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 electricity (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. During power outages, the emergency loads in the shelter (the identified receptacles and outlets) will be powered by the **batteries**. These batteries are kept constantly charged with power from the array by the **charge controller**. It is the charge controller's job to monitor the batteries and keep them charged, so they will be ready to use at any time. The **data monitor** records information from the system and sends it over the internet to the Florida Solar Energy Center where it is posted for educational and diagnostic use. Below is a typical system with the parts identified.

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.

Further 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 panel produce? Obtain a copy of your school's monthly electric statement to find out what the total electric usage of your school is, and 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://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/

Austrailia'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

http://www.bowdenshobbycircuits.info/

Bowden's Hobby Circuits. Site includes over 100 circuit diagrams. Most of the circuits can be built with common components available at hobby stores or salvaged scrap equipment

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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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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

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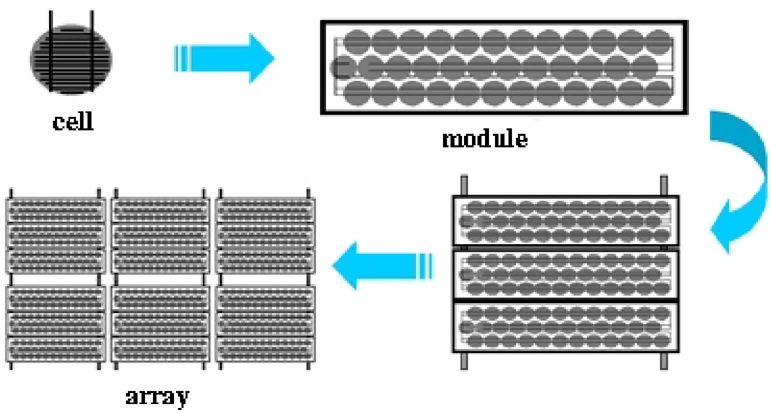
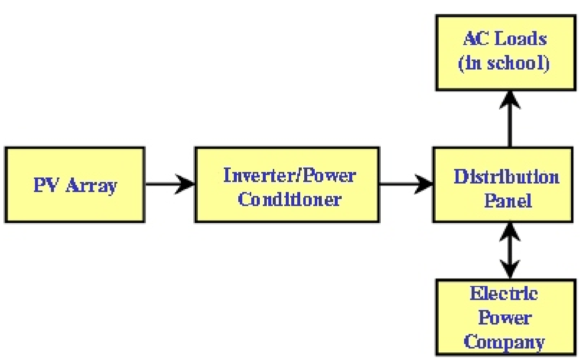
As part of the SunSmart Schools Program, your school has a photovoltaic (PV) system that provides part of the electricity to power your school. In your PV system, groups of solar cells are connected together in modules (or panels), and the modules are connected together to form a solar array. Each module 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?

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.

3. The section "System Specifications" tells about the system that is at your school. The 'capacity' is how many watts of electricity your system is designed to produce. What is the total capacity (in watts) of your photovoltaic system?

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

5. The current weather at the closest weather station to your school is shown. At the present moment, is the weather at your school the same as what is being reported by the weather station?

   If the weather at your school is different, why do you think the weather reported is different than what you see outside right now?

6. Your data acquisition system sends five channels of data to the website. This data is turned into graphs that are then posted on the website:
   - PV system AC power
   - PV system DC volts
   - PV system DC current
   - Plane of array irradiance (amount of sunlight hitting the array)
   - Ambient temperature (air temperature at the array site)

   Each graph covers a day. The hours 12, 36 and 60 on the x-axis correspond to noon on the three days. Study the graph titled "Air Temperature" (or 'ambient temperature on the 9-12 pages). 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?