LESSON 19: I've Got the POWER!
Solar Energy Potential at Your School

PURPOSE/QUESTION
To use NASA satellite data to help determine the solar energy potential in any given region and to estimate area of solar panels needed.

GRADE LEVELS
9-12

TIME TO COMPLETE
1-2 – 50 minute class periods

STANDARDS
See appendix below-page 8

LEARNING OUTCOMES
- Contrast amounts of solar energy with average cloud coverage in a given area in order to determine the most efficient location for establishing a solar collector
- Produce graphs in Excel
- Explain how solar energy can benefit society

STUDENT OBJECTIVES
- Investigate the role of solar energy in driving most natural processes within the atmosphere, the hydroshphere, and on the Earth's surface
- Identify appropriate uses and locations for a solar collector
- Draw conclusions about solar energy's societal benefits

TEACHER BACKGROUND
Solar energy is radiant energy that is produced by the Sun. Every day the Sun radiates an enormous amount of energy. How much solar energy a place on Earth receives depends on several conditions. Most importantly, it depends on latitude and season of the year (and thus the amount of daylight hours), as well as cloud cover.

In this lesson, you will explore real NASA satellite data for energy from the Sun and cloud cover for your area to determine if you can harness this solar energy, a renewable energy source, by using a solar collector.

A solar collector is one way to collect heat from the sun. A closed car on a sunny day is like a solar collector. As sunlight passes through the car's glass window, it is absorbed by the seat covers, walls, and floor of the car. The light that is absorbed changes into heat. The car's glass windows let light in, but don't let all the heat out. This is also why greenhouses work so well and stay warm year-round.

For more information on this subject, go to The NEED Project link under Lesson Links. The two links under Lesson Links to the Energy Kids Place sites provide discussions of renewable and non-renewable resources.

PREREQUISITES
- Familiarity with latitude and longitude positions on a map
- Basic familiarity with producing graphs in Microsoft Excel
- Clouds and Radiation
- Renewable Energy Resources

MATERIALS & TOOLS
- World and US map or atlas
- Computer with Internet access and Microsoft Excel

VOCABULARY
- Solar Insolation
- Renewable energy
- Solar collector
- Solar radiation

LESSON LINKS
- Live Access Server
- Radiation Budget Diagram
- Opening MY NASA DATA Microsets in Microsoft Excel

PART 1: Gathering data on solar energy in your area

ESSENTIAL QUESTIONS

1. What is the average annual solar energy your area receives with and without clouds?
2. Explain why knowing the average amount of cloud cover in a given area would be important when deciding whether or not to use solar energy as a power source.
3. How does the solar insolation in your location vary through the seasons? Why is there this seasonal cycle?

PROCEDURE

1. Access average monthly solar energy data for your school location.
    - a Determine latitude and longitude for your location.
    - b In the My NASA Data Live Access Server (Advanced Edition), click on the ***Choose Dataset*** button. Then choose ***Atmospheric Radiation > Surface > Monthly Surface Clear-sky SW Downward Flux (SRB).*** A map will be automatically generated.
    - c Under "LINE PLOTS", select: ***Time Series***
    - d Enter your latitude and longitude into the appropriate boxes just below the small grey map on the left of the screen.
    - e Set the time settings in ***Date Range*** to be ***Jul 1983*** and ***Jun 2007***.
    - f Click ***Update Plot*** and a time series plot will appear.
    - g We want to access the data used to create this plot, so that we can do our own calculations. Click the ***Show Values*** button and then click ***OK*** to accept the defaults. The data will appear in the second window.
    - h Follow the instructions in the Eco-Schools CCC Tech Tips Sheet to import the data into the Microsoft Excel worksheet for this lesson. Put the raw data in the tab titled ""Raw Data – Clear-sky".
    - i Repeat steps b-h for ***Atmospheric Radiation > Surface > Monthly Surface All-sky SW Downward Flux (SRB).*** Put the data into the Excel worksheet tab titled "Raw Data – All-sky".

2. Calculate and plot the long-term average solar energy flux.
    - a. Copy the values for Clear-Sky and All-Sky radiation into the appropriate columns in the worksheet tab titled "Average Fluxes".
    - b. The long-term averages for each month should be automatically calculated.
    - c. A graph with both clear-sky and all-sky variables will be automatically created.

PART 2: Estimate the solar energy potential for your school

ESSENTIAL QUESTIONS PART 2

1. What fraction of your school's energy needs could solar energy reasonably provide?
2. What are some limitations of the estimate of area needed for solar panels?
3. Do you think it would be cost efficient to build or buy a solar collector? Why or why not?
4. Some states allow residences or businesses to sell some power back into the grid. Would this be an option for your school? During which months might it be most sensible?

PROCEDURE

1. Make a rough estimate of the amount of solar energy available for converting into electric power.
    a. In the My NASA Data Live Access Server (Advanced Edition), click on the ***Choose Dataset*** button. Then choose ***Surface Meteorology and Solar Energy > Monthly Climatologies for Surface Meteorology and Solar Energy > Monthly Climatology Global Horizontal Radiation (SSE Release 6).*** A map will be automatically generated.
    b. Under "LINE PLOTS", select: ***Time Series***
    c. Enter your latitude and longitude into the appropriate boxes just below the small grey map on the left of the screen. Keep the default ***Date Range*** of Jan to Dec.
    d. Click ***Update Plot*** and a time series plot will appear.
    e. We want to access the data used to create this plot, so that we can do our own calculations. Click the ***Show Values*** button and then click ***OK*** to accept the defaults. The data will appear in the second window.
    f. Follow the instructions in the Eco-Schools CCC Tech Tips Sheet to import the data into the Microsoft Excel worksheet for this lesson. Put the raw data in the tab titled "POWER output". Copy and paste each monthly averaged value into the correct month under the variable name "Monthly Averaged Insolation Incident on a Horizontal Surface (kWh/m^2/day)".

2. Determine how many 1 m^2 solar panels your school would need to meet its energy needs
    a. From the Energy Audit conducted as part of Lesson 1, find the estimate of average monthly energy usage by your school in kWh/month. Enter the monthly values into the Excel spreadsheet, in the tab called "POWER output". If you only have average monthly energy use, enter the same value for every month.
    b. The monthly averaged insolation incident on a Horizontal Surface in units of **kWh/m^2/month** will be automatically calculated by multiplying the daily average value by the number of days/month.
    c. The area required to meet your school's energy needs (assuming 100% efficiency) will be calculated by dividing the (Average monthly energy usage by your school in kWh/month) by the (Monthly averaged Insolation Incident on a Horizontal Surface in kWh/m^2/month).
    d. Finally, solar panel inefficiencies will be accounted for by dividing the area by 0.20.
    e. The resulting value is a rough estimate of the area (in units of m^2) of solar panels needed to meet the school's energy needs each month.
    f. Estimate the area of your school's roof and/or any ground locations where solar panels could be located. Compare this estimate to the estimate of how much area is needed to meet the school's energy needs.

PART 3 - Put what you learned into a global context.

ESSENTIAL QUESTIONS PART 3

1. How does latitude affect the amount of energy that reaches the Earth's surface?
2. Why is it important to examine the available solar radiation in both July and January, when comparing the different continents?
3. What other factors might affect the distribution of solar radiation across the landscape?
4. Identify the six places among the continents that have the best solar energy potential?

PROCEDURE

1. To get a better idea of the availability of solar energy across the country or around the world, we will create maps of solar insolation across the globe. Divide the classroom into 6 groups and assign each a different continent (not including Antarctica, where there's very little sunlight on average!).
    - ***a.*** In the My NASA Data Live Access Server (Advanced Edition), click on the ***Choose Dataset*** button. Then choose ***Surface Meteorology and Solar Energy > Monthly Climatologies for Surface Meteorology and Solar Energy > Monthly Climatology Global Horizontal Radiation (SSE Release 6).*** A map for January will be automatically generated.
    - b. Use the small map to create a box around your continent. Then click ***Update plot.***
    - c. Print out the resulting map.
    - d. Now go back and create a map for July and print it out.

2. Reconvene as a class and compare the maps of solar radiation for different continents, as you answer the following questions.

WEBSITES FOR FURTHER LEARNING

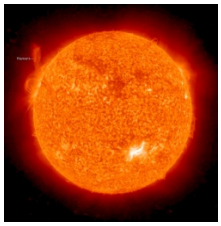
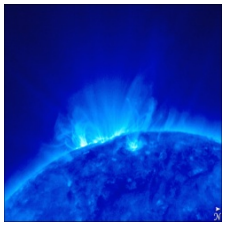
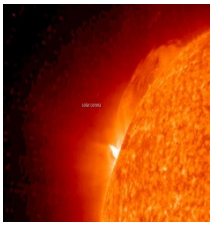
- SRoeCo Solar
- National Energy Education Development (NEED) Project
- Solar Schools
- Energy Star Kids
- Saving Energy
- NRDC's The Green Squad: Solar Energy in Schools
- Solar Power Plus

STUDENT READING RESOURCES

- Baking in the Sun
- Warren Schools Energy Conservation Saves District More than $200,000
- Sunshine Mapping from Space Means Brighter Solar Energy Future
- NJ Gets One of Nation's Largest Solar Farms
- Solar Power Mandatory in All Future NJ Schools
- Measuring Solar Insolation

TOOLS FOR ASSESSMENT

- Concept Quiz – found on pg. 12
- Essay – found on pg. 16
- Science Notebook and Student Reading Assessment Tools – found in the ***Rubrics*** folder

REFERENCES

Adapted from My NASA Data Lesson 44 by Cindy Henry

Tech Tips for Eco-Schools USA Climate Change Connections Curriculum

How do I import data into an Excel spreadsheet?

1. Access data from My NASA Data:
    a. Once you have all the parameters set for your desired data set (and have clicked "Update Plot" to have your preferences processed), click the "Show Values" button. A new window will pop up with a Table of Values.
    b. The first several lines of the Table will provide information that describes the data set, often called "metadata", such as the name of the variable, what subset of the data is included in the file, and what time range. Make sure to keep this metadata with the rest of the data when you copy it into Excel. This way you'll be able to easily keep track of which data you have!
2. Copy the data from the browser (note that these instructions are for Internet Explorer running on a PC, and may need to be modified for other platforms):
    a. In this new window, select all. You can do this by clicking anywhere in the window and then typing "Ctrl-A". Or you can right-click in the window, which will pop up a menu, and then choosing "Select All" from the options.
    b. Next, copy this data. Again there are two options. You can use the keyboard shortcuts, and type "Ctrl-C". Or you can right-click and choose "Copy" from the pop-up menu.
3. Paste the data into Excel:
    a. Now open your Excel worksheet and go to the tab where you want to put the raw data. Click in the A1 cell.
    b. Paste the data, either by typing "Ctrl-V", by clicking "Paste" (located at the left under the "Home" tab), or by right-clicking in the A1 cell and choosing "Paste".
4. Convert the data from text to columns:
    a. Now, we have the data in Excel, but we can't manipulate it very well because all the data for each row is lumped into one cell. We want to split out each data value into its own cell.
    b. Starting at the row where the column headers are located (probably around row 7), highlight the A column down to the end of the data.
    c. Click on the Data tab at the top of the window, and then choose the "Text to Columns" wizard (located a little to the right of center).
    d. A dialogue box will pop up to help you through the process.
    e. The first page of the wizard asks you to identify whether the data is "Delimited" or "Fixed width". In most cases, the M y NASA Data data will be "Fixed Width", so select that option and click "Next".
    f. The next page of the wizard gives you a chance to check whether the column breaks make sense and to adjust them as necessary. Make any changes that are needed. Or, go back and switch to "Delimited" on page 1 if you notice that the columns are not lining up as you expected. Once you are satisfied with the columns, click "Next".
    g. The final page of the wizard allows you to designate what kind of data values are in each column and a destination for the data. For the purposes of the CCC curriculum, we'll just accept the defaults and click "Finish".
    h. Now your data should be in beautiful columns and the values should make sense. It's always a good idea to double check that nothing crazy happened!

My NASA Data isn't working! What should I do?

1. Double check that you entered everything correctly. Especially check that you have the right data set and that you have entered dates and latitude/longitude values within the range of available data. Usually the user interface will prevent you from entering invalid data ranges, but sometimes there are glitches.
2. Refresh the browser and/or restart the browser. Occasionally, a fresh start is the easiest way to clear out any mistakes or glitches.
3. Update your browser and/or JAVA. If you have older versions of the software, then you might find that some functionality is lost.
4. If you're still struggling, consider whether problem might be at the My NASA Data website. It might be a temporary problem, in which case taking a break and returning to the site at a later time could be a good choice. Or it could be a more significant problem, in which case you'll want to explore the "help" resources provided by My NASA Data (link in upper right hand corner of page).
5. Ask your Eco-Schools contact for help or email eco-schoolsusa@nwf.org!

How do I print or save a map or graph?

1. Use the "Print" button to generate a version of your map or graph that is suitable for saving or printing. Once you click on the "Print" button, a new window will pop up with your map or graph.
2. Print a map or graph by using the print option on your browser.
3. Save a map or graph in one of two ways:
    a. By choosing "Save as" in the browser. Use the defaults to save as a "Web Archive, single file (*.mht)".
    b. By right clicking and choosing "Save picture as…" Use the defaults to save as a *.png file.
4. When saving, make sure to give your new file a descriptive name and put it somewhere that you'll remember!

How do I find my latitude and longitude?

A number of sites help you find your latitude and longitude. For example:

1. http://itouchmap.com/latlong.html
2. http://www.findlatitudeandlongitude.com/

LESSON 19-APPENDIX

WEB ADDRESSES FOR HYPER LINKS

Prerequisites

- **Latitude and longitude**
  http://www.compassdude.com/latitude-longitude.shtml
- **Clouds and radiation**
  http://earthobservatory.nasa.gov/Features/Clouds/
- **Renewable energy resources**
  http://energy.gov/energysaver/articles/tips-renewable-energy

Vocabulary

- **Solar insolation**
  http://en.wikipedia.org/wiki/Insolation
- **Renewable energy**
  http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=R
- **Solar collector**
  http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=S
- **Solar radiation**
  http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=S

Lesson Links

- **Live Access Server, LAS**
  http://mynasadata.larc.nasa.gov/live-access-server/
- **Radiation Budget Diagram**
  http://science-edu.larc.nasa.gov/energy_budget/
- **Opening NASA Data Microsets in Excel**
  http://mynasadata.larc.nasa.gov/opening-my-nasa-data-microsets-in-excel/

Websites for Further Learning

- **SRoeCo Solar**
  http://sroeco.com/solar/
- **National Energy Education Development (NEED) Project**
  http://www.need.org/
- **Solar Schools**
  http://www.solarschools.com/
- **Energy Star Kids**
  http://www.energystar.gov/index.cfm?c=kids.kids_index
- **Saving Energy**
  http://www.energyquest.ca.gov/saving_energy/index.html
- **NRDC's The Green Squad: Solar Energy in Schools**
  http://www.nrdc.org/greensquad/library/energy_solar.html
- **Solar Power Plus**
  http://www.solarpanelsplus.com/industry-professionals/insolation-charts/

Student Reading Resources

- **Baking in the Sun**
  http://earthobservatory.nasa.gov/Features/RenewableEnergy/renewable_energy4.php
- **Warren Schools energy Conservation Saves District more than $200,000**
  http://www.mycentraljersey.com/article/20101002/NEWS/10020361/Warren-schools-energy-conservation-saves-district-more-than-200-000?gcheck=1&nclick_check=1
- **Sunshine Mapping form Space means Brighter Solar Energy Future**
  http://earthobservatory.nasa.gov/Newsroom/view.php?id=27168
- **NJ Gets One of Nation's Largest Solar Farms**
  http://www.khou.com/news/national/105590813.html
- **Solar Power Mandatory in All Future New Jersey Schools**
  http://solarpanelspower.net/solar-power/solar-power-mandatory-in-all-future-new-jersey-schools
- **Measuring Solar Insolation**
  http://earthobservatory.nasa.gov/IOTD/view.php?id=1355

LESSON 19-STANDARDS

National Science Education Standards

Unifying Concepts and Processes

- Systems, Order, and Organization
- Evidence, Models, and Explanations
- Change, Constancy, and Measurement

Standard A – Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Standard C – Life Science

- Matter, energy, and organization in living systems

Standard D – Earth and Space Science

- Energy in the earth system

Standard E – Science and Technology

- Abilities of technological design
- Understandings about science and technology

Standard F – Science in Personal and Social Perspectives

- Science and technology in local, national, and global challenges

Standard G – History and Nature of Science

- Science as a human endeavor
- Nature of scientific knowledge

National Education Technology Standards

Standard 1: Creativity and Innovation

- Use models and simulations to explore complex systems and issues
- Identify trends and forecast possibilities

Standard 3: Research and Information Fluency

- Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.
- Process data and report results

Standard 4: Critical Thinking, Problem Solving, and Decision Making

- Collect and analyze data to identify solutions and/or make informed decisions.

Standard 5: Digital Citizenship

- Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.

Standard 6: Technology Operations and Concepts

- Understand and use technology concepts
- Select and use applications effectively and productively
- Troubleshoot systems and applications
- Transfer current knowledge to learning of new technologies

National Council of Teachers of Mathematics Education Standards

Algebra

- Understand patterns, relations, and functions
- Use mathematical models to represent and understand quantitative relationships
- Analyze change in various contexts

Measurement

- Understand measurable attributes

Data Analysis and Probability

- Develop and evaluate inferences and predictions that are based on data

Process

- Connections
  - Recognize and apply mathematics in contexts outside of mathematics
- Representation
  - Use representations to model and interpret physical, social, and mathematical phenomena

Climate Literacy Principles

Principle 1: The sun is the primary source of energy for Earth's climate system.
Principle 2: Climate is regulated by interactions among components of the Earth system.
Principle 3: Life on Earth depends on, is shaped by, and affects climate.
Principle 4: Climate varies over space and time through both natural and man-made processes.
Principle 5: Our understanding of the climate system is improved through observations, theoretical studies, and modeling.
Principle 6: Human activities are impacting the climate system.
Principle 7: Climate change will have consequences for the Earth system and human lives.

Energy Literacy Principles

Principle 1: Energy is a measurable quantity that follows physical laws.
Principle 2: Physical Earth processes are the result of energy flow through the earth system.
Principle 4: Various sources of energy can be used to power human activities, and often this energy must be transferred from source to destination.
Principle 5: Individuals and communities make energy decisions every day.
Principle 6: The amount of energy human society uses depends on many factors and can be reduced in many ways.
Principle 7: The energy choices made by individuals and societies affect quality of life.

LESSON 19-ESSENTIAL QUESTIONS ANSWER KEY

Essential Questions-1

1. What is the average annual solar energy your area receives with and without clouds?
   [Depends on the school and location chosen.]

2. Explain why knowing the average amount of cloud cover in a given area would be important when deciding whether or not to use solar energy as a power source.
   [Clouds block solar radiation from hitting the surface, thus cloudy areas receive less energy than areas that have more clear skies.]

3. How does the solar insolation in your location vary through the seasons? Why is there this seasonal cycle? [Solar insolation is highest in the summer months, when the Sun is more directly overhead. Solar insolation is at a minimum in winter months.]

Essential Questions-2

1. What fraction of your school's energy needs could solar energy reasonably provide?
   [Depends on the school and location chosen]

2. What are some limitations of the estimate of area needed for solar panels?
   [The value is an optimistic estimate because it does not account for the inefficiencies in transporting the electricity from the solar panels to the places it is used around the school. Also, it does not account for any limitations in terms of shading from trees or inability to get the solar panels at a good angle.]

3. Do you think it would be cost efficient to build or buy a solar collector? Why or why not?
   [Depends on school and location chosen.]

4. Some states allow residences or businesses to sell some power back into the grid. Would this be an option for your school? During which months might it be most sensible?
   [Depends on the school and location chosen.]

Essential Questions-3

1. How does latitude affect the amount of energy that reaches the Earth's surface?
   [Higher latitude locations (toward the poles) receive less sunlight on average throughout the years than lower latitude locations (closer to the equator). This means that their solar energy reaching the surface is less at higher latitudes.]

2. Why is it important to examine the insolation in both July and January, when comparing the different continents? [When comparing solar energy received at southern hemisphere locations to those at northern hemisphere locations, it is important to compare the insolation during the same season.]

3. What other factors might affect the distribution of insolation across the landscape?
   [The average distribution of clouds would be the largest factor affecting the solar insolation across the landscape.]

4. Identify the six places among the continents that have the best solar energy potential?
   [Students will identify locations.]

Name: _____ Date: _____

Science Concept Quiz
Lesson 19: I've Got the POWER!
Solar Energy Potential at Your School

Use the map that shows the average solar insulation for January and April 1984-1993 to answer the question.

What is one conclusion that can be drawn from the information analyzed in the map?

A. Solar panel installations are not recommended for North Pole region due a low level of kWh/m^2/day.

B. The southwest region of North America is not a good candidate for solar panel insolation based on their low level of kWh/m^2/day.

C. When looking to install solar panels for your campus you should only look at solar insulation for the summer months.

D. Solar panel installation would be feasible in Norway, but not for Northern Australia.

_____ points out of 20

I. Answer

A.○ B.○ C.○ D.○

_____ points out of 15

II. What is the main concept behind the question?

1. Solar insolation
2. Solar panel installation
3. Drawing conclusions based on scientific graphs
4. Seasons

_____ points out of 25

III. Provide the reasoning for choosing your answer in part II.

_____points out of 40

IV. Why are the other responses in part I not the best answer choice?

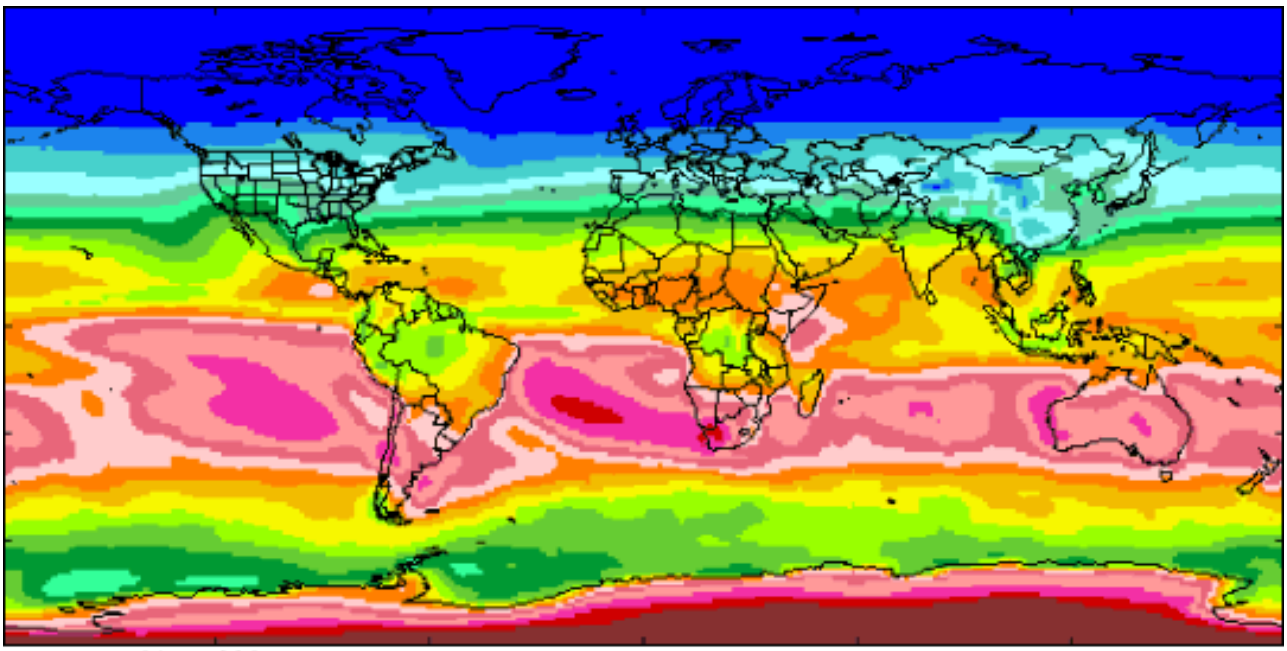
1.

2.

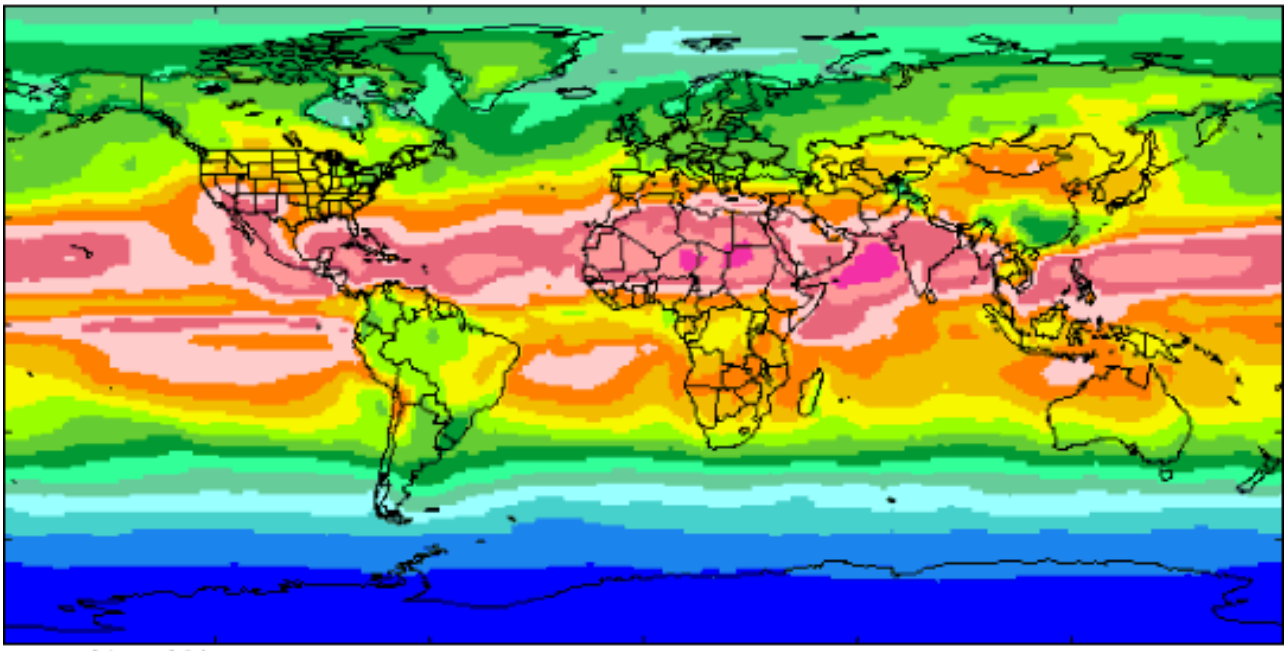
3.

4.

Use the rest of this page if more room is needed to fully communicate your thoughts.



January 1984–1993



April 1984–1993

Solar Insolation (kWh/m^2/day)

0 >8.5

Teacher Answer Key

1. A

2. 3

3. Answers will vary. To be able to draw a conclusion about the information in the graphs one first has to observe and analyze what information is in the map.

4. Answers will vary.

   A) This is the correct answer. Solar panel installation would not be recommended to the North Pole region as its solar insolation is low all year.

   B) This is not a true statement. Based on the graph the southwest region of North America is a good candidate for solar panel installations.

   C) No, you must look at solar insolation rates for summer and winter. This will allow you to see if solar power is feasible for your campus.

   D) This statement is not true based on the graphs. Norway would not be a good candidate but Northern Australia would be.

Student Name
Teacher/Class
Date

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Solar Energy Potential at Your School

Based on your analyses, collaborations, and writings provide evidence for understanding what solar insolation is, how it varies seasonally, and how this affects your decision to potentially install solar collectors at your campus. Elaborate further by also providing evidence for understanding how POWER could be a beneficial tool for the global community.

What Is the Expectation?

Accurate science relating to solar insolation, local renewable energy potential, and the societal benefits of the POWER project.

Evidence supporting your claims

Visual representations

Key vocabulary

Evidence of on grade level spelling and grammar usage