Solar Powered System - 2

Student Objective
The student:
- 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)
distribution panel
inverter
kilowatt hours
photovoltaic array
photovoltaic cell
photovoltaic module
semiconductor material

Materials:
- viewing access to school's photovoltaic system
- computer with internet access

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.

Procedure

1. Group students together for this Data Acquisition activity according to how many computers are available.
2. **Engage:** Discuss background information with the class. Points to cover include:
   - Photovoltaic cells are made up of silicone, 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 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. The circuits in homes, schools and businesses carry alternating current (AC) electricity
- Electric meters measure how much electricity flows through them. This electric energy is measure in kilowatt hours units

3. Escort students outside to observe the school system. If possible, let them look at the system components that are housed inside also.
4. **Explore:** Students should analyze, compare and contrast information as they complete their Laboratory Manual pages.

Further Research

1. Research 'single crystal', 'polycrystalline' and 'thin film' photovoltaics. Which type of PV cells is your school's system made out of? What are the advantages and disadvantages of this type of cell?
2. What percentage of your school's electrical usage does the PV array produce? Obtain a copy of your school's monthly electric statement or cost of its monthly electric usage and caldulate 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 money.

Internet Sites:

http://www.energywhiz.com/

Website produced by the Florida Solar Energy Center that hosts the PV for schools data.

http://www.fsec.ucf.edu/pvt/pvbasics/index.htm

Florida Solar Energy Center, "Photovoltaic Fundamentals"

http://wattsonschools.com/

Watts on Schools, the Texas PV for Schools program. Includes lesson plans and access to data from the Texas schools.

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 from Radio Shack or salvaged from scrap electronic equipment.

Solar Powered System - 2

Answers - Laboratory Manual

1-2. Answers will vary depending on your school's system.

3. Answers should match the information given for your school on the Energy Whiz website.

4. Answers will vary, but students should show an understanding of the need to tilt the array to be perpendicular to the rays of the Sun. Advanced students should show their understanding of solar noon, and the correlation of the tilt angle to the school's latitude.

5. Roof mount arrays are sometimes positioned to match the pitch of the roof. However, the ground mounted arrays in the SunSmart program should all be positioned at the optimal angle. For further information on your particular school's array (or if you seem to have an exception to this), contact the Florida Solar Energy Center's Education Department.

6. Students should show an understanding that since the DC is converted to AC, the shape of the graph will be the same.

7. The AC graph will show slightly less power on all points than the DC graph because of energy losses during the conversion to AC from DC at the inverter.

8. Differences in AC power graph not shown in the DC power graph would tell an operator that something was malfunctioning between the photovoltaic panel and the output of the inverter–possibly the inverter.

Answers - Problems

1-3. Answers will vary depending on the output of your system. Check student math.

4. Answers will vary from student to student, however, the average home could be powered by a 7 - 10 kW system. Check to see if students are using units correctly–comparing one week's power output of the school's system to one week's household power output.

Solar Powered System - 2

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Nature of Science																					
Standard 4	**SC.912.N.4**		**X**																		
Earth and Space																					
Standard 5	**SC.912.E.5.**				**X**																
Standard 6	**SC.912.E.6.**						**X**														
Physical Science																					
Standard 10	**SC.912.P.10.**															**X**					
Life Science																					
Standard 17	**SC.912.L.17.**																	**X**			
Mathematics Standards		**MA.912.A.1.4, MA.912.A.2.2, MA.912.A.2.7, MA.912.A.2.12, MA.912.A.5.5, MA.912.A.5.7**																			

Science Standards
Standard 4: Science and Society
- SC.912.N.4.2 - Weigh the merits of alternative strategies for solving a specific societal problem by comparing a number of different costs and benefits, such as human, economic, and environmental.

Standard 5: Earth in Space and Time
- SC.912.E.5.4 - Explain the physical properties of the Sun and its dynamic nature and connect them to conditions and events on Earth

Standard 6: Earth Structures
- SC.912.E 6.6 - Analyze past, present, and potential future consequences to the environment resulting from various energy production technologies.

Standard 10: Energy
- SC912.P.10.15 - Investigate and explain the relationships among current, voltage, resistance and power.

Standard 17: Interdependence
- SC.912.L.17.11 - Evaluate the costs and benefits of renewable and nonrenewable resources, such as water, energy, fossil fuels, wildlife, and forests.
- SC.912.L.17.17 - Assess the effectiveness of innovative methods of protecting the environment.

Mathematics Standards

Algebra - Standard 1: Real and Complex Numbers

- MA.912.A.1.4 - Perform operations on real numbers (including integer exponents, radicals, percent, scientific notation, absolute value, rational numbers, irrational numbers) using multi-step and real-world problems.

Algebra - Standard 2: Relations and Functions

- MA.912.A.2.2 - Interpret a graph representing a real-world situation.
- MA.912.A.2.7 - Perform operations (addition, subtraction, division, and multiplication) of functions algebraically, numerically, and graphically.
- MA.912.A.2.12 - Solve problems using direct, inverse, and joint variations.
- MA.912.A.1.13 - Solve real-world problems involving relations and functions.

Algebra - Standard 5: Rational Expressions and Equations

- MA.912.A.5.5 - Solve rational equations.
- MA.912.A.5.7 - Solve real-world problems involving rational equations (mixture, distance, work, interest and ratio)

Solar Powered System - 2

alternating current electricity (AC) – a flow of electric charge that reverses its direction at regular intervals. This type of electric flow in the United States is sent over electrical transmission lines, and typically used in homes, offices and schools.

data acquisition system – a system that 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.

direct current electricity (DC) – a flow of electric charge moving in one direction only. This type of electric flow is typically used in battery operated devices, automobiles and boats.

inverter – changes the DC electric charge produced by the modules into alternating current (AC) which is the type of electricity used in your school and homes.

kilowatt hours – the basic unit of electric energy used in one hour.

photovoltaic array – the term for the 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 will conduct electric energy under certain conditions; its electron flow is between conductors and insulators. Silicon, arranged in a crystalline structure, is used in microchips and PV cells to facilitate the flow of electricity.

silicon – a metalloid element with four valence electrons that is the main component of photovoltaic cells. Silicone is most commonly found in the earth's sand.

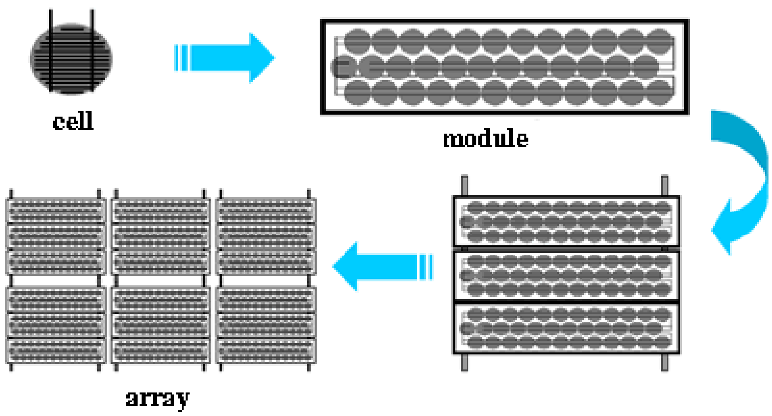
transformer – changes the voltage of the electricity coming from the inverter to match the voltage of electricity that is used in the school building.

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

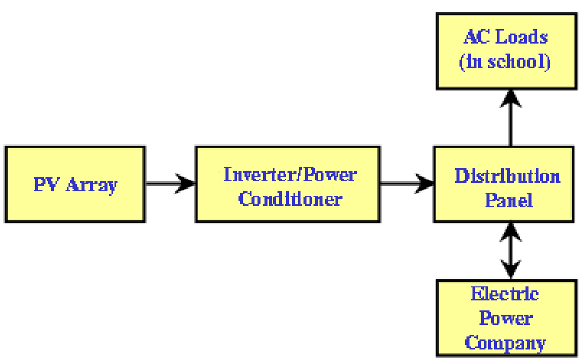
Solar Powered System - 2

As part of the PV for 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 converts sunlight directly into electrical current, which is then conducted along wires into the school building. At the inverter, the current is conditioned to match the voltage and current type present inside the school building (DC is converted to AC and the frequency of the utility's power grid is matched). 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 purchases from the electric company.

Parts of your Photovoltaic System



Photovoltaic array - The array which is made up of several photovoltaic modules converts or transforms 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

With your class, observe your school's photovoltaic system.

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

2. Locate your school's data page on the Energy Whiz website at: **http://www.energywhiz.com/** 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. From the total capacity (in watts) of your photovoltaic system, calculate the electric output of a single module in your system.

3. What is the tilt angle listed for your system?

4. From what you discovered in the previous photovoltaic investigations, why do you think your array is positioned at that angle?

5. If your array is not positioned at the 'optimal' angle for your location, why do you think it was installed at a different angle?

6. Look at the AC Power and the DC Current graphs on the Energy Whiz site. Why do you think they are similar?

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

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

Solar Powered System - 2

Given: $\text{Efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100$

1. Calculate your system's efficiency in converting the Sun's energy to DC electricity.

2. Calculate your system's efficiency in converting DC to AC electricity.

3. Calculate the dollar amount of electricity offset (savings to the school) for yesterday, last week, last February, and last July.
   Note: if you do not know the cost to your school for electricity, use 12 cents per kWh.

   a. Yesterday's savings -

   b. Last week's savings -

   c. February savings -

   d. July savings -

4. Using one of your family's monthly electric bills, and assuming the output from your school's system for the last week is typical of its output over a course of time, determine if a system the size of your school's SunSmart system would be sufficient for your family's power needs. If the system is either too large or too small, calculate the percentage increase or decrease in size your home system should be to be a more perfect match to your family's energy needs.