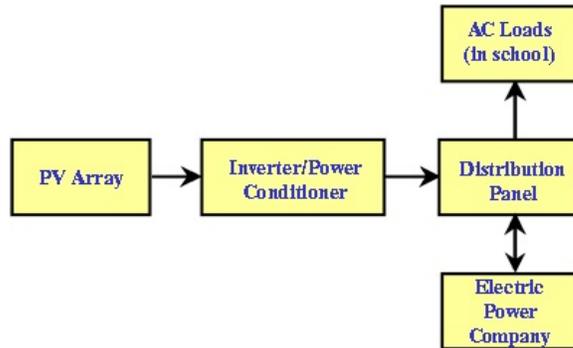
Background Information

Most typical 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. 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.



Besides the solar panels, there are several other pieces of equipment that makes 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 grid (other areas of the school) 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.

Distribution panel - Commonly called a ‘breaker box’, this 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 to feed into the general electric power lines if the school does not need the power at that time. This box is usually located in the school’s electrical room next to the breaker box.

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

Data acquisition system - The 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 all over the world.

Batteries - 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 are controlled by the **Charge Controller**

Procedure

1. Divide students into groups for Data Acquisition activities according to how many computers are available.
2. Discuss background information with the class. Points to cover include:
 - Photovoltaic cells are made up of silicone, the main component of sand. Silicone 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 that battery operated devices use. 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
 - Electric meters measure how much electricity flows through them. This electricity is measure 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. 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 all over the world
- **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** – keeps track of the amount of electrical energy produced by the photovoltaic system
- **inverter** – changes DC electricity produced by the modules into alternating current (AC) which is the type of electricity used in your school
- **kilowatt hours** – basic unit of electrical usage
- **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.
- **transformer** – changes the voltage of the electricity coming from the inverter to match the voltage of electricity that is used in the school building
- **voltage** – a measure of the force or ‘push’ given the electrons in an electrical circuit; a measure of electric potential

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.

Internet Sites:

<http://www.energywhiz.com/>

Florida Solar Energy Center’s website for the SunSmart Schools data

http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/index.htm

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.solar4rschools.org/>

Solar 4R School program

<http://www.txses.org/solar/content/solar-school>

State Energy Conservation Office of Texas’ solar school program

<http://www.solarschools.net/>

Australia’s solar school program

<http://www.pbs.org/wgbh/amex/edison/sfeature/acdc.html>

Public Broadcasting System animated page showing the difference between DC and AC electricity

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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.

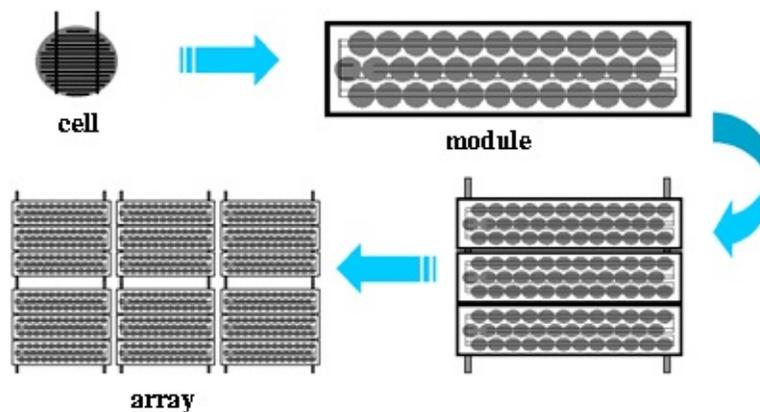
Science–Big Idea 11: Energy Transfer and Transformations

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

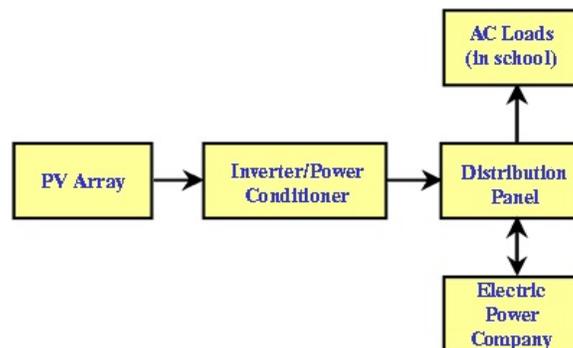
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As part of the SunSmart Schools Program, your school has a photovoltaic (PV) system that provides part of the electricity to power your school. In your PV system, groups of solar cells are connected together in modules (or panels), and the modules are connected together to form a solar array. Each module consists of many different solar cells made of semiconductor materials (mainly silicon) which convert sunlight directly into electrical current, which is then conducted along wires into the school building. Inside your school, the current is conditioned to match the voltage and current type in the electric lines coming from the power company. The energy output from the system can then be used in the school for lighting, computers, air conditioning, or any application powered by electricity. Your PV system does not produce enough energy to power all of your school's needs, but it does reduce the amount of electricity the school needs to purchase from the electric company.

Parts of your Photovoltaic System



Photovoltaic array - The 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).



Inverter - 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 homes.

Distribution panel - 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 to feed into the general electric power lines if the school does not need the power at that time.

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

Data acquisition system - The 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 all over the world.

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, go to the Energy Whiz website at: <http://www.energywhiz.com/> Follow your teacher's instructions to locate your school's SunSmart Schools page.

4. The section "System Specifications" tells about the system that is at your school. The 'system size' is how many kilowatts of electricity your system is designed to produce. What is the total capacity (in watts) of your photovoltaic system?
5. Calculate the electric output that each module adds to the total capacity of your system.
6. Your data acquisition system sends many channels of data to the website. Four of these are turned into graphs that are then posted on the website; the others are available as raw data. The graphs available are:
 - DC power in kW (kilowatts)
 - AC power in kW
 - Irradiance (amount of sunlight hitting the array)
 - Ambient temperature (air temperature at the array site)Each graph covers a day. Study the graph titled "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?