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.

Key Words:

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

Materials:

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

Time:

1 class period

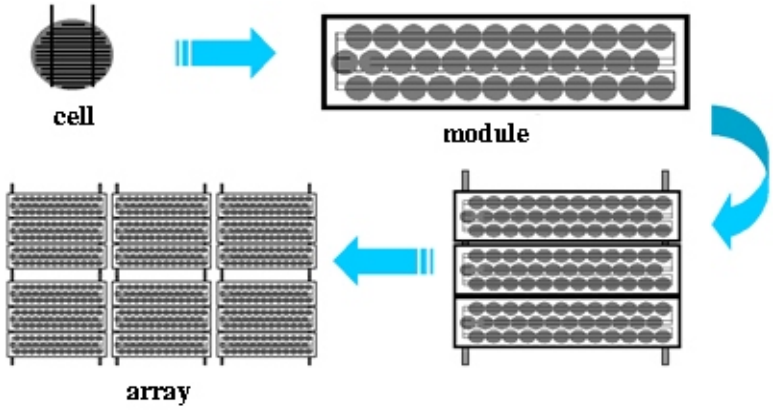
Background Information

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.

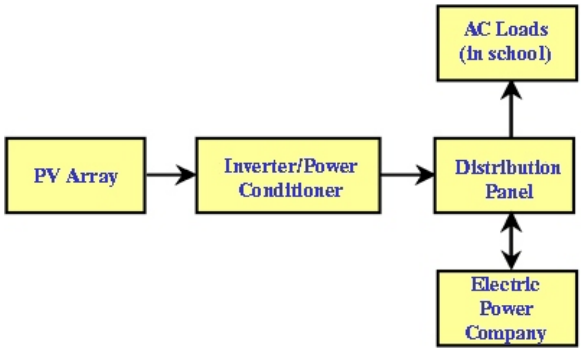
Because typical silicon solar cells produce only about ½ volt, cells are connected together to give more useful voltages. Usually 30 - 36 solar cells are connected in a circuit to give a final voltage of about 15-17 volts. To increase the power output further, modules are connected together to form an array.

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.

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 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 3										
The Practice of Science	Big Idea 1	SC.3.N.1	**X**	**X**					**X**	
Earth Structures	Big Idea 6	SC.3.E.6	**X**							
Grade 4										
The Practice of Science	Big Idea 1	SC.4.N.1	**X**	**X**		**X**				
Grade 5										
The Practice of Science	Big Idea 1	SC.5.N.1	**X**							

Third Grade Benchmarks

Science–Big Idea 1: The Practice of Science

- SC.3.N.1.1 - Raise questions about the natural world, investigate them individually and in teams through free exploration and systematic investigations, and generate appropriate explanations based on those explorations.
- SC.3.N.1.2 - Compare the observations made by different groups using the same tools and seek reasons to explain the differences across groups.
- SC.3.N.1.7 - Explain that empirical evidence is information, such as observations or measurements, that is used to help validate explanations of natural phenomena.

Science–Big Idea 6: Earth Structures

- SC.3.E.6.1 - Demonstrate that radiant energy from the Sun can heat objects and when the Sun is not present, heat may be lost.

Fourth Grade Benchmarks

Science–Big Idea 1: The Practice of Science

- SC.4.N.1.1 - Raise questions about the natural world, use appropriate reference materials that support understanding to obtain information (identifying the source), conduct both individual and team investigations through free exploration and systematic investigations, and generate appropriate explanations based on those explorations.
- SC.4.N.1.2 - Compare the observations made by different groups using multiple tools and seek reasons to explain the differences across groups.
- SC.4.N.1.4 - Attempt reasonable answers to scientific questions and cite evidence in support.

Fifth Grade Benchmarks

Science–Big Idea 1: The Practice of Science

- SC.5.N.1.1 - Define a problem, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigations of various types such as: systematic observations, experiments requiring the identification of variables, collecting and organizing data, interpreting data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

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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.

voltage – a measure of the force or 'push' given the electrons in an electrical circuit; a measure of electric potential

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Observations

1. With your class, observe the parts of your SunSmart solar 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 system? _____

4. How much of the total output does each module provide? _____

5. Your system sends data to this website. This data is turned into graphs that are then posted for everyone to study. These include graphs for:

- PV system AC power in kWh (the power your school uses)
- PV system DC power (what the array produces before the inverter changes it)
- Amount of sunlight hitting the array
- Air temperature at the array site

Each graph covers a day. Study the graph titled "Air Temperature" (or 'ambient 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.

Date: _____

High Temperature _____ Time _____

Low Temperature _____ Time _____

Date: _____

High Temperature _____ Time _____

Low Temperature _____ Time _____

Date: _____

High Temperature _____ Time _____

Low Temperature _____ Time _____

6. What was the weather like yesterday? Was it sunny? Cloudy? Rainy? Write a description of yesterday's weather below:

_____

_____

_____

7. Look at the Amount of Sunlight (Irradiation) graph for yesterday. How does it compare to what you remember about yesterday's weather?

_____

_____

_____

8. If the Amount of Sunlight graph has 'bumps' in it, what do you think caused these bumps?

_____

_____

9. Why do you think the Amount of Sunlight graphs often are shaped like a hill?

_____

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