Photovoltaics and Solar Energy (Two Activities)

Grades: 5-8

Topic: Solar

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National Science Standards:

Content Standard A: Science as Inquiry: Students have the ability to develop questions/ideas, formulate tests and experiments, analyze data and come to conclusions about their questions/ideas.
Specific standards met in this module:

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

Content Standard B: Physical Science: Students know and understand the nature of matter from the microscopic to the macroscopic levels and the interaction of energy and matter. Students understand mathematics as an interpretation of physical phenomena.
Specific standards met in this module:

- Conservation of energy and increase in disorder
- Interactions of energy and matter

Content Standard D: Earth and Space Science: Students understand the earth's processes, interaction of matter and energy, origin and evolution of the earth system and the universe.
Specific standards met in this module:

- Energy in the earth system

Content Standard E: Science and Technology: Students understand the interrelationship between science and technological design and advancement.
Specific standards met in this module:

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives: students understand health issues relating to their own health and the health of communities. Students understand the human impact on natural resources and the environment and that they are part of a global environment.
Specific standards met in this module:

- Natural Resources
- Environmental quality
- Natural and human induced hazards
- Science and technology in local, national, and global challenges

Standard G: History and Nature of Science: Students understand that science is done by humans either individually or in teams and can be done on a small scale of field tests or on a large scale with many scientists working on one question. Science is also a unique way of knowing which depends on logic and observation of the natural world and also is ever changing based on new ideas and data.
Specific standards met in this module:

- Science as a human endeavor
- Nature of scientific knowledge

Teacher's Overview:
This module will address issues dealing with the energy from the sun, the energy needs of students in the classroom, and ultimately our energy needs as a nation. Students will use a photovoltaic (PV) cell to measure the energy from the sun. Using a light bulb with a known wattage, the students will illuminate the light bulb using the PV cell. This way the students will know the approximate energy coming from the PV cell. An alternative way for the students to calculate the energy coming from the PV cell is to measure the voltage and the current output from the PV cell across a resistor and use the equation P = IV to calculate the power produced. This is the way that is planned out in the labs related to this unit. From here the students use the efficiency of the PV cell and the area of the cell to calculate the energy of the sun at that time of day. Also, students will experiment with different color filters to determine the energy output of the solar panel at different wavelengths. This will allow them to determine the spectrum of light in which the sun emits the most energy.

At home, the students keep track of the energy they use in terms of kilowatt-hours by finding the energy usage of all of the appliances they use on a daily basis. After investigating their daily usage of energy the students can then calculate how many PV cells they would need in order to supply them with the energy they use on a daily basis. Next they compare the benefits of using PV energy rather than conventional means of electricity generation such as coal burning or nuclear power. Specifically, the students calculate how much coal is required to create the electricity they use on a daily basis and then compare this cost to the cost of the PV system they would need. Environmental benefits and consequences are also addressed in this comparison.

Learning Objectives:
Students will learn about energy conservation and transformation, specifically from radiant energy to electrical energy. Students will understand scientific inquiry as it pertains to taking data and making conclusions about that data. Students will understand their personal connection to the energy they use and the cost of generating that energy. Students will explore further the energy associated with the Earth/Sun system and how the energy from the sun drives many of the processes on Earth. Finally, the students will begin to understand

the connection between science and technology, the limitations of technology and what science and engineering are doing to overcome these limitations.

Time Allotted:

Pre-Test and Review:	45-50 min
Introduction and basic instruction:	2 hrs
Lab: Measuring the Sun's Energy(Weather Dependent):	2 hrs
HW: Student Energy Use worksheet:	30 min
Lab: Measuring the Sun's Spectrum(Weather Dependent)	1 hr
Lab: Measuring the Sun's Spectrum(Plant setup in advance)	1 hr
Review of nation-wide energy use:	30 min
Research traditional methods of electricity production:	1 hr
Design a PV system that fits students energy needs:	30 min
Research cost of PV system:	30 min
Compare/Contrast PV electricity and coal electricity	1 hr
Post-Test	1 hr

Vocabulary:

Photovoltaic	Photoelectric Effect	Efficiency
Watts	Current	Spectrum
Kilowatts	Voltage	Wavelength
Kilowatt Hours	Power	Filter

Resources/Materials:

Materials

- Photovoltaic Solar Cells with attached resistor (10 Ohm)
  (www.siliconsolar.com prices range from $6.00 to $20.00)
- Color Filters (Clear, Red, Green, Blue, Black)
  (www.pasco.com "Ray box color filter set")
- 5 Cardboard Boxes (Shoe boxes work well. Students can donate them from home.)
- 5 Plants (Any green house, Home Depot, Lowes etc…)
  $2 - $3 per plant

Worksheets (see attached)

- "Measuring the Sun's Energy" Lab
- "Measuring the Sun's Wavelength" Lab
- Plant Info Sheet
- Student Energy Use worksheet
- Pre-Test
- Post-Test
- Electricity generation research on the World Wide Web
- Price list of PV cells for home use

Resources

Access to the World Wide Web is required for research on electricity generation and PV price lists.

Prerequisite Knowledge:

Before they begin the lesson, the students must have a basic knowledge of the photoelectric effect. Generally, students will not come into class with this knowledge, so the introduction must give a short explanation of the effect. This does not have to be in much detail. They only need to understand that light can be converted to electricity.

Main Activities:

Labs-Measuring the Sun's Energy and Spectrum

1. Students are given an introduction to the equipment they will be using and are told how to use the equipment properly and safely.
2. Students read the procedure as they follow along while the teacher demonstrates each step of the lab. This is presented in front of the entire class.
3. Give students time to set up the lab and begin testing their apparatus.
4. The next day, students have the class period to set up their apparatus and take data for the lab.

HW Student Energy Use Profile

1. Hand out profile worksheet to each student.
2. Explain the procedure for the profile and explain any calculations that need to be done within the profile worksheet. This should be presented to the entire class.
3. Answer any individual questions that may arise after the explanation.

Research Traditional Electricity Production

1. This will be done on the Internet. Suggested websites should be given so students may find the information.
2. Present assignment to the entire class explaining each question they must answer.
3. Give the rest of the class period for the students to do independent research on the internet.

Design a PV System

1. Students must have their energy use profile done and with them to do this activity.
2. Each student will use their energy profile and the data they collected in the "Measuring the Sun's Energy" lab to calculate the area of PV they would need to supply them with electricity.
3. Walk the students through a simple example calculation of the area of PV that they would need.

4. Give students websites or handouts that have the price lists of PV systems that they can choose from. Students then decide on the cost of their personal PV system.

Compare/Contrast PV Electricity to Traditional Electricity

1. Demonstrate to the students the format of writing desired by the teacher. (A two column list, paragraph form, essay form, etc.)
2. Each student should have their work from the previous activities finished before they attempt this activity. Students should use the information that they obtained through the unit to support their points in this activity.

Evaluation:

Pre-Test

The pre-test will evaluate the students' knowledge of PV cells and solar energy at the beginning of the module.

Post-Test

The post-test will be given to the students after the module to formally examine their understanding of the covered material. This test will cover the basic knowledge students should have gained about PV systems, the sun's spectrum, the environmental impact of traditional energy production, the cost analysis of the PV system, energy conservation and transformation, the earth/sun energy relationship, and the basic calculations that the students performed during the module.

Formative Assessments

The formative assessments such as the lab, the compare/contrast assignment and other activities will assess students' knowledge of scientific inquiry, energy transfer and conservation, the connection between science and technology, and personal and social perspectives of the science.

Photovoltaic Pre-Test

Answer the following questions to the best of your ability.

1. Electricity is generated when a photon of light reacts with what other type of substance?
   a. metal b. water
   c. glass d. plastic

2. How much estimated energy reaches the surface of the earth?
   a. 300 watts b. 1500 watts/meter^2
   c. 1000 watts/meter^3 d. 1000 watts/meter^2

3. A particular solar panel produces 500 watts of power. How many 150 watt light bulbs could the solar panel completely light up?
   a. 4 light bulbs b. 3 light bulbs
   c. 7 light bulbs d. 9 light bulbs

4. How is most of the electricity generated in the United States?
   a. Coal power plants b. Hydroelectric power plants
   c. Nuclear power plants d. Wind farms

5. In a solar panel we convert _____ energy to _____ energy.
   a. chemical, electrical b. electrical, radiant
   c. kinetic, chemical d. radiant, electrical

6. (True/False) The energy from the sun is completely transformed into electrical energy by using a solar panel.

7. (True/False) We will never run out of the fossil fuel natural resources that create the majority of the electricity we use in the United States.

8. Describe, in the space below, how you might measure the amount of energy is coming from the sun at any given time during the day.

LAB:
Measuring the Power from the Sun

In this lab you and your partner will measure the energy of the sun using a small solar panel, a meter stick and a calculator. You will see that the energy from the sun can be calculated from just a few simple calculations and measurements.

Part I: Angle of the sun

1. Write down the time of day you are taking the measurements in the box to the right.
2. Measure the height of the post in meters.
3. Measure the length of the shadow of the post in meters.
4. Draw a diagram of this situation and label the lengths on the diagram.
5. Calculate the angle of the sun from your measured height and length using the following equation:

Tanθ = Post height/shadow length

6. This is the angle of the sun at this time of day.

Time: _____

Post height: _____

Shadow Length: _____

Diagram:

Angle: _____ (show work below)

Part II: Set up of the solar panel

Use the solar panel that you have been given and set it up so that its face is perpendicular (90 degrees) to a ray of sunlight that is coming from the sun. Measure the angle of the solar panel with respect to the ground and label this angle in a diagram you draw in the space provided below.

Solar Panel Diagram

Part III: The Data

Now you must perform the experiment and collect data from it.

1. Measure the area and find the efficiency of the solar panel. Draw a diagram of that area below and label the length of each side.

2. Measure the current and voltage coming from the solar panel when everything is set up correctly.

The Data:

1. Area of Solar Panel: _____
   Efficiency: _____

2. Current: _____
   Voltage: _____

Part IV: The calculations

Now that you have measured the current and the voltage from the solar panel you can calculate the power given by the solar panel using the equation Power = Current x Voltage. Do this calculation and show your work below. (Don't forget units!)

Power: _____

The power calculated above is the power given by the solar panel, but the solar panel has a particular efficiency. This means that the solar panel only converts part of the energy of the sun to electricity. Use this efficiency to calculate the power coming from the Sun. (Don't forget units!)

Power of the Sun: _____

The power of the sun is a bit misleading because the power that the solar panel produces is a function of its area. Thus it is better to talk about the energy of the

sun per area. We call this quantity the **irradiance** of the sun, and we use the units W/m^2. Use the area measurement of the solar panel and determine the irradiance of the sun in W/m^2. Use the space provided below to show your work.

Irradiance of the Sun: _____

<u>Part V</u>: Analysis Questions

1. A house that is run completely on solar power will have a maximum need of 10.5 kW of energy at any given time. If you use the solar panels that we used in this lab to supply the power, what would the total solar panel area need to be?

2. What would we have to do in order to decrease the area of the solar panels in question 1 above?

3. What are the advantages of using solar power to provide energy to a house over the traditional methods of providing energy?

4. What are the disadvantages of using solar power to provide energy to a house?

LAB:
Measuring the Sun's Spectrum

In this lab you and your partner will measure the energy of different light spectra using a small solar panel, a meter stick, color filters, plants, cardboard boxes, and a calculator. You can then decide which spectrum of light the sun is radiating more and then find out why certain things in nature are how they are.

Part I: Setting up the plant boxes

Start with 5 plants that are as close to identical as possible. Measure the individual plants' heights and take note of how healthy the plants look. Make notes of any dead or wilting leaves. Keep the plant info sheet with the plant so that its info isn't mixed with any other plants.

Now take the five cardboard boxes and remove the top and one side for each box. Place a plant in each box and center it. Now tape the individual color filters onto each box so that they fully enclose the plant, but do not tape it so securely that it can't be removed easily. This is because you'll still need to water the plants daily. Tape the plant info sheet to the back of the box.
You should now have 5 boxes, one with a clear filter, one with a black filter, one with a green filter, one with a red filter, and one with a blue filter. Each plant should have its plant info attached. Place the boxes in the window so that each is facing outward to get the most sunlight into the box.

Part II: Measuring the angle of the sun

1. Write down the time of day you are taking the measurements in the box to the right. 2. Measure the height of the post in the court yard in meters. 3. Measure the length of the shadow of the post in meters. 4. Draw a diagram of this situation and label the lengths on the diagram. 5. Calculate the angle of the sun from your measured height and length using the following equation: $\tan\theta$ = Post height/shadow length 6. This is the angle of the sun at this time of day.	Time: _____ Post height: _____ Shadow Length: _____ Diagram: Angle: _____ (show work below)

Part III: Set up of the solar panel

Use the solar panel that you have been given and set it up so that its face is perpendicular (90 degrees) to a ray of sunlight that is coming from the sun. Measure the angle of the solar panel with respect to the ground and label this angle in a diagram you draw in the space provided below.

Solar Panel Diagram

Part IV: The Data

Now you must perform the experiment and collect the data for this experiment.

1. Measure the current and voltage across the resistor attached to the panel when everything is set up correctly. Only record numbers as positive when measuring voltage and current.
2. Now place the color filters over the solar panel and record the voltage and current for each filter in the data box.

The Data:

No Filter Current: _____
No Filter Voltage: _____
Clear Current: _____
Clear Voltage: _____
Red Current: _____
Red Voltage: _____
Green Current:_____
Green Voltage:_____
Blue Current:_____
Blue Voltage: _____
Black Current: _____
Black Voltage: _____

Part V: The calculations

Now that you have measured the current and the voltage from the solar panel you can calculate the power given by the solar panel using the equation Power = Current x Voltage. Do this calculation and show your work below. (Don't forget units!)

No Filter Power: _____

Clear Filter Power:_____

Red Filter Power:_____

Green Filter Power:_____

Blue Filter Power:_____

Black Filter Power:_____

According to your Data above number the filters according to their power output 1 through 5 in the box below, 1 being the most power and 5 the least.

Clear Filter: _____
Red Filter: _____
Green Filter:_____
Blue Filter: _____
Black Filter:_____

Part VI: Analysis Questions

1. If you add the red, green, blue, and black filter powers together and compare that to the clear filter power, is the power larger or smaller than the clear filter power? Why do you think this is?

2. According to your data, which of the three color spectrums—red, blue, or green—does the sun emit the most? Can you describe anything around you in nature that would benefit from this?

3. Describe the changes for each of the plants with the color filters on them.
   Clear-

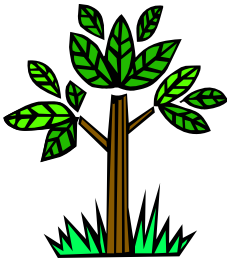
   Red-

   Green-

   Blue-

   Black-

4. Compare the plants to each other. Explain the differences and why you think they occur. (Example: The blue filter plant was nearly the same size as the red filter plant, but much smaller than the clear filter)



Plant Info Sheet

Starting Size (height):_____

Color of Filter:_____

Noticeable Features (wilting, coloring, etc):

Final Size (height):_____

Final Noticeable Features(wilting, coloring, etc):

PV Design
How Much PV Do You Need?

In the following calculations you will determine the area of the photovoltaic system you would need to supply your energy requirements. Given an efficiency of 10%, how big an area does a photovoltaic system need to have in order to supply the energy needs at your house? Assume 750 W/m^2 is the average irradiance of the sun.

1. Assuming 10% efficiency, how much energy would a $1m^2$ solar panel supply in watts?

2. Add the power for each appliance in your house together to get the maximum power needed at any given time. (Use the energy use homework)

3. What is the area of the solar panel system that you will need to supply the power needs for you house?

Homework:
Energy Use In The Home

Group Names: _____

For each part a picture must be taken that shows all appliances used in this task and all of the people in the group.

Part I: Energy in your room

Pick three appliances that you use on a daily basis and find the power used by each of them. Estimate the time each appliance is used each day and calculate the total energy used in kilowatt hours. Show work below.

Appliance #1 Name:	Appliance #2 Name:	Appliance #3 Name:
Power: _____	Power: _____	Power: _____

Total Power used in kWhrs (SHOW WORK!)

Total Power used: _____

Part II: "The Guzzler"

Find the appliance that uses the most energy in the house. This may be an object that runs continuously or an object that uses a huge amount of power at one time. Find this appliance and determine the energy used in kilowatt hours for one day.

"The Guzzler"

_____

SHOW WORK HERE!

Power Used: _____
Time: _____
Total energy used (kWhrs):
_____

Part II: Energy usage for one day

This part will require you to find your energy consumption meter. This meter has five dials and a wheel that spins underneath the dials. You will check the reading on the meter at a particular time during the day and then re-check the meter at the exact same time the following day. The difference in the readings will tell you the energy used in the house during that 24 hour period of time.

Time of day: _____	Energy used (kW): _____
Meter Reading: _____	Total Elapsed Time (hrs): _____
Time of day: _____	
Meter Reading: _____	Energy used in kWhrs: _____

Part IV: Energy Cost$$$

Now we will determine the cost of the energy you use on your own and the cost of the energy used in your house. Obtain the most recent utility bill for your house and determine the price of energy per kilowatt hour. Then calculate the cost for the energy you use individually on a daily basis and the cost for the energy used by your house on a daily basis.

Individual Cost	Household Cost
Price per kWhr: _____	Price per kWhr: _____
Total kWhrs used: _____	Total kWhrs used: _____
Cost of energy for one day: _____	Cost of energy for one day: _____

Independent Research:
Traditional Electricity vs. Photovoltaics

In Part I of the following assignment, you will research three traditional methods of producing electricity. You will do your research on the Internet and answer the following questions. In Part II you will use the information from your energy use homework to research the cost of using photovoltaics for your energy needs.

Part I: Traditional power plants

1. Coal burning power plants

A. Describe the production of electricity using a coal burning power plant in the space below.

B. What percent of the United States electricity needs are produced by coal burning power plants?_____

C. What are the byproducts of coal burning power plants? (For example, waste, greenhouse gas emissions, environmental impacts.)

D. What is the average cost per kilowatt hour for electricity produced by this method? _____

F. What other industries must be in production to supply electricity by these means? (For example, mining or construction.)

2. Nuclear Power Plants

A. Describe the production of electricity using a nuclear power plant in the space below.

B. What percent of the United States electricity needs are produced by nuclear power plants? _____

C. What are the byproducts of nuclear power plants? (For example, waste, greenhouse gas emissions, environmental impacts.)

D. What is the average cost per kilowatt hour for electricity produced by this method? _____

F. What other industries must be in production to supply electricity by these means? (For example, mining or construction.)

3. Hydroelectric Power Plants

A. Describe the production of electricity using a hydroelectric power plant in the space below.

B. What percent of the United States electricity needs are produced by hydroelectric power plants? _____

C. What are the byproducts of hydroelectric power plants? (For example, waste, greenhouse gas emissions, environmental impacts.)

D. What is the average cost per kilowatt hour for electricity produced by this method? _____

F. What other industries must be in production to supply electricity by these means? (For example, mining or construction.)

Part II: Photovoltaics used for electricity production

Now we will compare photovoltaic electricity production with traditional methods and find how much it would cost to power your house using photovoltaics.

A. Describe the production of electricity using photovoltaics in the space below.

B. What percent of the United States electricity needs are produced by photovoltaics? _____

C. What are the byproducts of photovoltaics? (For example, waste, greenhouse gas emissions, environmental impacts.)

D. What is the average cost per kilowatt hour for electricity produced by this method? _____

F. What other industries must be in production to supply electricity by these means? (For example, mining or construction.)

Now you will do some research on the Internet to find a photovoltaic system that will fit the needs of your household. Go to the following Web site to determine the system that you will need: www.mrsolar.com. Once at the Web site, click on "Remote Home," under Pre-Packaged systems, on the left side of the window. Using the Energy Use homework that you received, determine the following:

1. The daily electric power needs for your house in kilowatt hours: _____
2. The average power needed in Watts for one day. (Divide the answer above by 24hrs). _____
3. Determine the system you need for your home. (Remember that you need Alternating Current (AC), and not Direct Current (DC).) Give the name of the system you chose and why you chose that system.

4. List the parts that come with the package that you have chosen and give the efficiency for the solar panels you get in that package.

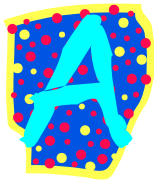
5. What is the price of this system? _____

6. How long would you have to run this system for it to pay for itself? (How many years would it take paying for traditional electricity to equal the price of the photovoltaic system?) Show your work below.

7. Would the photovoltaic system be cost effective over the short run? How about the long run?

Compare/Contrast:
Photovoltaics vs. Coal Produced Electricity

In the space provided, compare and contrast the benefits and drawbacks in using coal and photovoltaics to produce electricity. Consider environmental impacts, economic impacts, practicality, and other points while writing your statement. You should not pick a side in this paper. You should give an unbiased comparison of the two technologies. Write in complete sentences and use proper paragraph format. Use extra paper if needed.



Photovoltaics Test

1. Electricity is formed when a photon of light reacts with what other type of substance?
   a. metal b. water c. glass d. plastic

2. How much estimated energy reaches the surface of the earth?
   a. 300 watts
   b. 1500 watts/meter^2
   c. 1000 watts/meter^3
   d. 1000 watts/meter^2

3. A particular solar panel produces 500 watts of power. How many 150 watt light bulbs could the solar panel completly light up?
   a. 4 light bulbs
   b. 3 light bulbs
   c. 7 light bulbs
   d. 9 light bulbs

4. How is most of the electricity generated in the United States?
   a. Coal power plants
   b. Hydroelectric power plants
   c. Nuclear power plants
   d. Wind farms

5. In a solar panel we convert _____ energy to _____ energy.
   a. chemical, electrical
   b. electrical, radiant
   c. kinetic, chemical
   d. radiant, electrical

6. What is the current approximate maximum efficiency reached by a solar panel?
   a. 100%
   b. 54%
   c. 10%
   c. 35%

7. Solar panels must be faced in which direction in order to receive the most sunlight during any given day?
   a. South
   b. North
   c. West
   d. East

8. A house that supplies all of its own energy needs is called…
   a. Energy Efficient
   b. a Tree Hugging Home
   c. Off the Grid
   d. Non-Existent

9. What is the main element used in most photovoltaics?
   a. Silicon
   b. Copper
   c. Aluminum
   d. Iron

10. Photovoltaics are mainly used for what purpose currently?
    a. small applications such as street lights and small well pumps
    b. large power grids feeding power to entire cities
    c. supplying power to commercial vehicles such as a passenger car
    d. supplying power to perform electrolysis to obtain hydrogen

11. (True/False) The energy from the sun is completely transformed into electrical energy by using a solar panel.

12. (True/False) We will never run out of the fossil fuel natural resources that create the majority of the electricity we use in the United States.

13. (True/False) All of the energy needed in a house can be supplied by photovoltaics.

14. (True/False) Photovoltaics do not produce pollution to our atmosphere unlike coal power plants.

15. (True/False) Photovoltaics are very cost effective in the long run but not in the short run.

16. Describe, in the space below, how you might measure the amount of energy is coming from the sun at any given time during the day.

17. Calculate how much energy is produced by a photovoltaic cell that has an efficiency of 13.4% if the average sun irradiance is 745 W/m^2? The dimensions of the cell are 1.25m long and 3.2m wide.

18. How much energy will the photovoltaic cell from #17 produce in kilowatt hours if it is allowed to produce electricity for 4.6 hours?

19. A well has a power need of 1200W. How big does a photovoltaic cell need to be in order to supply this power if the cell has an efficiency of 35% and the solar irradiance is approximately $940W/m^2$?

20. Do you think that photovoltaics have the ability to meet the power needs of the United States if the country would commit to using solar energy? Describe why or why not and use evidence from the class to support your argument.

21. Label the following diagram of a simple solar cell and describe the process in which electricity is generated by sunlight passing through the layers of the solar cell.