Solar Energy in New York

Suggested Level: Middle school students – physical science or social studies

LEARNING OUTCOME

Students realize that even though New York State is not considered a Sunbelt location, sufficient solar energy is available this far north, even through cloud covers, to address our electrical needs.

LESSON OVERVIEW

In this lesson, students examine a variety of information for New York State including insolation data and economic/political data, such as tax credits. They decide for themselves whether greatly increasing the amount of surface area devoted to photovoltaic systems would be a wise investment for New York State.

MATERIALS

- Student worksheet
- PV array
- Yellow-colored pencil
- Red-colored pencil

SAFETY

There are no particular safety precautions for this lesson.

TEACHING THE LESSON

Introduce this worksheet activity through a class discussion. Concentrate on the feasibility of using solar energy for the generation of electric power in the northeastern United States, in general, and in New York State, specifically. Determine preexisting student biases regarding solar energy. Make a list of such opinions for later use.

- Allow students adequate time to complete the worksheet.
- Conduct a post-worksheet discussion to address previously-stated opinions on the class list.
- Consider supplementing this lesson by making a PowerPoint presentation for your students using information about solar electric power.

ACCEPTABLE STUDENT RESPONSES

1. There is not much potential for the successful use of solar energy.
2. The difference is about 38% between the southwestern U.S. deserts and downstate New York, using the values 725 for the southwest and 525 for the northeast.
3. Roofs of buildings
4. 22/160 = 13.75%
5. About 60 watt-hours per day
6. A 2.5-watt light bulb
7. 20 square feet

8. Clouds reduce sunlight by absorbing and reflecting radiation, while there is virtually no sunlight at night other than reflected moonlight.

9. Air conditioning

10. Turn the air conditioner thermostat up a few degrees.

11. Because New York City is in the lightest region, there is a close correlation between demand and PV supply.

12. A fixed solar array cannot adjust to the changing position of the sun during the day. Both the altitude and the direction of the sun change during the day as the earth rotates on its axis. Both of these variables also change during the year as the earth changes its position in its orbit. The sun-tracking system turns with the sun so that it receives maximum radiation intensity. Such a system is more effective, but it is more costly and requires higher maintenance and additional space.

13. Fixed

14. Because the tracker can aim at the sun, the overall pattern is controlled by the thickness of the atmosphere that the sun's rays pass through as the sun moves across the sky (less atmosphere when the sun approaches a perpendicular position). The irregular pattern during the day is caused by factors such as clouds and smog.

15. Because we are trying to provide electricity during July afternoons in New York City, aiming the solar panels 35 degrees to the west of south would maximize solar collection around 2:20 p.m. (15 degrees of the earth's rotation/hour). The 30-degree tilt of the collector would produce perpendicular sun's rays when the sun is 70 degrees above the horizon. Since NYC has a latitude of about 41 degrees north, maximum altitude of the sun on June 21 = 90 – (41 – 23.5) = 90 – 17.5 = 72.5 degrees. During July the maximum altitude is in the low 70s to high 60s.

16. Responses should vary, but the desirable state is that a collector array collects as much energy as possible during the entire year. So the array should be aligned facing south directly at a pitch of 90 degrees minus the school's latitude.

17. By small sections in the upper right section of each graph peak

18. Release of energy from a generator that is not working at full capacity or the use of a pump storage hydroelectric-type facility such as the one located at Gilboa, New York.

19. Because fortuitously it provides an energy supply that peaks at the same time that electricity demands peak for running air conditioning in office buildings.

BACKGROUND INFORMATION

The efficiency of solar PV cells is limited by two major constraints:

1) only 45% of solar radiation is of a wavelength less than that needed to free the electrons in the PV cells' silicon component, and

2) radiation having wavelengths less than the threshold wavelength of 1.15 microns has more energy than needed and this extra energy is lost as heat.

$$\frac{22{,}000 \text{ watts x hours}}{\text{year}} \times \frac{\text{year}}{365 \text{ days}} = \frac{22{,}000 \text{ watts x hours}}{365 \text{ days}} = \frac{60 \text{ watt-hours}}{\text{day}}$$

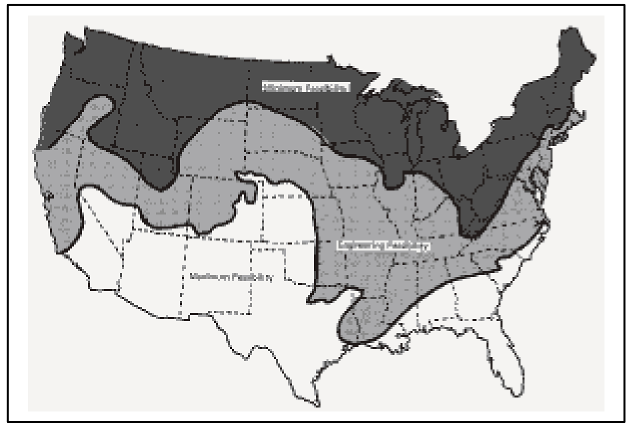
(STUDENT HANDOUT FOLLOWS)

Name

Date

Solar Energy in New York

Not Enough Sun

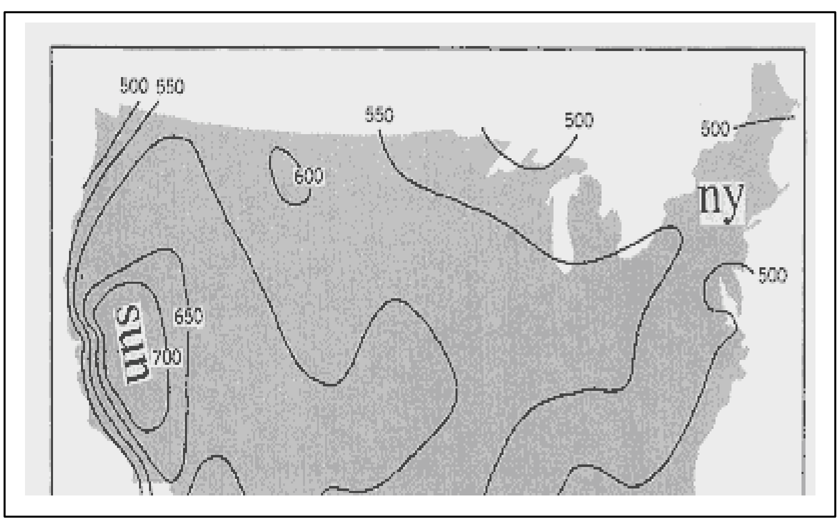


Solar energy is typically perceived as “good for Arizona or Florida” but not good for New York State. Maps showing solar home-heating potentials such as the one to the right have tended to bias our opinions and limit our minds as to the possibilities for the use of solar power as an energy source. This is particularly true for the darkly shaded area, which includes most of New York State. In the past, misconceptions about solar energy have kept us from investigating the unique opportunities for clean energy solutions in this state.

1. What does this map alone lead us to believe about the solar potential for New York State?

The climatic map below for the continental U.S. indicates the average amount of solar radiation received by the earth during July on a horizontal surface. The numbers are in Langleys per day, which are measured in calories per square centimeter.

- Use a yellow-colored pencil to lightly shade the area between the lines on the map where New York State (“NY”) is located.
- Use a red-colored pencil to shade the area of the southwestern United States that receives the greatest amount of sunlight.



2. How much more sunlight energy is received in the southwestern Sunbelt than we receive in New York State? (Answer this question as a percentage.)

Not Enough Space

Some people believe that the collection of solar energy requires a lot of space. Misinformed news media sometimes report that large tracts of farmland and forests must be replaced in order to set up additional solar collectors.

3. Recalling what you know about solar collectors, describe the type of area normally used for the mounting of solar collectors.

Actually, solar resources can be quite space-efficient. In NYC, each square foot of the earth's surface receives 160 kilowatt-hours (kWh) of "raw" solar energy every year. On such a square foot of space, a photovoltaic (PV) system can typically convert that source of energy to 22 kWh of electrical energy.

4. On the basis of this information, what is the typical sun-to-electricity conversion efficiency of a photovoltaic (PV) system?

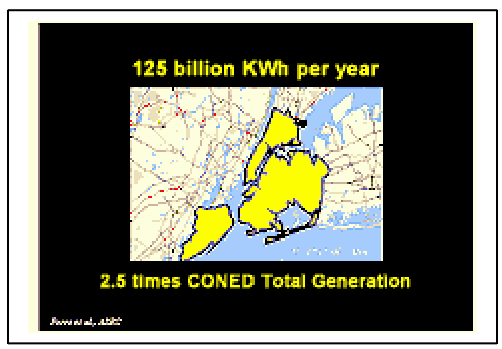
5. Since each square foot of surface area could yield 22,000 watt-hours of electricity each year, how much electricity could be produced each day?

6. What wattage light bulb could be kept lighted for the day by each square foot of solar collector?

7. How many square feet of horizontal solar collector surface are needed to light a 100-watt light bulb all day?

Amazing as it may seem, solar collectors covering an area equal to the acreage of New York City, the densest energy-use hub in the world, would yield 2.5 times more PV-generated electrical energy than the region's total electricity consumption. For the state as a whole, this ratio is greater than 100.

A substantial portion of New York City's acreage— commercial, industrial, and residential roofs, and parking lots—could be used to deploy the PV technology. The PV technology has evolved and is now adequate to support deployment in these different settings.



Not Reliable

A major ***perceived*** drawback of PV technology is that the use of solar resources is limited because solar energy is inconsistently available; use is constrained by clouds and the day-night cycle. As a consequence, the contributions that solar energy could make toward increasing the available capacity of local electric power grids have been underestimated.

8. How do clouds and the day-night cycle interfere with solar energy absorption?

Available When Needed

Actually, the solar energy peaks for production coincide with the maximum need for electrical power (peak loads) in the large northeastern metropolitan areas. This is because peak loads occur during summer, when loads are driven by weather-related heat waves. Such heat waves are themselves associated with larger amounts of incoming sunshine (increases in both duration and intensity of sunlight).

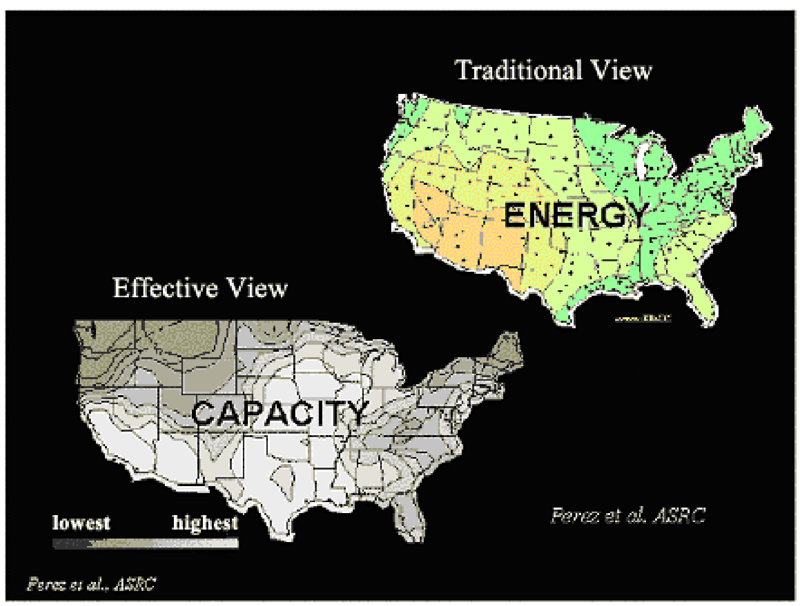
9. For what purpose is this peak energy demand mainly used?

10. How might this energy demand at these peak demand times be reduced by humans?

PV Reliability:

A few years ago, while analyzing electrical demand data for hundreds of U.S. electric utilities, researchers determined the time of greatest need for electrical power and the availability of solar resources. An "effective" solar resource map was produced and is shown to the right; the effective view is labeled "CAPACITY." The lightest shading present indicates those areas for which the output of electricity from solar energy coincides with the peaks of electric energy demands.

11. How closely do the electricity demands of the New York City area coincide with the availability of solar power?



The features of this map are markedly different from the “traditional” climatic map. In particular, the map shows that the New York City metropolitan area scores near the top for coincidence of need and electrical power availability.

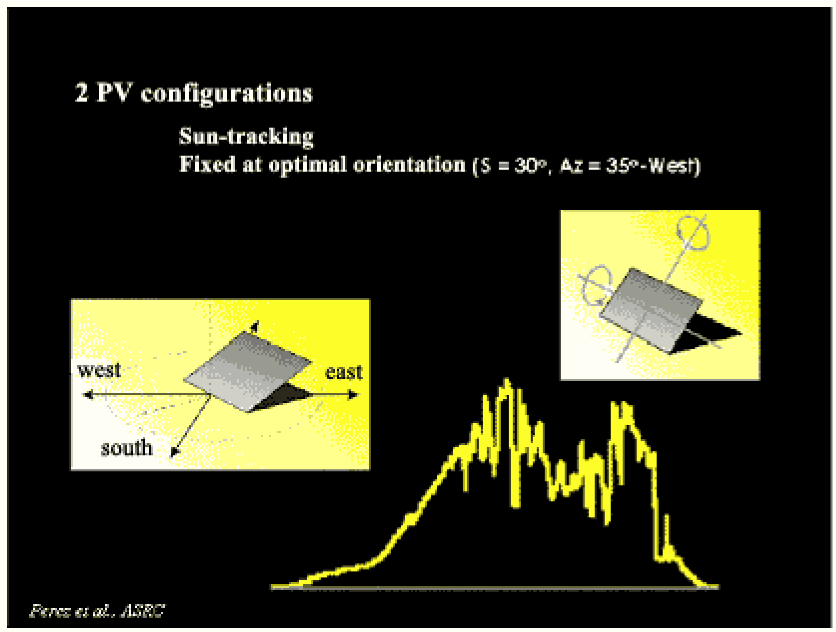
Solar Collectors

Two solar deployment technologies were considered in the study: (1) the ideal case, using sun-tracking solar arrays; (2) the practical case, using fixed solar arrays (i.e., the kind easily deployable on building roofs and other available structures).

12. What is the difference between these two systems? What makes the sun-tracking system more “ideal”?

The diagram to the right shows two types of solar collector mountings. The sun-tracking PV array is shown to the right. The circular arrows indicate the ways the array can be aimed at the sun. The fixed PV array is shown to the left. These arrows are compass directions.

13. Which type of solar collector array is most common on school buildings?



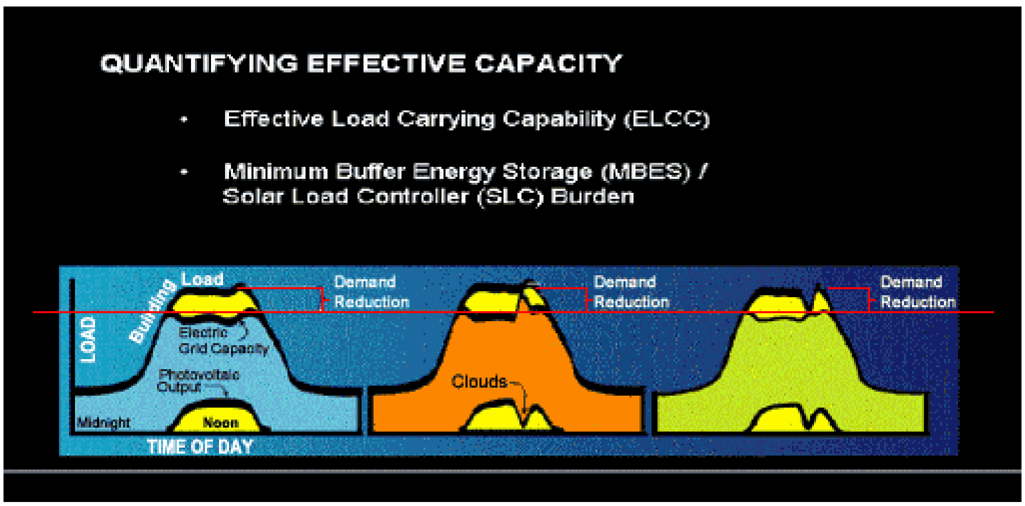
The graph at the bottom of the diagram shows typical solar energy collection by an ideal sun- tracking PV array from sunrise to sunset on a July day.

14. What factors affect the amount of energy displayed on the graph? (Think about the general pattern present and the irregularity of the changes that are seen to occur.)

15. Why is the fixed PV array oriented in the direction and at the altitude shown by the diagram? (You might want to review the ideas discussed in the earlier part of this worksheet before responding.)

16. If your school has a solar array, what is its orientation? Why is it aligned that way?

Addressing the Demand



The diagram to the right illustrates how solar energy could be used to address all or some of our peak electricity needs. The red line indicates normal electricity supplies from standard sources. The left-hand graph shows how demand increases during the middle of the day for a typical hot weather spell. Because solar production also increases during this time, the excess demand can be met by adding energy from the solar generation of electricity. When solar conditions are not good, backup energy supplies would be needed at that time (see middle graph), or alternatively, a reduction in consumer consumption would be necessary to guarantee that all resources above the red line are provided (see right graph).

17. How are these last two situations shown by the diagram above?

18. Identify one source of backup energy supply.

DEVELOP YOUR UNDERSTANDING

19. How is it that solar energy offers a potential solution to energy needs in the northeastern United States, even though that area is outside the solar belt location? Explain.