We've Got the Power!

Student Objective
The student:

- will be able to explain the relationship between irradiance and the amount of power (DC) output of the photovoltaic array
- given a graph of a photovoltaic system's power output will be able to deduce what the weather was for the given day
- given the weather outside and the time, will be able to approximate the power output of the array

Key Words:
direct current (DC)
irradiance
kilowatts per hour (kWh)
photovoltaic array
watts/kilowatts

Time:
1 class period

Materials:

- computer or handheld device with internet access
- computer with internet access capable of projecting for the class (alternately, graphs could be reproduced on overhead transparencies)
- web based weather application with current and historical (past month) weather data

Background Information

Local weather has a dramatic effect on the electrical output from a photovoltaic array. The most obvious factor is cloud cover, but temperature also affects the output from the array (higher temperatures decrease the electrical output slightly–this will be covered in the later lesson, *Changes in Latitude*). Additionally, in areas without adequate rainfall, the photovoltaic output can be adversely affected by an accumulation of dust and bird droppings, and of course snow cover will block sunlight from reaching the surface of the solar cells. Luckily in Florida, we don't usually have to worry about either of these two conditions!

Irradiance is the measure of the intensity of sunlight, and is expressed as watts per square meter (W/m^2). On a sunny, clear-sky day at solar noon, at sea level, the typical irradiance level is 1,000 W/m^2. This value of irradiance is used as the standard test condition (STC) for photovoltaic testing and design calculations, and is the basis of the manufacturers stated output for cells and panels.

On a clear cloudless day, irradiance will peak at solar noon; a graph of irradiance over time will produce a bell shaped curve. Large banks of clouds, thunderstorms and weather fronts are all readily apparent on a graph of irradiance, and since photovoltaic output is directly related to irradiance, these weather events can be seen on a graph of the output.

On consistently overcast days, the curve will have the same width but will be much lower, and on partly cloudy days with patch of clouds intermingled with bright sun, the curve will tend to be spiky, showing that the system produces more energy during sunny periods and less energy during cloudy periods.

Procedure (prior to class)

1. Familiarize yourself with the Sun Town static graphs on the Energy Whiz website. These can be accessed by selecting the Sun Town school on the pull down menu.
2. Familiarize yourself with the data being collected for your school's system, or alternately if your school does not have a monitored photovoltaic array, choose an available school from the list on the Energy Whiz website (www.energywhiz.com) for classroom use. If possible, use a school that is nearby or one that usually has the same general weather patterns as your school. Navigate through the different screens, so you will be able to guide your students in locating irradiance and DC output, and also historical data (irradiance and DC output) for the last month.
3. Locate a weather app that gives accurate current and historical weather data for your school (or the school you have chosen).

Procedure (during class)

1. If necessary, divide the students into groups according to how many computers are available to them.
2. Lead the class in a discussion/review of their findings from previous lesson on the different factors that can affect the output of photovoltaics, making sure that weather is mentioned and discussed.
3. Tell the students that they will be investigating how weather conditions affect the amount of electricity that the array at their school produces.
4. Lead a discussion on the nature of sunlight during the day.
    - Ask the class to describe how the 'brightness' of sunlight changes throughout the day.
    - Guide the students to talk about how the light from the Sun gets stronger and brighter from dawn to solar noon, and then slowly gets weaker and dimmer until sundown.
5. Draw the framework of a two axis graph on the board (intensity of sunlight on the y and time on the x. Don't worry about putting any numerical values on the y axis yet). Ask students to draw on a sheet of paper what they think a graph of the intensity of sunlight would look like. (Students may work in groups or individually)

- After the majority of students have put something on their paper, ask for a volunteer to share their idea on the board.
- Lead a discussion about this graph; have students modify the graph to show their suggestions. Guide them as necessary.
- When the students have closely approximated a bell shaped curve, write the Energy Whiz website address on the board and have the students navigate there and then select the Sun Town school. (This ensures that they will be using graphs that will be easy for them to analyze). Guide the students to the irradiance graph.
- Have the students explain how this graph is similar and different from the graph that they created. Ask the students to describe the weather for that day.

6. Have the students switch to the graph showing irradiance on a day with an afternoon rainstorm. They should be able to explain and point out sunrise, sunset, clouds and afternoon heavy clouds (thunderstorm).
7. Students should complete their Science Journal pages. Assist them as needed. If the students are unable to print the graphs for use in the exercise, they can trace them off of the screen using tracing paper.
8. After the students complete their Science Journal pages, lead a discussion on their findings. Points to include are:
   - One measurement (weather) may be inferred by looking at another measurement (in this case the amount of sunlight)
   - Shading the array with trees or other structures would cause a decrease in the amount of electricity that the array would produce

Further Research

1. Have the students shade large areas of the array with sheets of cardboard or blankets to simulate heavy clouds. Observe the output. Have them cover areas with screen or gauze material to simulate hazy conditions. Observe the output.

Internet Sites

http://rredc.nrel.gov/solar/old_data/nsrdb/

National Solar Radiation Database contains 30 years (1961-1990) of solar radiation and supplementary meteorological data from 237 NWS sites, plus a user manual to help in reading the tabular information.

http://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/solar-radiation/

National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center is responsible for preserving, monitoring, assessing, and providing public access to the Nation's treasure of climate and historical weather data and information. Here you can find data on solar radiation and climate conditions in the United States

http://wrdc-mgo.nrel.gov/

World Radiation Data Centre.Worldwide solar radiation site.

http://en.openei.org/wiki/Main_Page

Open Energy Information (OpenEI) is a knowledge sharing online community dedicated to connecting people with the latest energy information and data.

http://www.weather.com/

The Weather Channel provides local weather conditions and historical data.

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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

irradiance - measure of the amount of sunlight at a particular time and place

kilowatt - 1000 watts

kilowatts per hour (kWh) - the standard unit used to describe electricity usage over time

photovoltaic array - complete unit of solar modules

watts - the standard unit used to measure electricity, specifically the rate at which electrical energy is dissipated. Watts are calculated by multiplying amperage and voltage.

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1. **Irradiation** is the scientific term for the amount of sunshine that strikes an object. How does the amount of irradiation (sunlight) affect the amount of electricity that your school's photovoltaic system produces? Write a hypothesis below that describes the relationship between the amount of solar irradiance and the electric output of your system. Your hypothesis should include what would happen on a sunny day, an overcast day, and a partly cloudy day (one with big puffy clouds).

Gather the data to verify your hypothesis. On the Energy Whiz website, print a copy of the SunTown data graphs for two different days. Cut out the two graphs *Plane of Array Irradiance* and *PV System DC Current*, and tape them below, for each day taping the irradiance graph directly above the DC current graph.

2. From the *Plane of Array Irradiance* graphs, what can you say about the weather on the two days? Describe each day below.

Day 1: ____

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Day 2: ____

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3. Study the two graphs for Day 1 (Irradiance and DC Output). Are they similar or different? Describe below how they are similar and how they are different.

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4. Now look at the two graphs for Day 2 (Irradiance and DC Output). Are they similar or different? Describe the how they are similar and how they are different below.