Solar Electricity Works for Texas

RENEWABLE ENERGY
THE INFINITE POWER
OF TEXAS

For Grades 6, 7 and 8

OVERVIEW

In this activity, students will learn about how the diverse Texas geography affects our solar energy resources. Students will map areas of Texas for solar insolation to learn where photovoltaic power has the greatest potential. Students will also investigate various geographic regions in Texas, their climatic conditions and how they can influence solar energy potential. The many possibilities for using solar power is a central theme. Students can research rainfall amounts and other weather information throughout Texas to determine where there is less sunlight, in addition to creating a solar insolation map.

OBJECTIVES

See Middle School Teacher Resource Guide for TEKS objectives and additional information regarding this and other middle school units.

SUGGESTED TIME FRAME

Teacher will need to determine how many class periods to devote to each activity, based on the suggested timeframe and length of classes.

Time	Activity Description	Content Area
10 minutes *15 minutes* *45 minutes*	**Activity 1** – Teacher Introduction **Activity 2** – Assessment of Current Student Knowledge **Activity 3** – Vocabulary and Reading Passage **Homework Assignment**	Science Vocabulary Reading Language arts
20 minutes *45 minutes*	**Activity 4** – Pre-Lab **Activity 5** – Lab – Mapping Insolation Values in Texas	Social Studies Geography, Science & mapping
45 minutes	**Activity 6** – Lab – Library/ Internet Research	Technology & Science
45 minutes	**Activity 7** – Post-Lab – Discuss lab results	Science
45 minutes	**Activity 8** – Assessment	Science

REQUIRED MATERIALS

- copy of the Reading Passage and Student Data Sheets (includes reading comprehension questions, vocabulary and Lab Activity) for each student
- copy of the Assessment Questions for each student
- colored pencils: green, yellow, & blue

ADVANCED PREPARATION FOR LAB WORK

Arrange for library and/or Internet research time for the class. The students will need access to pollution data in Texas cities to complete this lab investigation. Students can research rainfall amounts throughout Texas to determine where there is less sunlight, in addition to creating a solar insolation map.

Teachers should read the entire sequence of activities before starting the lab.

BACKGROUND INFORMATION

Fossil fuels captured solar energy millions of years ago and provide most of our energy today. Photovoltaic systems convert solar energy directly to electrical energy. The amount of solar energy reaching the Earth's atmosphere is about 1.94 calories per square meter per minute! This number is known as the "solar constant." However, the amount that actually reaches the ground varies depending on weather conditions, the amount of particulate matter and water in the air, and the angle of the Earth's surface in relation to the direction of the sun. Most of Texas receives enough sunlight to make using solar energy feasible.

SUMMARY OF ACTIVITIES

Activity 1 – Teacher Introduction (10 minutes)

Explain to the class that for the next unit of study, they will be learning about the potential for solar energy in various regions of Texas and how the geographic and climatic conditions can affect the solar resource that is available.

Activity 2 – Assessment of Current Student Knowledge (15 minutes)

To assess what students already know, prompt a class discussion based on the 5 questions listed below. Based on this discussion, create a graphic organizer of the points that were discussed that can be displayed throughout the unit of study. Refer to the Teacher Resource Guide for sample organizers.

1. What is renewable energy?
2. What are the benefits of renewable energy?
3. Have you ever seen photovoltaic or solar electric panels before?
4. What are some things that photovoltaic panels are used for?
5. Are some areas in Texas better suited for solar energy? Why?

See Teacher Resource Guide for alternative or additional assessment activity.

Activity 3 – Vocabulary and Reading Passage (45 minutes)

Each student will need a copy of the Reading Passage and the Student Data Sheets, which include reading comprehension questions, vocabulary words and the Lab Activity. (As an alternative to making copies, the Study Data Sheets can be displayed so the entire class can view them and copy the information into their science notebook.) Instruct students to study the Reading Passage and complete the questions and vocabulary. This activity will help them learn how weather conditions impact solar energy uses and will build mapping capabilities. At the teacher's discretion, students can review the Reading Passage after completing the vocabulary definitions to help them better understand the material. Key vocabulary words in the Reading Passage will assist them in understanding the Lab Activity instructions. For students who wish to learn more of the detailed principles behind the operation of alternative energy for creating electricity, direct them to the appropriate resources. Suggested resources are included in the Teacher Resource Guide. At the end of this activity, collect and grade the student's work. Return their graded work the following day.

Homework Assignment – Key Vocabulary List

1. Instruct students to create in their science notebooks meaningful sentences that reflect an understanding of the definition of each vocabulary word. Students should have written the definition of the words in their science notebooks during class. See Teacher Resource Guide for alternative vocabulary homework.
2. Collect and grade this assignment the next day.

Activity 4 – Pre-Lab (20 minutes)

1. Explain to the class that the Lab Activity consists of 2 parts: creating a map of solar insolation in Texas and researching weather data for specified cities in Texas.
2. For teachers interested in exploring the scientific method more fully as it applies to this Lab, see the Teacher Resource guide for guidelines.
3. Distribute a copy of the Lab Activity to each student. Direct the class to read the Lab Activity together and lead discussion on each paragraph. Students will need direction on how to proceed with locating their map coordinates. Review locating latitude and longitude on a large wall map or on a transparency of the student Lab Activity map. Students can work in small groups, but each student should complete all parts of the activity.

Activity 5 – Lab – Mapping Insolation Values in Texas (45 minutes)

Once students have read and understood the background information and instructions, tell them to create their map.

Activity 6 – Library/Internet research – Weather Data for Texas Cities (45 minutes)

1. Instruct students to list the Texas cities marked on their maps in Data Table 1 of their Lab Report Form. Review with students the information they will need to complete for each city in their Data Table. Table 1 includes columns for annual and average weather data as well as latitude and longitude. Using either library or Internet resources, instruct students to work in small teams to find the required weather information for each city. (Refer to the Teacher Resource Guide section on Internet and Library Research for more information on how to conduct this activity.) Each student should complete his or her own Data Table.

   Sunlight days for Austin, Amarillo, Brownsville, Dallas/Fort Worth, El Paso, Houston and San Antonio can be found here:

   http://www.traveltex.com/weather.asp?SN=5470131&LS=0

   Sunlight days for San Angelo can be found here:

   http://www.sanangelo.org/weather.html (San Angelo)

   Rainfall data can be found here:

   http://web2.airmail.net/danb1/climate.htm OR http://www.tpwd.state.tx.us/expltx/eft/activities/rainchart.htm (includes El Paso, Amarillo, Dallas, Austin and Houston)

2. Students should answer the questions at the end of the Lab Report Form.

Activity 7 – Post-Lab (45 minutes)

1. After the students have completed their Lab Report Forms, discuss their lab results.
2. Divide the class into 3 groups and assign each group to one of the 3 solar insolation regions identified on their map. On a wall map of Texas, instruct each group of students to indicate their lab results. What are the best cities in Texas for utilizing photovoltaic cells? Why? Where are the worst areas in Texas for using PV? Why?
3. Post the wall map results.

Activity 8 – Assessment (45 minutes)

Distribute a copy of the Assessment Questions to each student. Instruct each student to work alone and answer the short answer and multiple-choice questions. Collect the handouts, grade and return them to the students.

ADDITIONAL ACTIVITY

Air Pollution Research

The unit mentioned that the amount of particulate matter in the air affects the actual solar insolation that reaches the earth. Ask students to research PM10 (pollutant particles smaller than 10 microns in diameter), what it consists of, how it affects our health, and how it is regulated. Using Internet or library resources, ask students to identify the average daily PM10 values for the Texas cities studied in this Lab Activity. Students can add a column for these values in Data Table 1 of their Lab Report Form. Discussion or assignment questions can include:

1. Why do you think PM10 affects the amount of sunlight that reaches the earth?
2. According to the PM10 values researched for Texas cities, which city's solar insolation level would be affected the most by PM10? Which city would be the least affected?

Suggested website: www.texasep.org/html/air/air_2std_rpm.html

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HIGHLIGHTS

- **Photovoltaics offer a cost effective, reliable and flexible source of electricity**
- **Photovoltaic systems have no moving parts, use no fuel, and create no pollution**
- **Photovoltaic systems are becoming cheaper and more common**

SUMMARY

From pocket calculators to hi-tech telecommunications equipment, photovoltaic (PV) systems are a viable and cost-effective power source for many uses. First developed for use in the U.S. space program, PV power now costs only a fraction of what it once did. Decreasing costs along with greater dependability and ease of use have led to greater acceptance of the technology. PV now powers over 1.5 million homes around the globe, and the PV industry is growing 20 times faster than the oil industry. Here in Texas, PV is being used for everything from powering school crosswalk warning signs to powering homes and water pumping systems.

SCHOOL CROSSING SIGNAL POWERED BY PV *Photovoltaics can provide small amounts of power that can be depended upon.*

THE EVER-PRESENT PV

Calculators, refrigerators, gate openers, railroad switches, weather stations and navigational buoys are just a few of the items now being powered by photovoltaic cells. When electricity is needed in a location that is far from existing power lines, PV can be a less expensive source. PV is also cost-effective for items that require small amounts of energy. The cost of a PC system is about $4 to

USING THE SUN TO WATER LIVESTOCK *This PV system powers a small pump sitting on top of the water storage tank. During sunny weather, when cattle are most thirsty, PV watering systems work the best.*

$5 per Watt for single modules and $8 to $12 per Watt for complete systems. PV is growing more popular because it is so flexible. For power needs ranging from milliwatts to kilowatts, PV can handle the job anywhere on Earth or beyond. Because of its decreasing costs and high dependability, PV is being used more and more every day.

COMMON PV USES

TELECOMMUNICATIONS

PV has become a common power source for many types of telecommunications equipment. More common uses you might recognize are wireless phone towers, emergency telephones and weather stations. Other telecommunications uses include radio-controlled valves used on oil and gas pipelines, and remote monitoring equipment.

CONSUMER PRODUCTS

We are all familiar with solar-powered electronic calculators. Calculators were among the earliest uses of PV power. Their batteries are recharged by small PV cells, allowing them to run for very long periods without any maintenance. Because PV requires little or no maintenance, PV cells are being used in many small electronic devices such as outdoor patio lights and toys. PV-powered chargers are also used to recharge batteries for small electronics as well as in recreational vehicles, golf carts and boats.

EMERGENCY POWER

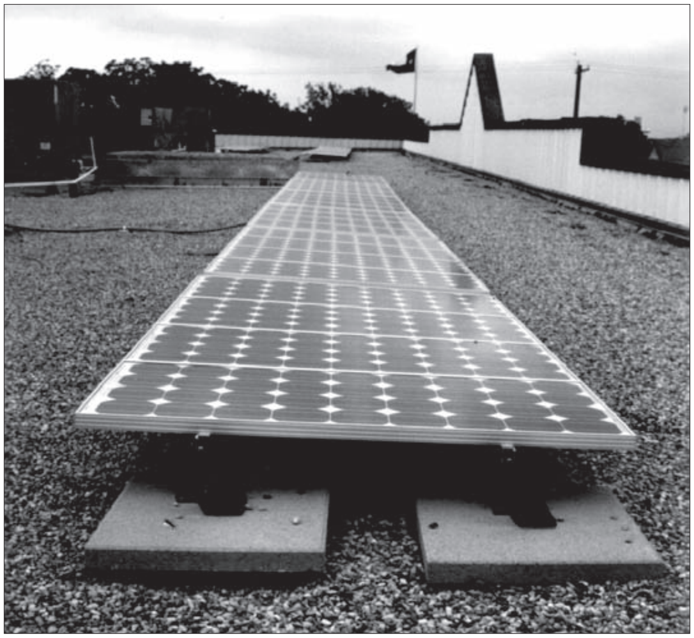
The portability and self-contained nature of PV has made it a very popular source of emergency power during disaster relief. After a storm when electric power is not available due to damaged electricity lines, PV modules can provide the power needed for search and rescue operations and other critical activities.

SPACE APPLICATIONS

Photovoltaics have always been the favorite power source in space. PV cells provide power for telecommunications satellites that orbit the Earth, the international space station, and other exploration probes. NASA’s Texas laboratories have recently developed a refrigerator system that is battery-free for the international space station. This refrigerator is now being commercialized for use on the ground as well.

BUILDING INTEGRATED SYSTEMS

When is an awning more than an awning? When it also doubles as a PV module. Solar shingles and skylights that are coated with PV material and other new building products can generate electricity while also serving as an important element of a home or office. Architects and building designers are now including these new products into their designs.



EBENESER BAPTIST CHURCH DAY CARE CENTER HOUSES PV PANELS *Thanks to Austin Energy and volunteers from the Texas Solar Energy Society, the Day Care Center in East Austin has PV panels that will lower their electric bill by about $900 annually.*

WATER PUMPS

Powering water pumps up to about 2 horsepower in size is one of the most cost-effective uses for PV since it is simple, reliable and needs little maintenance. If a PV water pumping system was designed well and is maintained, it can last 20 years or more.

GATE OPENERS

Gate openers are an ideal candidate for PV power because they are often located far from available power lines. Some models are powerful enough to open gates 16 feet wide and weighing up to 250 pounds. These gate openers use wireless remote control mechanisms or digital keypads, both of which offer convenience and security.

A ROOF FULL OF CELLS

While there are many low-power applications suitable for PV use, the biggest market for PV power may lie on your house. As always, the first step would be to make your home as energy efficient as possible, such as adding insulation and using more efficient appliances, lighting and windows. The electrical needs you have after that would then require a PV system with a capacity of about four kilowatts. A complete PV system for your home can provide you with electricity that does not make any pollution. Clean energy is appealing to many electric consumers. Perhaps more importantly, PV allows homeowners greater flexibility in choosing a home site, since self-sufficient PV homes would not need to be located near existing power lines.

SOLAR LIGHTING

There are thousands of school zone flashing lights powered by PV in Texas. PV saves taxpayers time and money by avoiding expensive construction costs to install underground power lines. In addition, PV power is used for road maintenance warning signs, security lights, bus stops, and billboard lighting.

BUILDING INTEGRATED PV PANELS *The University of Texas Health Science Center in Houston has a wall mounted PV awning to provide shade for windows below it as well as electricity.*

Understanding The Reading Passage

1. When are photovoltaic systems the most cost-effective?

____

____

2. What was one of the earliest uses of PV? ______________________________

____

3. How is PV used for schools? ______________________________

____

4. List 4 other uses for PV:

1 ______________________________

2 ______________________________

3 ______________________________

4 ______________________________

5. If you are considering PV for your home, what should you do for your home first?

____

____

Vocabulary

Based on the Reading Passage, write down your understanding of these words or word pairs and verify your definitions in a dictionary, on the Internet if available or with your teacher:

calorie ______________________________

candidate ______________________________

capacity ______________________________

cost effective ______________________________

insolation ______________________________

integrated ______________________________

kilowatt ______________________________

latitude ______________________________

longitude ______________________________

milliwatt ______________________________

monitoring ______________________________

photovoltaic (PV) cells ______________________________

PV module ______________________________

remote ______________________________

telecommunications ______________________________

self-sufficient ______________________________

solar constant ______________________________

viable ______________________________

watt ______________________________

LAB ACTIVITY: INVESTIGATING SUNLIGHT AND OTHER WEATHER DATA IN TEXAS

BACKGROUND

Insolation is a measurement of the amount of solar energy that reaches the Earth every day. The amount of energy that reaches the Earth's surface depends on the conditions of the atmosphere and the angle of the surface in relation to the Sun. Cloudy or clear skies, rain or sunshine impact the amount of the Sun's energy that reaches the Earth. Because the Earth is a sphere, the surface angle on the Earth slopes away from the Sun at the poles. Imagine a pole that goes through the Earth from the North Pole to the South Pole. Now, think of this pole as pointing away from or towards the Sun. This pointing or sloping of the Earth is called tilt. The tilt of the Earth's axis causes a change in the angle of incidence, or tilt, throughout a year. This is the reason for the change of seasons.

It is important to find areas of land on the Earth where the surface angle would be the best for capturing and using the Sun's energy. Finding places on the globe requires some sort of numbering system or grid. Imagine a grid of lines drawn on the face of the Earth. These lines are known as latitude and longitude that divide the Earth's surface into equal places. Positions across the planet's surface are measured in units called degrees, minutes, and seconds. Latitude is determined by an angle at the center of the Earth measured in a north-south plane pole-ward from the Equator. There is a 90-degree arc between the Equator and the North Pole, and a 90-degree arc between the Equator and the South Pole, so the greatest latitude possible is 90 degrees North or 90 degrees South. Starting at the Equator, equal distant circles are drawn parallel to the Equator and to each other. We call these equal distant circles parallels.

Longitude is the amount of arc created by drawing a line from the center of the Earth to an intersection of the Equator. Longitude is a measurement of location east or west of the Prime Meridian of Greenwich, England. Longitude measures 180 degrees both east and west of the Prime Meridian, drawn from Pole to Pole where they meet. There are 69.17 miles per degree of longitude at the Equator with 0 miles at the poles.

INSTRUCTIONS

In this activity, you will create an insolation map and determine which areas in Texas are best suited for production of electricity through photovoltaics. (The areas receiving the greatest amount of solar energy are best suited for photovoltaic production of electricity.) The map already has the degrees of latitude printed to make your task easier. Based on this map, you will answer questions in your Lab Report Form.

STUDENT DATA SHEET

1. On your Texas insolation map, plot the following points and mark them as groups "A" and "B"
   Points "A":
   N36, W102
   N34, W101
   N32, W101
   N30, W102
   Points "B":
   N33, W94
   N29, W98
   N27, W100

2. Draw a line connecting all points "A"

3. Draw a line connecting all points "B"

4. Color your map according to the following information (kilowatt hours per meter squared per day = kWh/m²/day):

   - The area west of the line "A" receives 4-5 kWh/m²/day. Color this area yellow.
   - The area between lines "A" and "B" receives 3-4 kWh/m²/day. Color this area green.
   - All the area east of the line connecting points "B" receives 2-3 kWh/m²/day. Color this area blue.

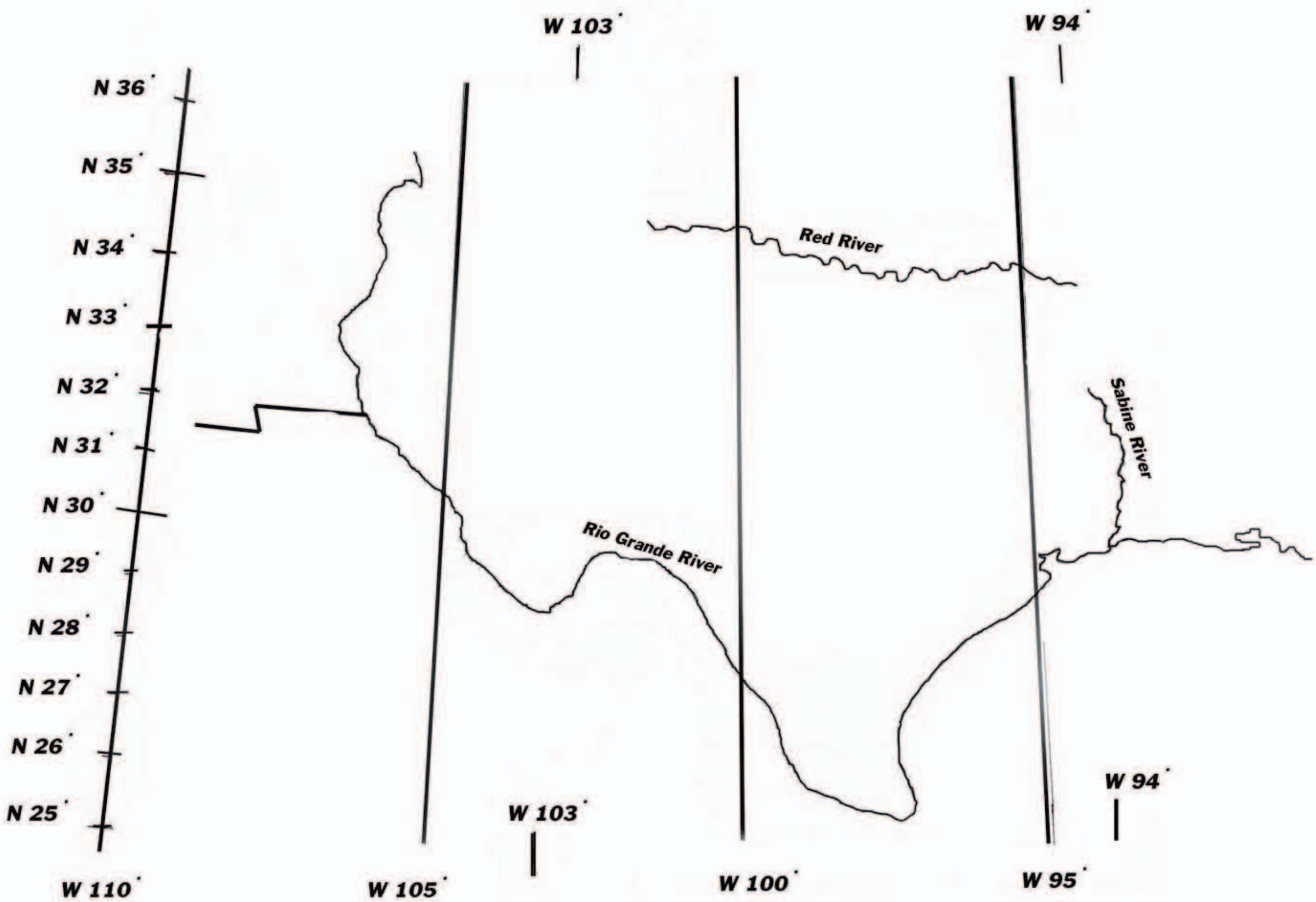
5. Plot the following points on your map and number them 1-9
   1. N32, W106
   2. N32, W103
   3. N36, W103
   4. N36, W100
   5. N34, W100
   6. N33, W94
   7. N32, W94
   8. N29, W93 (The Sabine River enters the Gulf of Mexico)
   9. N26, W96 (The Rio Grande enters the Gulf of Mexico)

6. Trace a line between each number. The space between points 5 and 6 must be traced on the Red River. The space between points 7 and 8 must be traced along the Sabine River. Trace a line between points 9 and 1 along the Rio Grande. You have now outlined the state of Texas on your map.

7. Now locate the following metropolitan areas on your map. Place a dot for each coordinate and label the city. (All longitude and latitude coordinates have been rounded to the nearest whole degrees.)

City	Latitude, Longitude
Austin	N30, W97
Amarillo	N34, W101
Brownsville	N25, W97
Corpus Christi	N27, W97
Dallas	N32, W96
El Paso	N31, W106
Fort Worth	N32, W97
Houston	N29, W95
San Angelo	N31, W100
San Antonio	N29, W98

TEXAS INSOLATION MAP



Lab Report Form – Investigating Sunlight and Rainfall in Texas

Lab Title ____

Date ____

Purpose of this lab is to ____

____

Instructions

Using either Internet or library resources, complete Data Table 1 by filling in weather data and latitude and longitude for the Texas cities you marked on your solar insolation map.

DATA TABLE 1. Weather and Geographic Data For Texas Cities

City	Annual Rainfall (Inches)	Annual # Days of Sunlight	Latitude (° N)	Longitude (° W)

DATA ANALYSIS

1. Based on the solar insolation map you just created, which cities noted on your map have the greatest amount of sunlight?

   1 ______________________________

   2 ______________________________

   3 ______________________________

2. If the area receiving the greatest amount of sunlight is the best candidate for photovoltaics, which city on your map would be the WORST candidate for photovoltaics?______________________________

3. Based on data you recorded in Table 1, which city has the most number of days of sunlight AND the lowest amount of rainfall per year? ____________________ Is this city a good candidate for solar? Why or why not? ____________________

   ____

4. What is the relationship between the annual number of days of sunlight and rainfall? ______________________________

   ____

5. Do cities with the greatest amount of sunlight share a common latitude or longitude? What does this mean? ____________

   ____

   ____

Assessment Questions

1. List 2 advantages and 2 disadvantages to photovoltaic systems:

_______________ _______________

_______________ _______________

2. Locate your hometown on the insolation map you created and identify its insolation rate for installing photovoltaic power: _______________

3. What is the largest possible number for latitude? _______________

4. How far is the sun from the Earth? _______________

5. Where is the Prime Meridian? _______________

Multiple Choice Questions

1. A solar-powered instrument you have probably used is:
   a) a car
   b) a calculator
   c) a washer
   d) an iron

2. PV power currently is
   a) cheaper than ever before
   b) used in over 400,000 homes
   c) depends on wood
   d) a and b only

3. PV usage is growing:
   a) only in Australia
   b) ten times faster than oil usage
   c) very slowly in space
   d) only for producing cars

4. PV is used for:
   a) telecommunications
   b) water pumps
   c) gate openers
   d) all answers a, b, c

5. The greatest site for placing PV modules may be:
   a) caves
   b) Alaska
   c) rooftops
   d) landfills

6. Some small solar electronic devices include:
   a) solar watches
   b) solar calculators
   c) solar battery chargers
   d) all answers a, b, and c

7. One of PV's useful qualities is:
   a) reliability
   b) flexibility
   c) can be used anywhere
   d) all answers a, b, and c

8. You would be willing to use solar power in your future home:
   a) yes
   b) never
   c) only if someone else pays for everything
   d) perhaps

9. The greatest possible latitude is:
   a) 90 degrees
   b) 10 degrees
   c) 50 degrees
   d) 44 degrees

10. Solar energy is less efficient with the presence of:
    a) particulate matter
    b) islands
    c) water vapor
    d) a and c

TEACHER ANSWER KEY

DATA TABLE 1. Weather and Geographic Data for Texas Cities

City	Latitude	Longitude	Rainfall (in inches)	Days of Sun
El Paso	N31	W106	8.39	293
Amarillo	N34	W101	19.56	261
San Angelo	N31	W100	20	251
San Antonio	N29	W98	31	244
Fort Worth	N32	W97	31.4	232
Dallas	N32	W96	36.08	232
Brownsville	N25	W97	27	231
Austin	N30	W97	31.9	230
Houston	N29	W95	50.83	208
Corpus Christi	N27	W97	34	

Understanding the Reading Passage

1. when electricity is needed in a location that is far from existing power lines; when used for items that require small amounts of energy
2. calculators, space applications
3. in school zone flashing lights, solar lighting
4. (Answers vary) emergency power, space applications, water pumping, telecommunications
5. Make your home as energy-efficient as possible.

Lab Report Data Analysis

1. El Paso and Amarillo; also accept San Angelo, San Antonio, Austin, Dallas, Fort Worth
2. Accept Houston, Corpus Christi or Brownsville
3. El Paso. Yes, a PV system installed here will generate more electricity than other cities on the map because it receives the most sunlight and has very few rainy, cloudy days.
4. Typically cities with a greater number of days of sunlight also have lower annual rainfall amounts.
5. Cities with the greatest amount of sunlight have similar longitude values. Cities in the western part of the state have a greater solar resource than the rest of the state.

Assessment Questions

1. Advantages to using photovoltaic systems include creating less environmental pollution, not relying on other countries for energy, no cost fluctuations for energy usage, flexibility, independence, reliability, no transportation or on-going generating costs for the energy, little maintenance required, no need for military protection of resource sites. Disadvantages include storage in stand-alone systems for night use of energy, high initial cost, less efficiency where there is heavy rainfall.
2. Hometown locations will vary.
3. The greatest latitude possible is 90 degrees.
4. The sun is about 93,000,000 miles from the Earth.
5. The Prime Meridian is drawn through Greenwich, England.

Multiple Choice Questions

1 b; 2 d; 3 b; 4 d; 5 c; 6 d; 7 d;
8 a (best answer); 9 a; 10 d

Vocabulary Definitions

calorie – the quantity of heat required to raise the temperature of one gram of water by one degree centigrade

candidate – a person, place or object that is being considered for something

capacity – the maximum production or ability possible

cost effective – producing desirable results for a reasonable monetary value

electrical power grid – a network of high voltage transmission lines distributing electrical power throughout a region

insolation – solar radiation that has been received

integrated – a collection of distinct elements or components that have been built into one unit

kilowatt – a kilowatt is 1,000 watts (see definition of **watt**)

latitude – angular distance on a meridian; locality defined by parallels of latitude

longitude – angular distance, east or west, measured as the angle between the 2 meridians

milliwatt – a milliwatt is 0.001 watts (see definition of **watt**)

monitoring – The on-going process of reviewing a program or activity to determine whether set standards or requirements are being met

photovoltaic (PV) cells – convert sunlight into electricity; made from layers of semiconductor materials (silicon); comes from "photo" meaning light and "voltaic" meaning producing electricity

PV module – dozens of PV cells interconnected and sealed to be waterproof

remote – far apart in nature, inaccessible or sparsely populated

self-sufficient – able to provide your own means without help from others

solar constant – the average rate per unit area at which energy is received by the Earth from the sun, equal to approximately 1,388 watts per square meter

viable – capable of being done with means at hand and circumstances as they are

watt – unit of electrical power (current of 1 amp flowing through a potential difference of one volt); wattage is amount of electric power in an appliance; symbol is w

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