

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
- 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 or hand held device with internet access
- Science Journal pages

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 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

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:
 - 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.

Key Words & Definitions

- **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

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 Center. Worldwide solar radiation site.

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Grade 6														
Practice of Science	# 1	SC.6.N.1	X											
Grade 7														
Practice of Science	# 1	SC.7.N.1	X											
Energy Transfer & Transformations	# 11	SC.7.P.11		X										
Grade 8														
Practice of Science	# 1	SC.8.N.1	X											

Sixth Grade Benchmarks

Science–Big Idea 1: The Practice of Science

- SC.6.N.1.1 - Define a problem from the sixth grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

Seventh Grade Benchmarks

Science–Big Idea 1: The Practice of Science

- SC.7.N.1.1 - Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

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.

Eighth Grade Benchmarks

Science–Big Idea 1: The Practice of Science

- SC.8.N.1.1 - Define a problem from the eighth grade curriculum, using appropriate reference materials to support scientific understanding, plan and carry out scientific

investigations of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

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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/m²-day – for Orlando, FL (28.55° North Latitude)

Array Tilt	Jan	Feb	Mar	Apr	Ma	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
0°	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
15°	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
20°	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
25°	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
30°	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
35°	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
40°	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

1. 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 2 - 6.

2. According to the chart above, which month has the greatest amount of sunlight, March or August?
3. We usually think of the summer months as being the sunniest and therefore the best for photovoltaic systems. Is this a correct assumption?

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

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

6. 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/m²-day – for Orlando, FL (28.55° North Latitude)

Array Tilt	Jan	Feb	Mar	Apr	Ma	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
0°	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
15°	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
20°	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
25°	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
30°	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
35°	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
40°	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/m²-day – for Spokane, WA (47.63° North Latitude)

Array Tilt	Jan	Feb	Mar	Apr	Ma	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
0°	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
35°	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
40°	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
45°	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
50°	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
55°	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
60°	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

7. 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:

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

9. Which location has the greatest yearly average irradiance?