Solar Education for NY
SchoolPower ...Naturally

Solar Energy in New York

SPN LESSON #10

TEACHER INFORMATION

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.

GRADE-LEVEL APPROPRIATENESS: This Level II middle-level lesson works well in physical science and/or social studies classrooms.

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

SAFETY
There are no safety concerns 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, in order to 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 solar information available at http://www.asrc.cestm.albany.edu/perez/slc/slc-paper.htm

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

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. Since 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 Earth rotates on its axis. Both of these variables also change during the year as Earth changes its position in its orbit. The Sun-tracking system turns with the Sun, so that it receives maximum radiation intensity; thus, such a system is more effective (but it is more costly, and requires higher maintenance and additional space).
13. Fixed
14. Since 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. Since 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 Earth 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

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY

This activity was adapted from a report produced by Richard Perez et al., at the University at Albany (ASRC); the report is available online at http://www.asrc.cestm.albany.edu/perez/slc/slc-paper.htm.

BACKGROUND INFORMATION

The website (listed above) of Richard Perez at the University at Albany (ASRC) provides a wealth of information regarding the feasibility of solar energy use.

The text and question-and-response sections should provide you the information you need. A few items needing further explanation are expanded upon below.

4. 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.

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

REFERENCES FOR BACKGROUND INFORMATION

The report cited above is available at http://www.asrc.cestm.albany.edu/perez/slc/slc-paper.htm.

LINKS TO MST LEARNING STANDARDS AND CORE CURRICULA

Intermediate Science Core

Standard 4—The Physical Setting: Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Key Idea 1: The Earth and celestial phenomena can be described by principles of relative motion and perspective.

1.1: Explain daily, monthly, and seasonal changes on Earth.

1.1e: Most objects in the solar system have a regular and predictable motion. These motions explain such phenomena as a day, a year, phases of the Moon, eclipses, tides, meteor showers, and comets.

1.1f: The latitude/longitude coordinate system and our system of time are based on celestial observations.

1.1g: Moons are seen by reflected light. Our Moon orbits Earth, while Earth orbits the Sun. The Moon's phases as observed from Earth are the result of seeing different portions of the lighted area of the Moon's surface. The phases repeat in a cyclic pattern in about one month.

1.1h: The apparent motions of the Sun, Moon, planets, and stars across the sky can be explained by Earth's rotation and revolution. Earth's rotation causes the length of one day to be approximately 24 hours. This rotation also causes the Sun and Moon to appear to rise along the eastern horizon and to set along the western horizon. Earth's revolution around the Sun defines the length of the year as 365 1/4 days.

1.1i: The tilt of Earth's axis of rotation and the revolution of Earth around the Sun cause seasons on Earth. The length of daylight varies depending on latitude and season.

Key Idea 4: Energy exists in many forms, and when these forms change energy is conserved.

4.1: Describe the sources and identify the transformations of energy observed in everyday life.

4.1a: The Sun is a major source of energy for Earth. Other sources of energy include nuclear and geothermal energy.

4.1b: Fossil fuels contain stored solar energy and are considered nonrenewable resources. They are a major source of energy in the United States. Solar energy, wind, moving water, and biomass are some examples of renewable energy resources.

4.1c: Most activities in everyday life involve one form of energy being transformed into another. For example, the chemical energy in gasoline is transformed into mechanical energy in an automobile engine. Energy, in the form of heat, is almost always one of the products of energy transformations.

4.1d: Different forms of energy include heat, light, electrical, mechanical, sound, nuclear, and chemical. Energy is transformed in many ways.

4.2: Observe and describe heating and cooling events.

4.2a: Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

4.2b: Heat can be transferred through matter by the collisions of atoms and/or molecules (conduction) or through space (radiation). In a liquid or gas, currents will facilitate the transfer of heat (convection).

4.4: Observe and describe the properties of sound, light, magnetism, and electricity.

4.4a: Different forms of electromagnetic energy have different wavelengths. Some examples of electromagnetic energy are microwaves, infrared light, visible light, ultraviolet light, X-rays, and gamma rays.

4.4b: Light passes through some materials, sometimes refracting in the process. Materials absorb and reflect light, and may transmit light. To see an object, light from that object, emitted by or reflected from it, must enter the eye.

4.4d: Electrical energy can be produced from a variety of energy sources and can be transformed into almost any other form of energy.

4.4e: Electrical circuits provide a means of transferring electrical energy.

4.5: Describe situations that support the principle of conservation of energy.

4.5a: Energy cannot be created or destroyed, but only changed from one form into another.

4.5b: Energy can change from one form to another, although in the process some energy is always converted to heat. Some systems transform energy with less loss of heat than others.

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www.nyserda.org

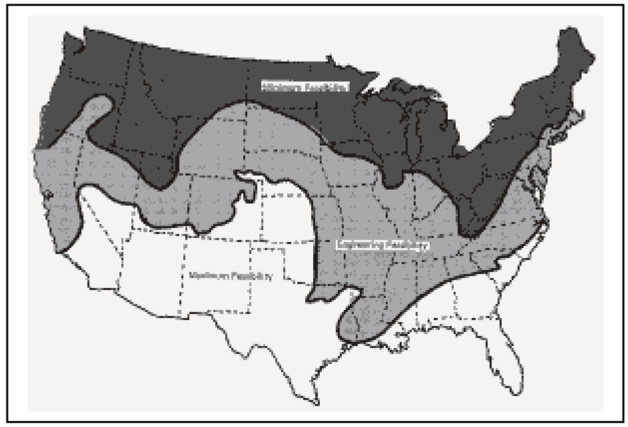
Should you have questions about this activity or suggestions for improvement,
please contact Bill Peruzzi at billperuz@aol.com

(STUDENT HANDOUT SECTION FOLLOWS)

Name ____________________________________

Date _____________________________________

Solar Energy in New York

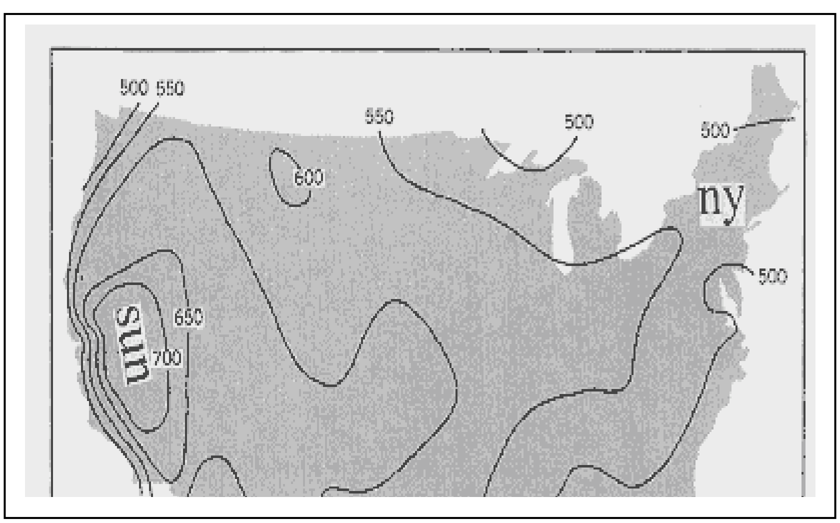


Not Enough Sun
Solar energy is typically perceived as "good for Arizona or Florida" but not good for New York State. Maps showing solar home-heating potentials such as the one to the right have tended to bias our opinions and limit our minds as to the possibilities for the use of solar power as an energy 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 risking 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 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.

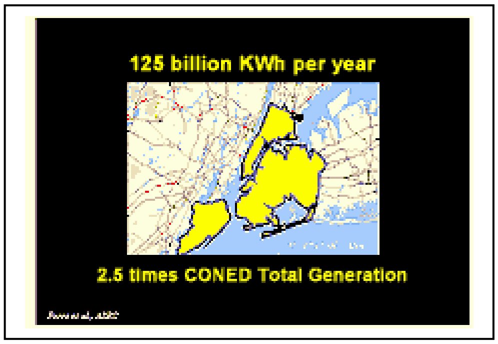
Actually, solar resources can be quite space-efficient. In NYC, each square foot of Earth's Surface receives 160 kilowatt-hours (kWh) of "raw" solar energy every year. On such a square foot of space, a photovoltaic (PV) system can typically convert that source of energy to 22 kWh of electrical energy.

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.

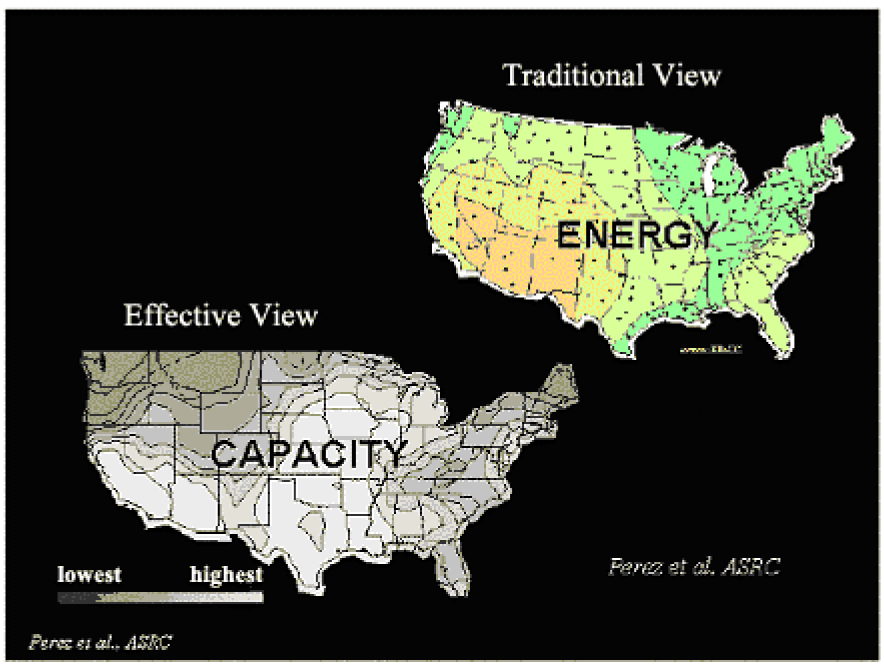
8. How do clouds and the day-night cycle interfere with solar energy absorption?

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, Perez and colleagues 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?

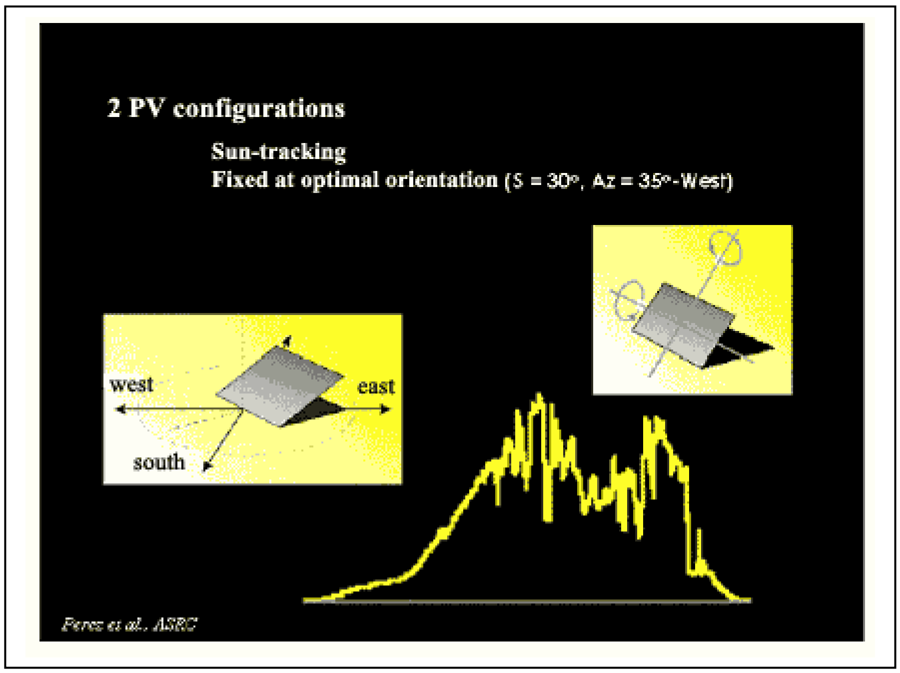
The features of this map are markedly different from the "traditional" climatic map. In particular, the map shows that the New York City metropolitan area scores near the top for coincidence of need and electrical power availability.

Solar Collectors
Two solar deployment technologies were considered in Perez's 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 mounted on your school building?



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.

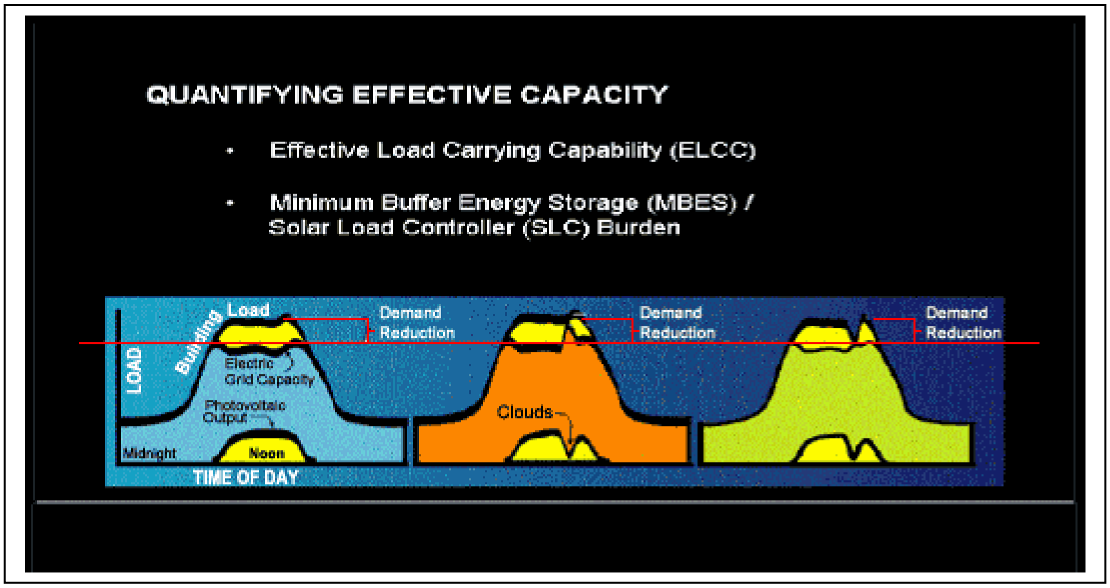
14. What factors affect the amount of energy displayed on the graph? (Think about the general pattern present and the irregularity of the changes that are seen to occur.)

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. What is the orientation of your school's PV array? 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. Since 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.