Good Day Sunshine!

Student Objective

The student:

- will be able to explain the relationship between the amount of sunlight and the power produced by a photovoltaic device
- given a graph of solar irradiance will be able to predict the performance of a photovoltaic system
- given a graph of a photovoltaic system's power output will be able to deduce what the weather was for the given days
- will be able to infer from a table of irradiation data the relative amount of sunlight in different locations at different times of the year.

Key Words:
hypothesis
irradiance
irradiation
pyronometer

Time:
1 class period

Materials:

- computer with internet access
- Science Journal pages

Internet Sites:

Background Information

The performance of the school's solar photovoltaic system at any given time depends primarily on the amount of sunlight available to it. On bright, sunny days, the system gradually produces more and more energy throughout the day until the sun is directly overhead. A graph showing the energy production of the PV system over time on a sunny day will resemble a smooth, tall, bell shaped curve.

On consistently overcast days, the curve will have the same width but will be much lower, and on partly cloudy days with patched 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

1. If necessary, divide the students into groups according to how many computers are available to them.
2. Lead a review discussion on their findings during the *Solar Powered System* activity as it related to sun and shade.
3. Students should complete their Science Journal pages. Assist them as needed.
4. 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.
5. After the students complete their Science Journal pages, lead a discussion on their findings. Points to include are:
    - Temperature has less to do with the amount of total irradiance than cloud cover.
    - Florida may call itself the 'Sunshine State', but other states have more sunshine at some times of the year!
    - Florida has rainy seasons, and times of afternoon thunderstorms. This reduces the total amount of sunlight we receive.
    - One measurement (weather) may be inferred by looking at another measurement (in this case amount of sunlight).

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			.1	.2	.3	.4	.5	.6	.7
Energy	**Standard 1**	**SC.B.1.3-**	**X**	**X**	**X**				
	Standard 2	**SC.B.2.3-**							
Earth and Space	**Standard 1**	**SC.E.1.3-**	**X**						
	Standard 2	**SC.E.2.3-**							
How Living Things Interact W/ Their Environment	**Standard 1**	**SC.G.1.3-**							
	Standard 2	**SC.G.2.3-**	**X**						
Nature of Science	**Standard 1**	**SC.H.1.3-**							
	Standard 2	**SC.H.2.3-**							
	Standard 3	**SC.H.3.3-**							**X**
Other Standards:	**MA.D.1.3.2, MA.E.1.3.1**								

Benchmark SC.B.1.3.1 - The student identifies forms of energy and explains that they can be measured and compared.

Grade Level Expectations

The student:

Sixth

- knows different types of energy and the units used to quantify the energy
- understands that energy can be converted from one form to another

Seventh

- knows examples of uses of energy in the home and ways to measure its use

Eighth

- knows examples of natural and man-made systems in which energy is transferred from one form to another.

Benchmark SC.B.1.3.2 - The student knows that energy cannot be created or destroyed, but only changed from one form to another.

Grade Level Expectations

The student:

Sixth

- understands that energy can be changed in form
- uses examples to demonstrate common energy transformations

Benchmark SC.B.1.3.3 - The student knows the various forms in which energy comes to Earth from the Sun.
Grade Level Expectations
The student:
Seventh
- knows the characteristics, effects, and common uses of ultraviolet, visible and infrared light.

Eighth
- knows ways to measure the various forms of energy that come from the Sun.

Benchmark SC.E.1.3.1 - The student understands the vast size of our Solar System and the relationship of the planets and their satellites.
Grade Level Expectations
The student:
Seventh
- understands that the tilt of the Earth on its axis as it rotates causes seasonal changes.

Benchmark SC.G.2.3.1 - The student knows that some resources are renewable and others are nonrenewable.
Grade Level Expectations
The student:
Sixth
- knows renewable and nonrenewable energy sources.

Eighth
- knows that some resources are renewable and others are nonrenewable

Benchmark SC.H.3.3.7 - The student knows that computers speed up and extend people's ability to collect, sort, and analyze data; prepare research reports; and share data and ideas with others.
Grade Level Expectations
The student:
Sixth
- uses a computer to collect, analyze, and report scientific findings

Seventh
- extends and refines use of a computer to collect, analyze, and report scientific findings

Eighth
- uses a variety of technologies to collect, analyze, and report scientific findings.

Benchmark MA.D.1.3.2 - The student creates and interprets tables, graphs, equations, and verbal descriptions to explain cause-and-effect relationships.
Grade Level Expectations
The student:

Sixth
- interprets and creates function tables and graphs.

Seventh
- interprets and creates function tables and graphs

Eighth
- interprets and creates tables and graphs.

Benchmark MA.E.1.3.1 - The student collects, organizes, and displays data in a variety of forms, including tables, line graphs, charts, bar graphs, to determine how different ways of presenting data can lead to different interpretations.

Grade Level Expectations

The student:

Sixth
- reads and analyzes data displayed in a variety of forms
- constructs, interprets, and explains displays of data, such as tables and graphs

Seventh
- interprets and analyzes data presented in a variety of forms, including box-and-whisker graphs and scatter plots
- constructs, interprets, and explains displays of data, such as tables and graphs and explains how different displays of data lead to different interpretations

Eighth
- reads and interprets data displayed in a variety of forms including histograms
- constructs and interprets displays of data, and explains how different displays of data can lead to different interpretations.

Good Day Sunshine!

hypothesis – An explanation for an observation, phenomenon, or scientific problem that can be tested by further investigation.

irradiance - The measure of the power density of sunlight. Expressed in watts per square meter.

irradiation - The measure of the energy density of sunlight reaching an area summed over time. Usually expressed in kilowatts per square meter per day.

pyronometer – a device to measure the amount of solar irradiance

Good Day Sunshine!

1. **Irradiation** is the scientific term for the amount of sunshine that strikes an object. How does the amount of irradiation 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 your school's data graphs. Cut out the two graphs *Plane of Array Irradiance* and *PV System DC Current*, and tape them below, one directly above the other.

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

Day 1:

Day 2:

Day 3:

3. Study the two graphs. Are they similar or different? Describe below how they are similar and how they are different.

4. Did the data agree or disagree with your hypothesis? Explain.

Scientists have been collecting irradiance data from places all over the world since 1960. This data has been used to calculate the average amount of sunlight at these places for different times of the year. In order to make the data comparable from place to place and even out the effects of daily weather, the data is converted into an equivalent number of maximum sun hours. A very sunny day would have a value of 4 - 6 sun hours while a cloudy day may only have the equivalence of 1 sun hour.

The irradiance data for Orlando, Florida is shown below.

Insolation (irradiance) – kWh/m^2-day – for Orlando, FL (28.55º North Latitude)

Tilt	Jan	Feb	Mar	Apr	Ma	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
0º	3.14	3.92	4.99	5.99	6.27	5.78	5.68	5.28	4.72	4.11	3.46	2.92	4.69
15º	3.75	4.43	5.30	6.05	6.10	5.54	5.49	5.24	4.89	4.53	4.06	3.56	4.91
20º	3.92	4.56	5.36	6.01	5.99	5.41	5.37	5.18	4.90	4.63	4.23	3.74	4.94
25º	4.07	4.67	5.39	5.95	5.85	5.26	5.23	5.10	4.89	4.70	4.37	3.90	4.95
30º	4.19	4.75	5.39	5.85	5.67	5.07	5.06	4.99	4.86	4.75	4.49	4.04	4.93
35º	4.29	4.80	5.36	5.72	5.47	4.87	4.87	4.85	4.79	4.77	4.58	4.15	4.88
40º	4.37	4.82	5.31	5.56	5.24	4.63	4.66	4.69	4.71	4.76	4.64	4.24	4.80

5. Notice that the irradiance data is listed for several different panel tilts (first column). According to your school's data page, what is the tilt of your school's panel?

Use the tilt angle in the table above, that is closest to your system's tilt angle to answer questions 6 - 10.

6. According to the chart above, which month has the greatest amount of sunlight, March or August?

7. We usually think of the summer months as being the sunniest and therefore the best for photovoltaic systems. Is this a correct assumption?

8. Which month out of the year has greatest amount of sun hours?

9. Which month of the year has the least amount of sun hours?

10. Draw a line graph to show the average amount of sun hours (y-axis) for the months of the year (x-axis).

The irradiance data for Orlando and Spokane, Washington are below.

Insolation (irradiance) – kWh/m^2-day – for Orlando, FL (28.55º North Latitude)

Tilt	Jan	Feb	Mar	Apr	Ma	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
0º	3.14	3.92	4.99	5.99	6.27	5.78	5.68	5.28	4.72	4.11	3.46	2.92	4.69
15º	3.75	4.43	5.30	6.05	6.10	5.54	5.49	5.24	4.89	4.53	4.06	3.56	4.91
20º	3.92	4.56	5.36	6.01	5.99	5.41	5.37	5.18	4.90	4.63	4.23	3.74	4.94
25º	4.07	4.67	5.39	5.95	5.85	5.26	5.23	5.10	4.89	4.70	4.37	3.90	4.95
30º	4.19	4.75	5.39	5.85	5.67	5.07	5.06	4.99	4.86	4.75	4.49	4.04	4.93
35º	4.29	4.80	5.36	5.72	5.47	4.87	4.87	4.85	4.79	4.77	4.58	4.15	4.88
40º	4.37	4.82	5.31	5.56	5.24	4.63	4.66	4.69	4.71	4.76	4.64	4.24	4.80

Insolation – kWh/m^2-day – for Spokane, WA (47.63º North Latitude)

Tilt	Jan	Feb	Mar	Apr	Ma	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
0º	0.99	1.91	3.28	4.72	6.05	6.57	7.44	6.13	4.53	2.65	1.25	0.81	3.86
35º	1.84	2.93	4.13	5.10	5.91	6.14	7.12	6.41	5.45	3.84	2.18	1.63	4.40
40º	1.92	3.01	4.16	5.04	5.76	5.95	6.92	6.31	5.46	3.93	2.27	1.71	4.38
45º	1.99	3.08	4.17	4.97	5.59	5.73	6.69	6.18	5.44	3.99	2.34	1.78	4.34
50º	2.05	3.13	4.16	4.86	5.39	5.49	6.42	6.01	5.39	4.03	2.40	1.84	4.27
55º	2.09	3.15	4.12	4.73	5.17	5.22	6.13	5.81	5.31	4.05	2.44	1.89	4.18
60º	2.12	3.16	4.06	4.58	4.92	4.93	5.80	5.59	5.20	4.04	2.46	1.92	4.07

11. On the average, which location has the greatest amount of sun hours in July? (Hint: Average the values for the different tilt angles together).

    July irradiance average for Orlando Florida:

    July irradiance average for Spokane Washington:

12. Is this what you would have expected? Why or why not?

13. Which location has the greatest yearly average irradiance?