Schools Going Solar

Data driven lessons and activities to support and incorporate installed photovoltaic systems into the classroom learning environment.

2019-2020

Grade Levels:

Int Intermediate

Sec Secondary

Subject Areas:

Science

Social Studies

Math

Language Arts

Technology

NEED National Energy Education Development Project

Dominion Energy SOLAR FOR STUDENTS

Teacher Advisory Board

NEED Mission Statement

The mission of The NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

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Teacher Advisory Board

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

Energy Data Used in NEED Materials

NEED believes in providing teachers and students with the most recently reported, available, and accurate energy data. Most statistics and data contained within this guide are derived from the U.S. Energy Information Administration. Data is compiled and updated annually where available. Where annual updates are not available, the most current, complete data year available at the time of updates is accessed and printed in NEED materials. To further research energy data, visit the EIA website at www.eia.gov.

NEED
National Energy
Education Development

1.800.875.5029
www.NEED.org

Schools Going Solar activities are intended for use in a solar school. These activities provide a means for schools to incorporate solar arrays into their solar/energy curriculum, in conjunction with the NEED solar curriculum and kits.

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Schools Going Solar

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Standards Correlation Information

www.NEED.org/educators/curriculum-correlations/

Next Generation Science Standards

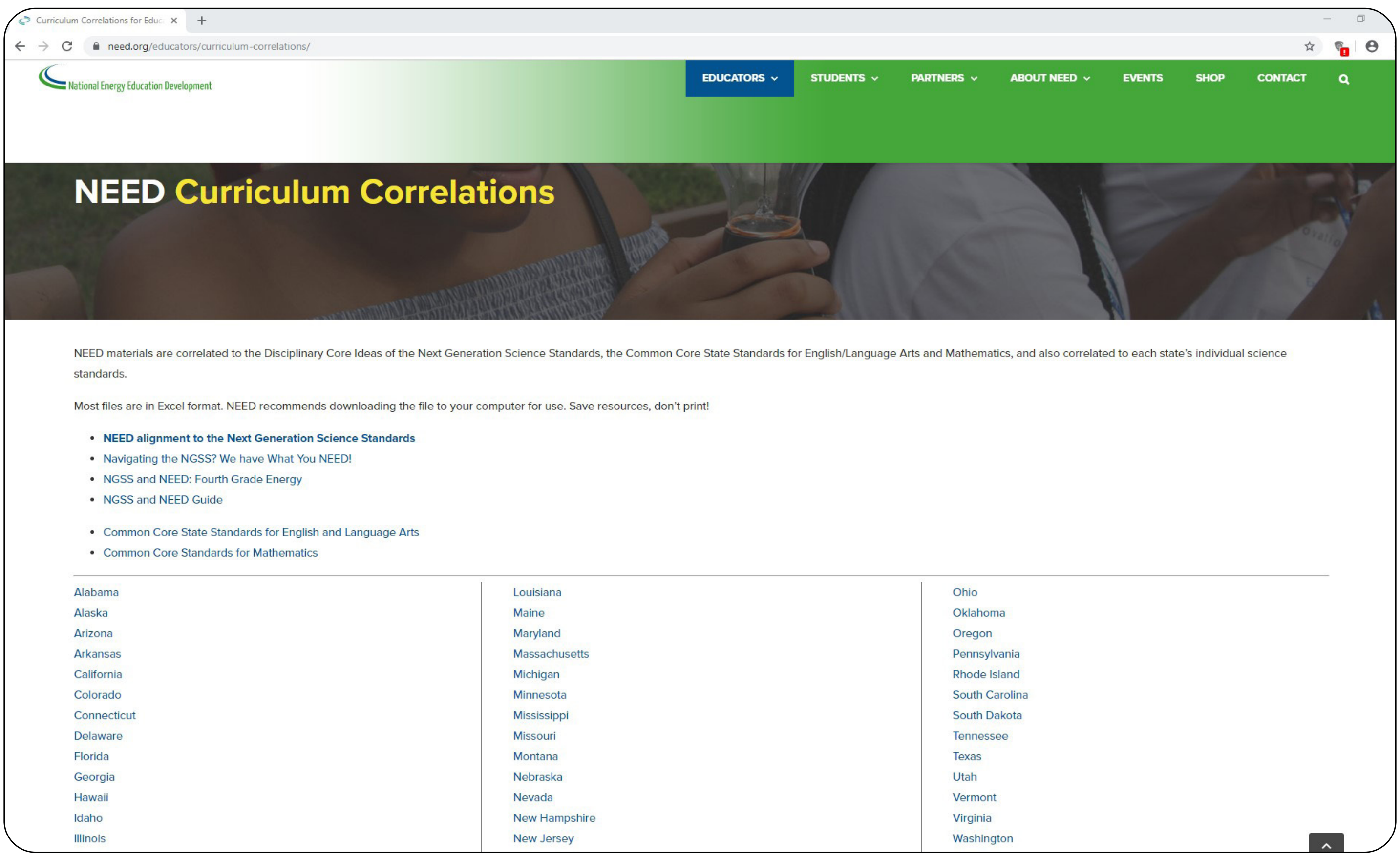
- This guide effectively supports many Next Generation Science Standards. This material can satisfy performance expectations, science and engineering practices, disciplinary core ideas, and cross cutting concepts within your required curriculum. For more details on these correlations, please visit NEED's curriculum correlations website.

Common Core State Standards

- This guide has been correlated to the Common Core State Standards in both language arts and mathematics. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED curriculum correlations website.

Individual State Science Standards

- This guide has been correlated to each state's individual science standards. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED website.



Schools Going Solar Materials

The table below contains a list of materials needed for hands-on or laboratory activities. There are several activities that are not listed below that do not require materials other than pencils, paper, and copies. Refer to the activity instructions within the teacher guide for more specific instructions. This unit works very nicely with NEED's solar curriculum kits. See page 54 for more information on these kits.

Contact NEED if you have any questions or difficulty locating a certain item.

ACTIVITY	MATERIALS NEEDED
Photovoltaic Cells and Their Variables	▪PV panels ▪Digital multimeters ▪Alligator clips ▪Cardboard ▪Tissue paper ▪Quilt batting ▪White paper ▪Black paper ▪Light source or sunny day
PV System Performance	▪Computer and Internet access ▪Sticky notes
Solar Data Predictions	▪Solar array access ▪Calendar ▪Calculators ▪Prizes (optional)
What Can Your Solar Panel Power?	▪Pluggable appliances and devices

Teacher Guide

Grade Levels

- Intermediate, grades 6–8
- Secondary, grades 9–12

Time

Approximately 2-3 weeks, using 45-50 minute class periods

NEED Resources

NEED has many resources available to you to enhance and extend your solar and/or energy unit. All are available to download for free from shop.NEED.org.

Solar Resources

- *Wonders of the Sun* (3–5)
- *Energy From the Sun* (6–8)
- *Exploring Photovoltaics* (9–12)

Science, Language Arts, and Social Studies Resources

- *Energy Enigma* (9–12)
- *Energy Expos* (4-12)
- *Energy Live!* (4–12)
- *Energy on Stage* (4–12)
- *Great Energy Debate* (6–12)

Why Introduce PV Projects In Schools?

Schools around the country are being offered opportunities to partner with government agencies, community foundations, utilities, businesses, and corporations to install PV systems. The Solar Electric Power Association states that, "…bringing solar to schools is an important first step to increasing the use of solar energy in the community at large. Schools make an excellent showcase for the benefits of solar photovoltaic electricity, solar thermal energy, and passive solar. Changes and improvements at schools are highly visible and closely followed. As has been the case with recycling programs, which were introduced to many communities by schoolchildren educating their parents, students can carry good ideas from the classroom into the mainstream."

A PV system installed at your school can provide significant energy savings. Depending on the geographic location and technology installed, a 2 kilowatt (kW) PV system can produce over 250 kilowatt-hours (kWh) of electricity per month, and an average annual output of more than 3,000 kWh. The environmental benefits include offsetting carbon dioxide (CO_2) produced by traditional power plants and vehicles.

For most schools, however, the decision to install PV systems is more about education and inspiration for their students than about cost savings. The students get a first-hand view of energy technologies. Integrating the data supplied by the PV systems into the school curriculum helps students learn about how solar electricity works and involves them in the study of the benefits of renewable energy and energy efficiency. The PV system also provides students with an opportunity to learn first-hand about employment opportunities in emerging renewable energy technology fields.

How Schools Benefit

Many schools that choose to enter into a PV demonstration partnership receive all of the hardware and software needed for complete integration into the curriculum system. The systems typically range from 500 watts to 10 kilowatts in size and are usually designed to be mounted on peaked or flat roofs. Some systems are designed for ground or wall mounts for increased public visibility.

In order for students to be able to explore the PV system's effects on electricity use, many schools also receive data acquisition systems and interactive educational monitoring software designed to transmit data for educational use from the PV system. The goal of the monitoring software is to provide interaction with students and teachers, while also logging PV system data to a database for simple integration into class curricula. Adding an optional Internet component to the data acquisition hardware will allow data to be sent directly to a centralized database for interactive web explorations.

The data acquisition systems allow schools to monitor the daily and cumulative production of electricity from the system. The Internet-compatible data acquisition systems supplied to many schools allow teachers and students to monitor local atmospheric conditions (wind speed, temperature, solar radiation, etc.) and compare this data to the electrical production of the system.

In order to make full use of a PV system as a real-world teaching tool, teachers must find ways to integrate its use throughout the school's curricula. This guide has been designed to provide teachers with ideas for integrating the system into your science, math, language arts, and social studies classes. The lessons in this guide will help your students master the concepts related to solar energy and PV systems.

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★Concepts

- The sun produces enormous amounts of energy, some in the form of radiant energy that travels through space to Earth.
- It is difficult to capture the sun's energy because it is spread out—not concentrated in any one area.
- Photovoltaic (PV) cells convert radiant energy directly into electrical energy.
- We can use the sun's energy to produce electricity.
- We can forecast the amount of electricity that will be generated based on the size of a solar array and historical and current weather data.
- The electrical appliances and machines we use consume a lot of energy.
- Using electricity impacts the environment.
- PV systems offset school electric needs, but do not usually generate all of the electricity needed.
- Using PV systems to generate electricity for schools decreases the amount of CO_2 emitted.

Unit Preparation

- Familiarize yourself with the activities in this guide.
- Familiarize yourself with your school's data acquisition system (DAS). If you do not have a system, find schools with websites that you would like your students to use. A listing of schools can be found on page 17. These can also be used for comparison activities.
- Make copies of the *Student Informational Text* and *Glossary* pages for students.
- Decide which activties you will conduct to enhance or support your discussions. Prepare digital copies for projection or physical copies for the class.
- Gather any materials needed for each activity.
- Secure computer and Internet access for students, as needed.

Science Notebooks

Throughout this curriculum, science notebooks are referenced. If you currently use science notebooks or journals, you may have your students continue using these.

In addition to science notebooks, student worksheets have been included in the guide. Depending on your students' level of independence and familiarity with the scientific process, you may choose to use these worksheets instead of science notebooks. Or, as appropriate, you may want to make copies of worksheets and have your students glue or tape the copies into their notebooks.

☑Evaluation

Evaluate the unit with your students using the *Evaluation Form* on page 55 and return it to NEED.

Activity 1: Introduction to Solar Energy

✪ Objective

- Students will be able to identify basic facts about energy and solar energy.

Time

- One to two class periods

Materials

- *KWL Organizer for Solar Energy,* page 22
- *Student Informational Text,* pages 41-51
- *U.S. Solar Resource Map,* page 23 (optional)

✔ Procedure

1. Distribute the worksheets to the students.
2. Introduce solar energy as the topic of exploration using the *KWL Organizer for Solar Energy*. Have the students make a list of the things they know and questions they have about solar energy.
3. Have students read the informational text, adding to their KWL charts. Discuss the questions they have and have them research specific questions as homework.

Extension

- Project or have students study the *U.S. Solar Resource Map*. Ask students to point out or find the location where they live on the map. Have them analyze their area's solar resources in comparison to other areas. Have students complete a quick-write about the possible reasons for their area's shading on the map and why other areas stack up differently. Ask students to share their ideas with a partner or the class.

Activity 2: Photovoltaic Cells and Their Variables

Objectives

- Students will be able to explain how radiant energy can be transformed directly into electricity.
- Students will be able to identify variables that affect the output or performance of a photovoltaic system.

Time

- One to two class periods

Materials

- Small PV panel
- Digital multimeter
- 2 Alligator clips
- Cardboard or posterboard
- Tissue paper
- Quilt batting
- White and black paper
- Light source – lamp or sunny day
- *Digital Multimeter* master, page 21
- *Photovoltaic Cells and Their Variables* worksheets, pages 24-25

Preparation

- Gather materials and set up stations, if needed.
- Prepare a copy of the *Digital Multimeter* master for projection.
- Make copies of the worksheets for each student.

✔ Procedure

1. Place students into groups and make sure each group has the materials needed.
2. Discuss how to use and read a digital multimeter, displaying the master as needed.
3. Explain the procedure and have the students complete the activity in their groups.
4. As a review, have the class make a list of the variables that might affect a solar panel's output. Make sure to connect the materials used in the experiment with their real-life counterparts. Ask students to suggest any variables that may not have been discussed or explored in this activity (i.e., geographic location, temperature of the panel, etc.).

Extensions

- Have students graph the output from their panel when tilted at different angles. Discuss what type of graph is the best for representing this data.
- Have students graph the output from their panel when covered by different amounts of cardboard. Discuss what type of graph is best for representing this data.

Activity 3: PV System Performance

Background

In this activity, students will investigate and analyze the variables affecting power generation using solar energy data. Web-based data acquisition systems (DAS) for installed panels collect downloadable data that allow students to compare and contrast variables for a single installation or to compare various installations. This data is often reported using graphs, tables, and infographics. This activity aims to familiarize students with the various forms of graphs and tables they may encounter, compare each format, and use the data to make inferences about a PV panel based on the data. While every DAS is different, the major focus of each is to bring real time and/or historical data to building users.

Objectives

- Students will be able to identify variables that affect photovoltaic system performance.
- Students will be able to analyze and interpret graphical representations of PV data.
- Students will be able to compare and contrast PV systems in different geographical areas.

Time

- 2 class periods at minimum, with additional time for optional data collection

Materials

- Computers with Internet access
- Sticky notes
- *Data Analysis* worksheets, pages 26-28
- *Data Reporting Form*, page 29
- *Student Informational Text*, pages 41-51
- *Variables Affecting Photovoltaic System Performance* worksheets, pages 30-31 (optional)

Preparation

- Become familiar with the DAS you will be using. Make sure you can easily navigate between pages and that you understand how to download data into a spreadsheet (most DAS programs download into Excel using comma separated values (CSV) format). Some DAS graph data on the web. If this is the case, you can choose to not have your students create their own graphs, but to use the ones provided by the DAS instead.
- If you are not already familiar with the terms used to describe photovoltaic installations and the variables surrounding power output, a glossary can be found at the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy website, https://www.energy.gov/eere/solar/solar-energy-glossary.
- Create a physical or digital copy of a map of your state. The map should be large enough that students may add data to the map for their studied location.
- Secure computer lab time, if needed.
- Make copies of student worksheets and informational text, as needed.

✔ Procedure

PART ONE

1. Hand out the data analysis worksheets and put students into pairs or groups.
2. Explain to students that data is often reported using graphs and tables.
3. Have students work through each of the worksheets and record their answers in their notebooks or on a separate sheet of paper.
4. Discuss their observations and data as a class. Ask students to discuss what types of graphs or charts are best for certain types of data, why they may prefer one over the other, and why software might report data in a certain way.

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PART TWO

1. Pass out the reporting form.
2. Take your students on a "virtual tour" of the DAS website, demonstrating how to navigate the site, including how to select particular locations, time frames (day, week, month, etc.), and how to select data output modes (CSV or graph).
3. Review the key types of data collected and critical terms: irradiance, cell temperature, and ambient temperature.
4. Make sure students understand how to select more than one school and how to specify which variables to display.
5. Have students log on to the DAS website and download PV output data for a location of their choosing, or select a location for each group. Discuss with students the time period, such as a day, week, month, or year, for which they will be collecting data. Direct students to record data on the data reporting form.

   OPTIONAL: Pull out CSV data and have students use this data to create graphs. Compare the student graphs to DAS graph output for the same data.
6. Discuss with students the options for finding other data or unreported data. For example, if students pick a school and the weather is not reported, show them other websites where they might get that information.
7. After the time period for data collection is over, students or groups should create a presentation (posterboard, PowerPoint slide, etc.) summarizing their location and its data. Presentations should be sure to include averages of data, maximum and minimum data points, and explanations for data extremes or anomalies.
8. Student groups should create a sticky note that includes their location, average daily generation (kWh), and their average temperature. If you choose, students can substitute different information to fit the needs of your unit. For example, you may choose to showcase differences in latitude, or CO_2 offset. Instruct students to add their sticky note to the map. If locations are close together, give students string to draw out from a cramped map location. Discuss differences and similarities by location.

OPTIONAL: Older or more independent students can also create their own reporting form for recording data. Spreadsheets or a format of their choosing can easily be created.

PART THREE (Optional)

1. Ask the class to brainstorm some questions they have about solar generation based on the previous activities or unanswered by previous activities. Sample questions may include:
   - Is the time of day for peak solar electric output the same everywhere?
   - Is solar electric output influenced by ambient temperature?
   - How does geographic location impact solar electric output?
   - Does the time of year/season impact solar electric output?
2. Re-group students according to the questions they would like to answer. For older students, you may decide to allow each student to answer his/her own question. However, it may be easier for younger students to work in a group to answer the same question. Allow time for students to discuss and plan for what data they need to collect in order to answer their question. Direct them to outline how they will organize and analyze their data. Students or groups should begin completing the *Variables Affecting Photovoltaic System Performance* worksheets.
3. Have students revisit the DAS site and other DAS sites for other schools and arrays (see page 17 for a listing). Students should collect and record data. It may be helpful to designate a time limit for which data must occur, so that projects do not become too lengthy.
4. Have students determine the best way to handle their data and analyze it. Make sure students choose appropriate visuals to answer their questions and share their data with the class. Have students continue working to answer questions on their worksheets.
5. Allow students or groups to review their data analysis with the class and share their conclusions. Have students ask each other questions about methodology used and conclusions drawn. Discuss any conflicting and complementing conclusions.

CONTINUED ON NEXT PAGE

Extensions

- Have students calculate how many panels or modules a researched array has. They would do this by taking the total capacity of the array and dividing it by the panel capacity.
- Invite a solar installer to lead a tour of a PV system at your school or in the community. Have students prepare questions ahead of time about the system, the work the installer does, and how he/she got involved in the solar industry.
- Have students predict PV output based on weather forecasts. Use local weather forecasts or the National Oceanic and Atmospheric Administration's National Weather Service website at www.weather.gov.
- Have students investigate the impact of more than one variable on PV performance, such as comparing solar irradiation, temperature, and power.
- Have students determine the circuit wiring for a PV system. A complete lesson plan with background information can be found on NYSERDA's School Power Naturally website at https://www.nyserda.ny.gov/Communities-and-Governments/P-12-Schools/School-Power-Naturally/Level-III-Lessons. The lesson is found in the "Electric Energy" grouping and is called *Series or Parallel*.
- Have students determine the equivalent behavioral energy savings to one day's PV production.

Activity 4: Solar Data Predictions

Background

Students will process a number of variables and attempt to predict the time at which a solar array will reach a generation milestone. This will vary depending on the size of the array, time of year, and how close you set the goal to the current kilowatt-hours (kWh) generated by the system. Students will investigate the variables using web-based data acquisition systems (DAS) for installed panels.

Objective

- Students will be able to use historical data to make predictions regarding future PV generation.

Time

- 1 class period, with additional time for data collection and reporting

Materials

- Access to solar array (on school property or online)
- Calendar
- Calculators
- Optional prizes (i.e., extra credit, "cut-in-line" pass for lunch, a "kilo-cent" prize (1,000 pennies), etc.)

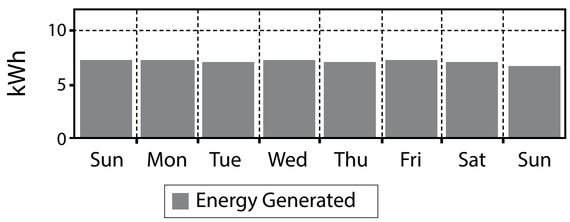
Preparation

- Before the lesson, choose a solar array (local or online) that your students will focus on and determine the benchmark you want students to predict. Design the goal so that it can be reached in a reasonable amount of time (2-4 weeks). Do some estimation yourself beforehand to set the goal.
    - For example: a 1-kW array (1,000 watts) might make up to about 24 kilowatt-hours (kWh) per day, depending on the many variables students studied in Activity 2.
    - See page 17 for a listing of solar schools projects with online data.

CONTINUED ON NEXT PAGE

✔ Procedure

1. Have students list the variables for solar generation they studied in Activity 2. Include amount of daylight, weather, angle of rays, cleanliness of panels, temperature (too much heat can actually decrease solar-electric production), shading by trees or buildings.
2. Look at production history of the array for which you are trying to predict output. A typical graph may look like the graph below, listing days of the week or calendar dates.



3. Allow students or groups time to estimate when the array will reach a goal you have set. You may want to, as a class, begin by subtracting the array's current generation totals from the goal to come up with the actual number of kWh you are trying to predict.
4. Have students or groups select a day and hour that the array will reach the goal. Record their predictions on a calendar.
5. Designate students to record the data each day and report to the class. Students who are reporting should make sure to let the class know how close they are to meeting their predicted goal.
6. Celebrate the students or groups that came closest to the goal. All students can reflect on their predictions and hypothesize why they were early or late.

Extensions

- Do the activity again later in the year. Generally the range of predictions is much closer the second time around.
- Conduct the Solar 8 Investigation from *Exploring Photovoltaics* that examines how surface temperature affects the electrical output of PV cells.

Activity 5: What Can Your Solar Panel Power?

Background

Students will explore the electric load of appliances in their school. They will be able to compare the electrical output of the PV system to the electrical consumption of their appliances. Students will then determine the amount by which the PV system offsets the school's electric consumption.

Objectives

- Students will be able to measure electric consumption of certain appliances and devices.
- Students will be able to estimate the total electric load of the classroom and/or building.
- Students will be able to explain how a PV system can offset the energy needs of a building.

Time

- 3 – 5 class periods

Materials

- *U.S. Solar Resource Map*, page 23
- Student worksheets, pages 32-36
- Pluggable appliances or devices (optional)

Preparation

- Obtain a copy of your school's electric bill or the total kilowatt-hours used per month (prior to the installation of the PV system). If desired, obtain a year's worth of information and incorporate mathematical averaging and graphing into the lesson.
- Determine the cost per kilowatt-hour for electricity for your school, or assign for students to determine it as part of the lesson. If unknown, use $0.107 per kilowatt-hour — the national commercial average.
- Ensure that your students are familiar with how solar energy is used to generate electricity and how electricity is measured. Review the informational text, if necessary.
- Obtain, or have the students determine, the measurements of the PV system on-site or one similar to the one the class is studying. Measurements should include the square footage of panels and maximum power output.
- Obtain permission for students to be in offices, other classrooms, labs, etc.
- Collect, if desired, sample small appliances on which the students may read electric nameplates for practice.
- Make copies of student worksheets, as needed.
- Prepare versions of the student worksheets above for projection, if necessary.

✔ Procedure

DAY ONE

1. Ask the class to think about how much electricity the school uses each day. Have students predict the electric consumption (use) of the school for a month.
2. Hand out the *Electric Nameplates Investigation* worksheet. Explain to students how to read electric nameplates and what information can be learned from them.
3. Divide the students into working groups. If using small appliances to practice nameplate reading, hand out a device to each group and have the students fill in one row of the chart. Check to make sure all groups understand the calculations and have correct information.
4. Send the groups to various rooms in the school where they can collect electric nameplate information. Be sure to include the office and the locations that house copiers, printers, laminators, and other large machinery. Assign the calculations as homework, if needed.

CONTINUED ON NEXT PAGE

DAY TWO

1. Review the data collected from the previous day.
2. Provide the students with copies of the school electric bill or share with them how much electricity the school uses each month.
3. Complete the *Cost of Using Machines Investigation* in class.
4. Have students complete the *Photovoltaic Systems and School Electricity Use* worksheets. Assign for homework, if needed.

DAY THREE

1. Work through the *Can Solar Energy Meet Your Electricity Demands?* worksheet with your students, using the *U.S. Solar Resource Map*, as needed.
2. Discuss with the students the feasibility of using solar generated electricity for the school's entire electric load.
3. Discuss with students the advantages and disadvantages to solar generated electricity.
4. Have students write persuasive pieces to the school board advocating for or against the addition of more solar panels to the school's PV system.

Optional Activity: Calculating PV Array Efficiency

1. Find the area of the solar array in square meters (m^2).
2. Use the DAS website to find the maximum power output of the system under optimal conditions, or its highest historic output in watts (W).
3. Find the irradiance (W/m^2) at the time of peak output.
4. Calculate PV array efficiency: $\frac{\text{maximum power output}}{\text{irradiance x area of array}} = \text{efficiency}$

$$\frac{W}{(W/m^2) \times m^2} = \text{efficiency}$$

Extensions

- Have students complete NEED's *Designing a Solar House* activity found in *Energy From the Sun*. Students will design an efficient, active solar house.
- Bring the PV system down to a smaller scale using *Your Solar-Powered Cabin* activity on pages 39-40. In this activity students inherit a cabin, but before they can take ownership they must design a PV system that will support some of the cabin's electrical needs.
- Have students research how a PV system is designed, manufactured, and installed. Have students brainstorm the career opportunities available through the solar industry. More information about careers can be found by visiting the following sites:
  - Bureau of Labor Statistics—www.bls.gov; and
  - U.S. Department of Energy—https://www.energy.gov/eere/solar/solar-energy-careers
- Have a community solar day where the students lead tours of the PV system. Students could create posters and educational displays with additional information about solar energy. Students could also prepare and present songs or plays as a part of the event.
- After completing the *Can Solar Energy Meet Your Electricity Demands?* worksheet, have students determine if there are any financial incentives for installing PV systems in their area. If incentives exist, have students recalculate their payback period. An incentive map and other resources can be found at www.dsireusa.org.
- Have students participate in a simulation where they determine the feasibility of installing a PV system on the roof of a school in the community. A complete lesson plan (*To Go Solar or Not to Go Solar!*) with student worksheets can be found on NYSERDA's School Power Naturally website at https://www.nyserda.ny.gov/Communities-and-Governments/P-12-Schools/School-Power-Naturally/Level-II-Lessons.
- Participate in the next National Renewable Energy Laboratory sponsored Model Car Competition. For more information visit https://www.nrel.gov/about/car-competitions.html.
- Have students research additional solar technologies. Have them consider if any are viable for use on the school in addition to a PV system.

Activity 6: PV Systems and the Environment

Background

Carbon dioxide (CO_2) is a greenhouse gas. Human activities have dramatically increased its concentration in the atmosphere. Since the Industrial Revolution, the level of CO_2 in the atmosphere has risen over 46 percent. Generating electricity accounts for a large portion of CO_2 emissions in the U.S. Some electricity generation, such as hydropower, solar, wind, geothermal, and nuclear, does not produce CO_2 because no fuel is burned.

Today, 64.6 percent of the nation's electricity comes from burning coal, natural gas, biomass, and petroleum. There is a direct correlation between the amount of electricity we use and the amount of CO_2 emitted into the atmosphere. The rule of thumb is that generating a kilowatt-hour of electricity emits 1.6 pounds of CO_2 into the atmosphere.

Students will learn that using electricity generated from fossil fuels emits CO_2 into the air. Students will show that using electricity generated from solar power can decrease the amount of CO_2 emitted. Students will determine how much CO_2 their PV system prevents from being emitted.

Objectives

- Students will be able to describe and quantify the impacts of electricity use on the environment.
- Students will be able to explain how using solar energy can offset carbon dioxide production.

Time

- Three to four class periods

Materials

- Completed copies of the student worksheets from Activity 5 *Photovoltaic Systems and School Electricity Use*
- *Photovoltaic Systems and the Environment* worksheets, pages 37-38

Preparation

- The *Photovoltaic Systems and School Electricity Use* activity needs to be completed prior to this activity. Data collected during that lesson will be used for this activity.
- Ensure that your students are familiar with how solar energy is used to generate electricity and how electricity is measured.
- Make copies of student worksheets, as needed

✔ Procedure

1. Complete the *Photovoltaic Systems and the Environment* analysis in class and discuss.
2. Have the class make a list of recommendations that the school could employ to reduce their carbon dioxide emissions contribution (carbon footprint).

Extensions

- Have students calculate their own carbon footprint and determine ways to offset their contributions to atmospheric pollution. There are many carbon calculators on the web, including one from the U.S. Environmental Protection Agency: https://www3.epa.gov/carbon-footprint-calculator/.
- Conduct an energy audit of the school to help reduce the carbon footprint of the school. Use materials and lesson plans from NEED's energy management curriculum, available at shop.NEED.org.

Solar Schools Websites

The following websites have data from schools with PV installations.

Bonneville Environmental Foundation—Clean Energy Bright Futures
https://cebrightfutures.org/exploredata

Illinois Solar Schools
www.illinoissolarschools.org/solar-schools/

Madison Gas and Electric
www.mge.com/environment/green-power/solar/solar-in-schools.htm

New York State Energy Research and Development Authority—School Power Naturally Performance Data
www.sunviewer.net/portals/NYSERDA/siteSelect.php

The following websites have data related to solar energy and weather.

National Oceanic and Atmospheric Administration Solar Calculator
www.esrl.noaa.gov/gmd/grad/solcalc

National Renewable Energy Laboratory—PV Watts
https://pvwatts.nrel.gov/

National Weather Service Solar Calculator
www.weather.gov

Solar Energy Websites

American Solar Energy Society
www.ases.org

Energy Information Administration—Energy Kids
www.eia.gov/kids

Florida Solar Energy Center
www.fsec.ucf.edu/en/

How Stuff Works
http://science.howstuffworks.com/environmental/energy/solar-cell.htm

The National Energy Education Development Project
www.NEED.org

National Renewable Energy Laboratory
www.nrel.gov/solar

Sandia National Laboratories
http://energy.sandia.gov/renewable-energy/solar-energy/

Smart Electric Power Alliance
www.sepapower.org

Solar Energy Industries Association
www.seia.org

The Solar Foundation
www.thesolarfoundation.org

DOE Office of Energy Efficiency and Renewable Energy, Solar Technologies Office
https://www.energy.gov/eere/solar/solar-energy-technologies-office

Electricity Unit-of-Measure Equivalents

Unit	Equivalent
Kilowatt (kW)	1,000 Watts
Megawatt (MW)	1,000,000 Watts
Gigawatt (GW)	1,000,000,000 Watts
Terawatt (TW)	1,000,000,000,000 Watts
Gigawatt	1,000,000 Kilowatts
Thousand Gigawatts	1,000,000,000 Kilowatts
Kilowatt-hours (kWh)	1,000 Watt-hours
Megawatt-hours (MWh)	1,000,000 Watt-hours
Gigawatt-hours (GWh)	1,000,000,000 Watt-hours
Terawatt-hours (TWh)	1,000,000,000,000 Watt-hours
Gigawatt-hours	1,000,000 Kilowatt-hours
Thousand Gigawatt-hours	1,000,000,000 Kilowatt-hours

- A **watt** is the electrical unit of power - that is, the rate of energy transfer equivalent to one ampere flowing under a pressure of one volt.
- A **watt-hour** is an electric energy unit of measure equal to one watt of power supplied to (or taken from) an electric circuit steadily for one hour.
- **Irradiance** is the density or power of radiation in a given surface area, measured in watts/ meter^2.

Glossaries of Energy Terms

For additional vocabulary related to solar energy and electricity, see pages 52-53.

Energy Information Administration Energy Kids

www.eia.gov/kids/energy.cfm?page=kids_glossary

Energy Information Administration

http://www.eia.gov/tools/glossary/

Calculation of Power

Power (P) is a measure of the rate of doing work or the rate at which energy is converted. **Electric power** is defined as the amount of electric current flowing due to an applied voltage. Electric power is measured in **watts (W)**. The formula is:

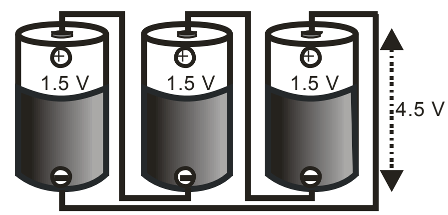
power = voltage x current

$$P = V \times I \quad \text{or} \quad W = V \times A$$

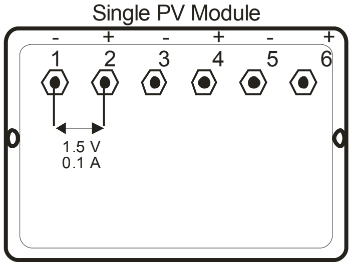
Series Circuits

In series circuits, the current remains constant while the voltage changes. To calculate total voltage, add the individual voltages together:

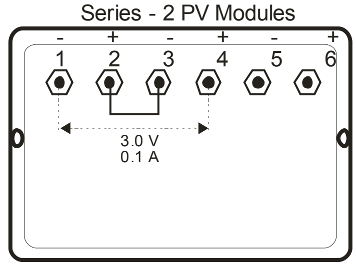
$$I_{total} = I_1 = I_2 = I_3$$
$$V_{total} = V_1 + V_2 + V_3$$



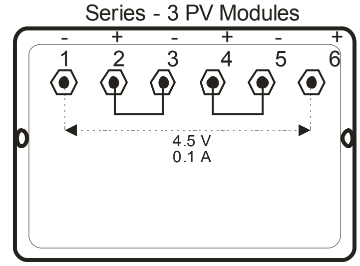
Single PV Module



Series - 2 PV Modules



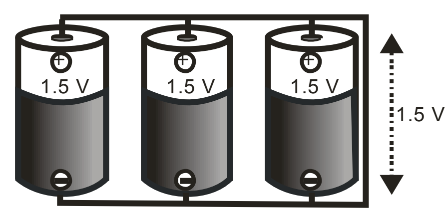
Series - 3 PV Modules



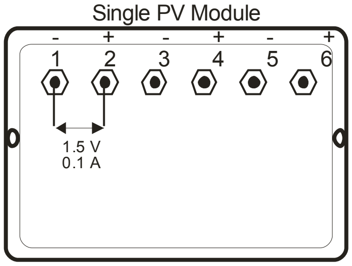
Parallel Circuits

In parallel circuits, the voltage remains constant while the current changes. To calculate total current, add the individual currents together:

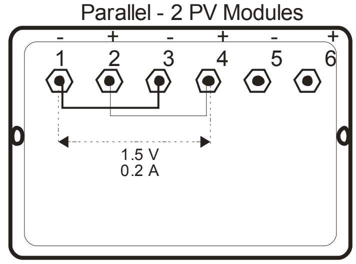
$$I_{total} = I_1 + I_2 + I_3$$
$$V_{total} = V_1 = V_2 = V_3$$



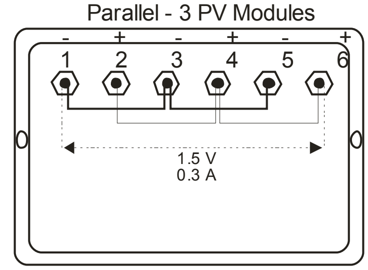
Single PV Module



Parallel - 2 PV Modules



Parallel - 3 PV Modules



Basic Measurement Values in Electronics

SYMBOL	VALUE	METER	UNIT
V	Voltage (the force)	Voltmeter	Volts (V)
I	Current (the flow)	Ammeter	Amps/Amperes (A)
R	Resistance (the anti-flow)	Ohmmeter	Ohms (Ω)

1 Ampere = 1 coulomb/second

1 Coulomb = 6.24 x 10^{18} electrons (about a triple axle dump truck full of sand where one grain of sand is one electron)

Prefixes for Units

- **Smaller**
  (m)illi x 1/1000 or .001

  (µ) micro x 1/1000000 or .000001

  (n)ano x1/1000000000 or .000000001

  (p)ico x 1/1000000000000 or .000000000001

- **Bigger**
  (k)ilo x 1,000

  (M)ega x 1,000,000

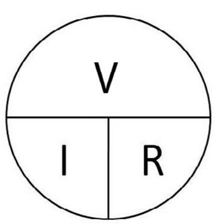
  (G)iga x 1,000,000,000

Formulas for Measuring Electricity

V = I x R

I = V/R

R = V/I



The formula pie works for any three variable equation. Put your finger on the variable you want to solve for and the operation you need is revealed.

- **Series Resistance (Resistance is additive)**
  $R_T = R_1 + R_2 + R_3 \ldots + R_n$

- **Parallel Resistance (Resistance is reciprocal)**
  $1/R_T = 1/R_1 + 1/R_2 + 1/R_3 \ldots + 1/R_n$

Note: ALWAYS convert the values you are working with to the "BASE unit." For example—don't plug kilo-ohms (kΩ) into the equation—convert the value to Ω first.

Digital Multimeter

Directions

DC Voltage

1. Connect RED lead to VΩmA socket and BLACK to COM.
2. Set SWITCH to highest setting on DC VOLTAGE scale (1000).
3. Connect leads to the device to be tested using the alligator clips provided.
4. Adjust SWITCH to lower settings until a satisfactory reading is obtained.
5. With the solar modules or array the 20 setting usually provides the best reading.

DC Current

1. Connect RED lead to VΩmA connector and BLACK to COM.
2. Set SWITCH to 10 ADC setting.
3. Connect leads to the device to be tested using the alligator clips provided. There must be a load in the circuit (bulb, fan, etc.) for current to be measured. Be sure the meter and its leads are part of the circuit.
Note: The reading indicates DC AMPS; a reading of 0.25 amps equals 250 ma (milliamps).

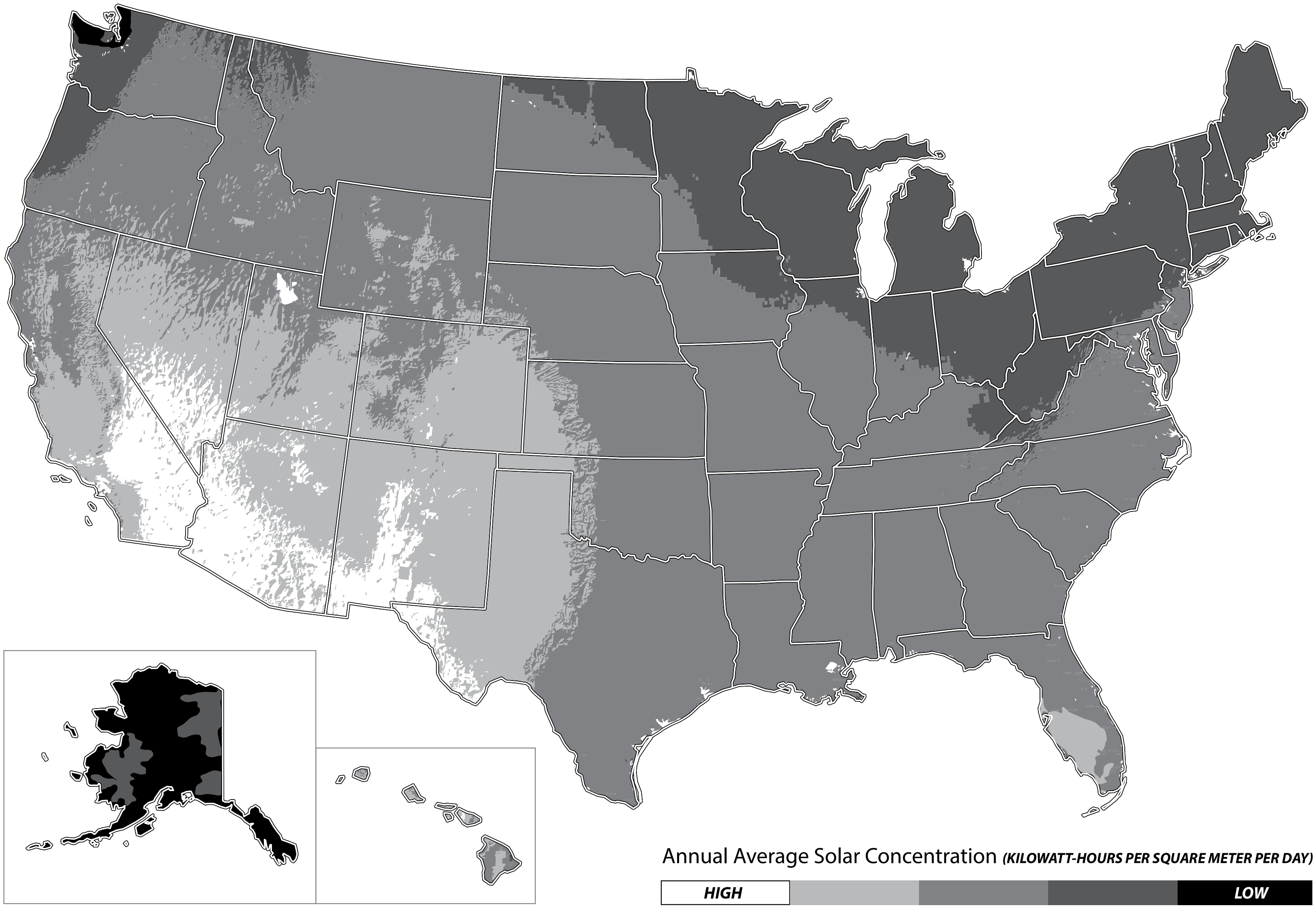
YOUR MULTIMETER MIGHT BE SLIGHTLY DIFFERENT FROM THE ONE SHOWN. BEFORE USING THE MULTIMETER READ THE OPERATOR'S INSTRUCTION MANUAL INCLUDED IN THE BOX FOR SAFETY INFORMATION AND COMPLETE OPERATING INSTRUCTIONS.

KWL Organizer for Solar Energy

What I Think I Know	What I Want to Know	What I Learned

U.S. Solar Resource Map

Annual Average Solar Concentration



Note: Alaska and Hawaii not shown to scale
Data: NREL

Photovoltaic Cells and Their Variables

Question

What variables affect the voltage output of a photovoltaic panel?

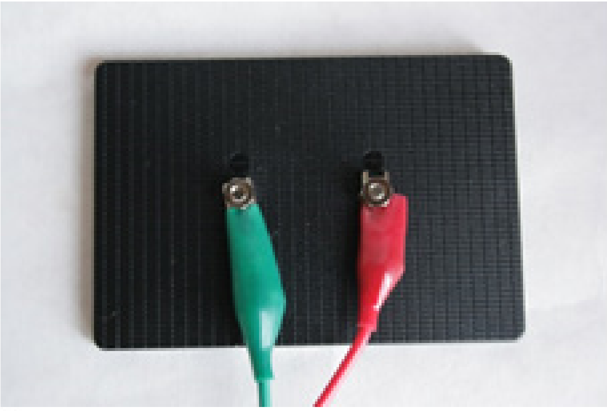
Hypothesis

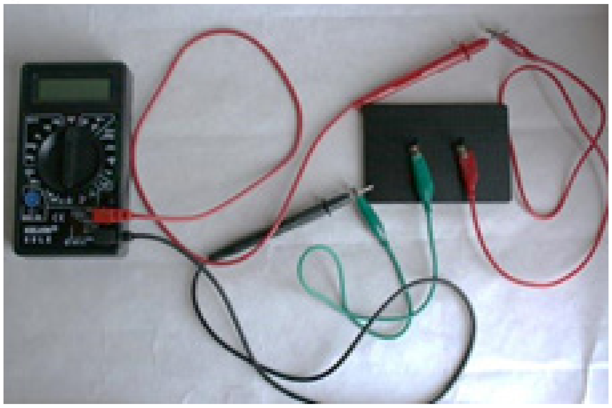
Write a hypothesis stating which variables you think will affect the voltage output of a photovoltaic cell, and how they will affect it (increase output, decrease output, etc.).

Materials

- Photovoltaic panel
- 2 Alligator clips
- Digital multimeter
- White paper
- Black paper
- Tissue paper, quilt batting, or other materials for covering PV panel
- Cardboard or posterboard
- Bright light source (or sunlight)

Procedure





1. Connect the alligator clips to the posts on the back of the photovoltaic panel as shown.
2. Connect the red lead of the multimeter to the alligator clip that is attached to the positive post of the PV panel.
3. Connect the black lead of the multimeter to the alligator clip that is attached to the negative post of the PV panel.
4. Make sure the red lead is plugged into the "VΩmA" connection of the multimeter.
5. Make sure the black lead is plugged into the "COM" connection of the multimeter.
6. Turn on the light source or go outside into the sunlight.
7. Turn the multimeter to the 20 V DC setting.
8. Aim the PV panel directly at the light source or sun. Record the reading on the multimeter in your data table.
9. Turn the photovoltaic panel so that it is tilted back away from the light source as far as possible. Record the reading on the multimeter in your data table.
10. Tilt the PV panel toward the light source, so that is not pointed directly at the light, or tilted all the way back. It should be angled halfway between these points. Record the reading on the multimeter in your data table.
11. Return the PV panel to be aimed directly toward the light source.
12. Completely cover the panel with a sheet of white paper. Record the reading on the multimeter in your data table.
13. Replace the white paper with a sheet of black paper. Record the reading on the multimeter in your data table.

14. Continue recording data, completely covering the photovoltaic panel with other materials your teacher has provided.
15. Cover ½ the panel with the cardboard, leaving the other ½ exposed to the light. Record the reading on the multimeter in your data table.
16. Cover ¼ the panel with the cardboard, leaving the other ¾ exposed to the light. Record the reading on the multimeter in your data table.
17. Disconnect the alligator clips from the photovoltaic panel and from the multimeter leads.
18. Turn off the digital multimeter.
19. Clean up your station and return materials.

Data

DESCRIPTION OF PHOTOVOLTAIC PANEL	VOLTAGE OUTPUT
Tilted completely toward light source	
Tilted completely away from light source	
Tilted halfway toward light source	
Completely covered with white paper	
Completely covered with black paper	
Completely covered with	
Completely covered with	
Completely covered with	
½ covered with cardboard	
¼ covered with cardboard	

Conclusions

1. What happened to the output voltage of your photovoltaic panel as it was tilted away from the light source? Cite your experimental data to support your answer.
2. Which materials that you used to cover the panel had the smallest effect on the voltage output? Cite your experimental data to support your answer.
3. List each of the materials you used to cover the panel, and describe the weather or daylight conditions they might simulate.
4. What happened when ½ of the panel was covered? What happened when ¼ of the panel was covered? What does this simulate in a real-world photovoltaic panel?
5. What variables can impact PV electricity generation?
6. Will you accept or reject your original hypothesis? Cite the experimental evidence that supports your answer.
7. What would you like to learn more about?
8. What data do you need to collect about a real photovoltaic system to test and prove or disprove your hypothesis? Be as specific as possible, listing things such as time of day, weather, etc.

Name: ______________________________ Date: ____________

Data Analysis 1

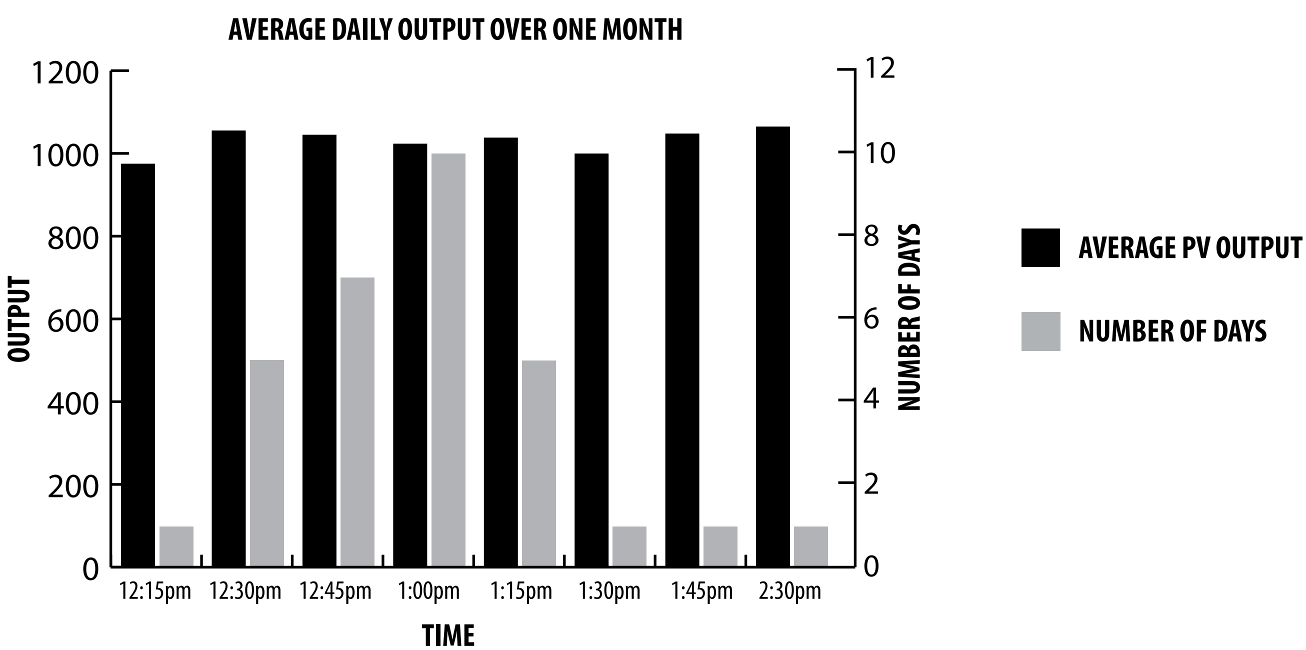
Look at the data below and answer the following questions in your science notebook or on a separate piece of paper.

1. What does the data table show?
2. What does the bar graph show?
3. Why would this information be shown in two different ways?
4. What time would you predict peak output to occur tomorrow. Why?

DATA TABLE

PEAK TIME	NUMBER OF DAYS	AVERAGE PV OUTPUT
12:15 pm	1	973.5 W
12:30 pm	5	1053.8 W
12:45 pm	7	1043.5 W
1:00 pm	10	1021.9 W
1:15 pm	5	1036.6 W
1:30 pm	1	998.1 W
1:45 pm	1	1046.4 W
2:30 pm	1	1063.3 W

GRAPH



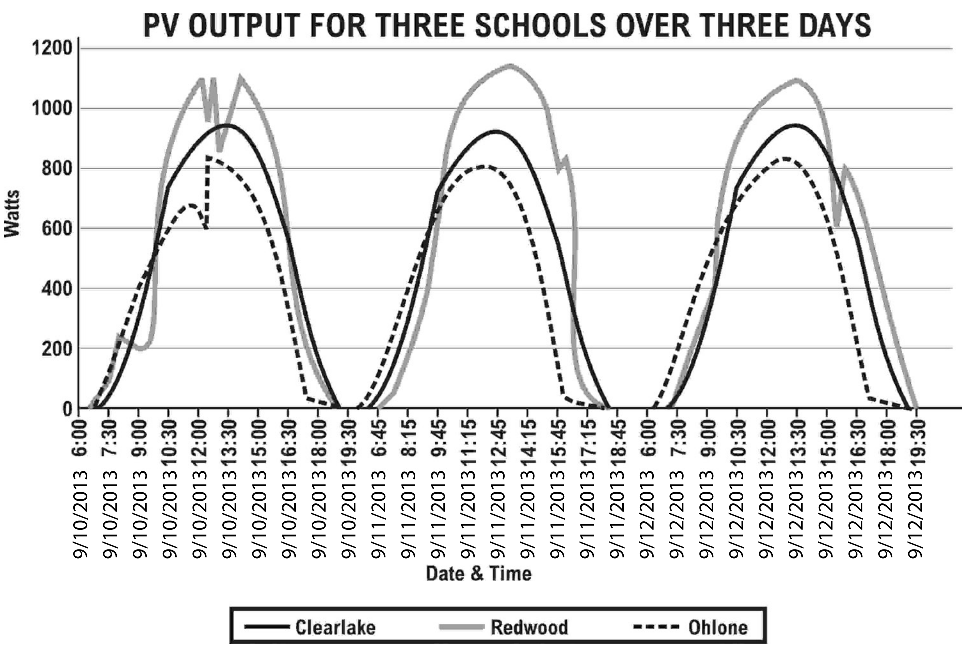
Name: ______________________________ Date: ____________

Data Analysis 2

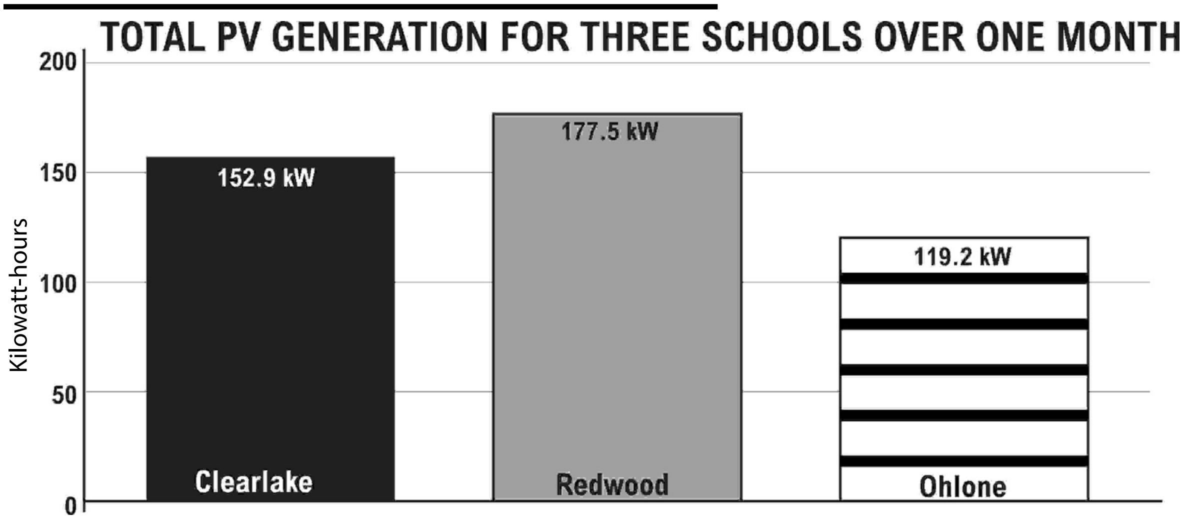
In the graphs below, students compared PV output for three different schools, each with a 1.1 kilowatt system. Answer the following questions in your science notebook or on a separate piece of paper.

1. Write two sentences summarizing the data in the triple line graph and the bar graph.
2. How does representing the data in the triple line graph differ from a bar graph? Compare and contrast.
3. Have a discussion about the PV output of these three schools. Record your observations of this data.

LINE GRAPH



BAR GRAPH



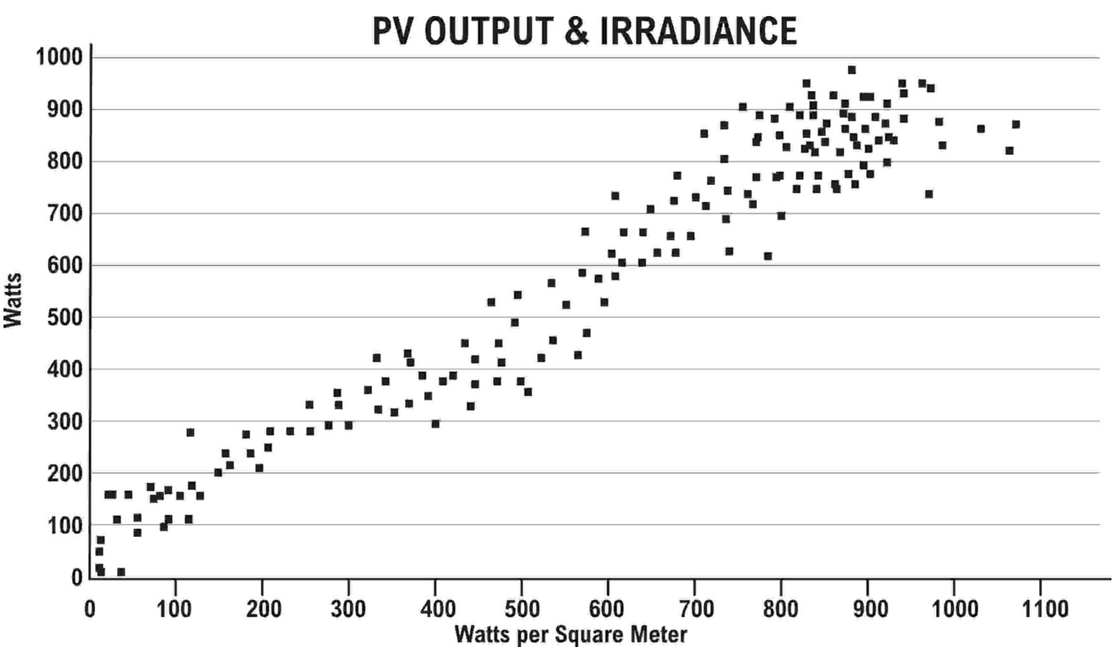
Name: ____________________________________ Date: ____________

Data Analysis 3

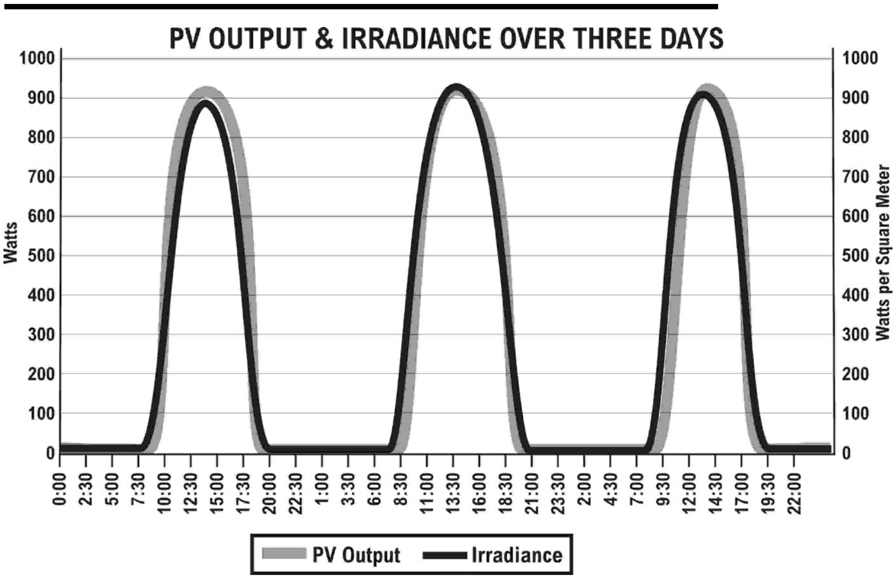
In the graphs below, students compared PV output and irradiance over three days. Answer the following questions in your science notebook or on a separate piece of paper.

1. Write two sentences summarizing the data in the scatter plot and the double line graph.
2. How does representing the data in a scatter plot differ from a double line graph? Compare and contrast.
3. Have a discussion about PV output and irradiance. Record your observations for this data.

SCATTER PLOT



LINE GRAPH



Data Reporting Form

DATE	CURRENT OUTPUT (Watts)	DAILY OUTPUT (kWh)	LIFETIME OUTPUT (kWh)	CARBON DIOXIDE OFFSET (LBS.)	SUNLIGHT (HOURS:MINUTES)	WEATHER (TEMP, CONDITIONS)
AVERAGES:						

Data obtained from website:

Month:______________________________

Monthly average output per day (kWh): ______________________________

Daily average sunlight: ______________________________

Daily average temperature: ______________________________

Name: ____ Date: __________

Variables Affecting Photovoltaic System Performance

1. What would you like to learn more about?

2. What is your hypothesis about your variable and PV system performance?

3. What data do you need to collect to verify your hypothesis? Be specific, include all important information, such as time frame and number of PV locations.

4. How do you plan to organize and analyze the data? Again, be specific. Include items such as graphs or tables, comparing averages or percentages, etc.

5. Clarify your hypothesis, if needed, based on group discussions and planned data gathering.

6. Attach your data analysis to this worksheet. What conclusions did you draw from your data? Explain how the data supports or disproves your hypothesis.

7. Did people in your group draw other conclusions? If so, how do they complement or conflict with your conclusions?

8. Did other groups come to conclusions that support or refute your hypothesis? If so, what data would account for the differences in conclusions?

9. If you were to complete this study again, what data would you include or leave out and why?

10. What other conclusions can be inferred from the data gathered?

Name: ____ Date: __________

Electric Nameplates Investigation

Some appliances use more energy than others to accomplish the same task. Appliances that are very energy efficient are approved by the government's ENERGY STAR® program and have the ENERGY STAR® label on them. This means they have met high standards set by the government for energy efficiency.

Every machine that runs on electricity has an electric nameplate on it. The nameplate is usually a silver sticker that looks like the picture below. The nameplate has information about the amount of electricity the machine uses. Sometimes, the current is listed. The current is measured in amperes (A). Sometimes, the voltage the machine needs is listed. The voltage is listed in volts (V). Sometimes, the wattage is listed. The wattage is measured in watts (W). If the wattage isn't listed, then the current and voltage are both listed.

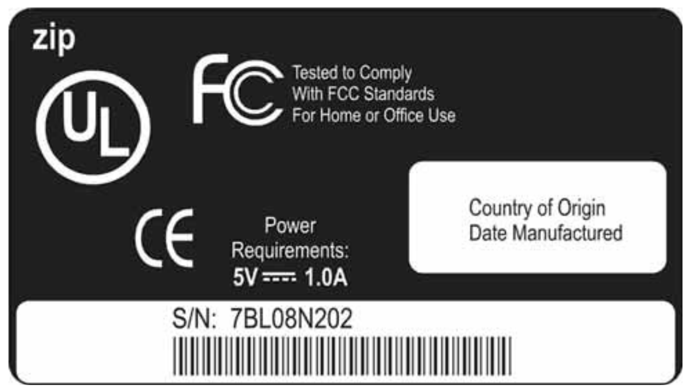
If the wattage is not listed, you can calculate the wattage using the following formula:

wattage = current x voltage

W = A x V

W = 1.0A x 5V

W = 5W



Often, the letters UL are on the nameplate. UL stands for Underwriters Laboratories, which conducts tests on thousands of machines and appliances. The UL mark means that samples of the machines and appliances have been tested to make sure they are safe.

You can find out how much it costs to operate any appliance or machine if you know the wattage. Let's take a look at some of the machines in your school. The nameplate is usually located on the bottom or back. See if you can find the nameplates on the computers, printers, monitors, televisions, and other machines in your classroom. Put the information in the chart below and calculate the wattage for each one.

MACHINE OR APPLIANCE	CURRENT	VOLTAGE	WATTAGE	UL TESTED
Copier	*11 A*	*115 V*	*1,265 W*	*yes*

Name: ____ Date: __________

Cost of Using Machines Investigation

Calculate how much it costs to operate the machines in your classroom that you looked at before. You need to know the wattage, the cost of electricity, and the number of hours a week each machine is used.

You can estimate the number of hours the machine is used each week, then multiply by 40 to get the yearly use. We are using 40 weeks for schools, because school buildings aren't used every week of the year. Using the copier as an example, if it is used for ten hours each week, we can find the yearly use like this:

Yearly use = 10 hours/week x 40 weeks/year = 400 hours/year

Remember that electricity is measured in kilowatt-hours. You will need to change the watts to kilowatts. One kilowatt is equal to 1,000 watts. To get kilowatts, you must divide the watts by 1,000. Using the copier as an example, divide like this:

kW = W/1,000

kW = 1,265/1,000 = 1.265

The average **cost of electricity for schools in the U.S. is about 10.7 cents ($0.107)** a kilowatt-hour. You can use this rate or find out the actual rate from your school's electric bill. Using the average cost of electricity, we can figure out how much it costs to run the copier for a year by using this formula:

Yearly cost	**=**	**Hours used**	**x**	**Kilowatts**	**x**	**Cost of electricity (kWh)**			
Yearly cost	**=**	**400 hours/year**	**x**	**1.265 kW**	**x**	**$0.107/kWh**			
Yearly cost	**=**	**400**	**x**	**1.265**	**x**	**0.107**	**=**	**$54.14**	

MACHINE OR APPLIANCE	HOURS PER WEEK	HOURS PER YEAR	WATTS (W)	KILOWATTS (kW)	RATE ($/kWh)	ANNUAL COST
Copier	*10*	*400 hours*	*1,265 W*	*1.265 kW*	*$0.107*	*$54.14*

Name: ____ Date: ____________

Photovoltaic Systems and School Electricity Use

The photovoltaic (PV) system installed on your school provides electricity for the school to operate. But how much of the total school consumption does it provide?

1. Predict how much of the school's electric consumption you think the PV system provides.

I predict the PV system provides ________ percent of the school's total electric needs.

2. Calculate the amount of electricity needed yearly for the appliances for which you already gathered data. Use the following formula:

Yearly Electric Use = Yearly Use x Kilowatts

Copier Yearly Electric Use = 400 h/yr x 1.265 kW = 506 kWh/yr

MACHINE OR APPLIANCE	YEARLY USE	KILOWATTS (kW)	YEARLY ELECTRICITY USE
Copier	*400 hours/yr*	*1.265 kW*	*506 kWh/yr*
		TOTAL:	

3. Add together the totals from other groups' charts to get an estimate of your school's yearly electric use. Be sure only to use each room once.

School's estimated annual electric consumption = ________________ kilowatt-hours/year

4. Determine how much electricity the PV system provides your school each year. You can gather the yearly production data directly from your data acquisition system (DAS) or you can add the monthly totals for one year.

PV system's annual electric production = ________________ kilowatt-hours/year

5. Next, determine what percentage was provided by the PV system for the electric needs of the appliances. Use the following formula:

$$\textbf{PV System Percentage} = \frac{\textbf{PV System Yearly Production}}{\textbf{Total Appliance Yearly Electric Use}} \times 100$$

$$\textbf{PV System Percentage} = \frac{\textbf{\_\_\_\_ kWh/yr} \times 100}{\textbf{\_\_\_\_ kWh/yr}} = \_\_\_\_\_\_\_\_\_\_\_\_ \%$$

6. Now you have an estimate of the electric needs of your school and the electric production of your PV system. But are the appliances and machines you looked at the only items that use electricity? List other electricity consuming devices.

7. Find out how much electricity your school used each year before the PV system was installed. Determine how much the PV system offsets the total electric needs of your school.

8. How much money is your school saving each year due to the PV system?

Bonus: Determine the size of your PV system in square feet. How many more square feet of PV panels would you need to produce half the electric consumption of your school?

Can Solar Energy Meet Your Electricity Demands?

Part One: How much energy do you need per day?

1. How much electricity does your family consume each month (in kilowatt-hours, kWh)? _____________ kWh
2. What is your daily electricity use in kWh? (Monthly kWh/30 days) _____________ kWh
3. What is your daily electricity use in watt-hours? (Multiply by 1,000) _____________ watt-hours

Part Two: How much energy can a module produce on an average day where YOU live?

1. Peak sun hours are the number of hours per day where solar insolation equals 1,000 watts/square meter. Use the U.S. Solar Resource Map to determine how many peak sun hours your home city receives each day. _______________ peak sun hours
2. How much energy will one 235-watt solar module generate on the average day?

   235 watts x _______ peak sun hours = ________watt-hours daily production per module

Part Three: How big does your system need to be for where you live?

1. How many 235-watt solar modules would you need to produce enough electricity for your home?

   Divide daily energy usage (Part One, Step 3) by the amount of power provided by one module (Part Two, Step Two).

   Answer: _______modules
2. What would the total system size be based on the number of modules you need?

   Multiply the number of modules (Part Three, Step 1) by the module rating in watts (235) divided by 1,000.

   Answer: ______________ kW system size
3. If each module costs $800.00 installed, how much would it cost for the number of solar modules you need? Answer: $______________

Part Four: How many years will it take before the system has paid for itself?

1. Calculate your current cost for electricity (multiply your monthly total kWh use by the rate in your city).
2. A) How much do you pay each month? $___________ B) How much do you pay each year? $_____________
3. The payback period is the time it will take for your system price to be offset by the electrical energy bills that will be avoided. Divide the total system cost (Part Three, Step 3) by your annual cost for electricity (Part Four, Step 2B).

   Answer:_______________ years

Part Five: Reflect

1. What are the different factors that impact payback period?
2. Under what circumstances is it NOT worth installing a solar generating system?
3. Think about when you use the most electricity. Do these hours coincide with peak sun hours? What would you need in order to use solar energy around the clock?

Name: ____ Date: ____________

Photovoltaic Systems and the Environment

Carbon dioxide (CO_2) is a greenhouse gas. Greenhouse gases hold heat in the atmosphere. They keep our planet warm enough for us to live. But in the last 200 years, we have been producing more carbon dioxide than ever before. Since the Industrial Revolution, the level of CO_2 in the atmosphere has risen over 46 percent.

Research shows that greenhouse gases are trapping more heat in the atmosphere. Scientists believe this is causing the average temperature of the Earth's atmosphere to rise. They call this global climate change or global warming. Global warming refers to an average increase in the temperature of the atmosphere, which in turn causes changes in climate. A warmer atmosphere may lead to changes in rainfall patterns, a rise in sea level, and a wide range of impacts on plants, wildlife, and humans. When scientists talk about the issue of climate change, their concern is about global warming caused by human activities.

When we breathe, we produce carbon dioxide. When we burn fuels, we also produce carbon dioxide. Driving cars and trucks produces carbon dioxide. Heating homes with natural gas, wood, heating oil, or propane produces carbon dioxide, too.

Making electricity can also produce carbon dioxide. Some energy sources, such as hydropower, solar, wind, geothermal, and nuclear, do not produce carbon dioxide because no fuel is burned. However, 64.6 percent of our electricity comes from burning coal, natural gas, petroleum, and biomass.

The general rule is that generating one kilowatt-hour of electricity produces, on average, 1.6 pounds of carbon dioxide that is emitted into the atmosphere.

1. You can use this standard to determine how much carbon dioxide is produced by the machines and appliances used in your school. The figures for the sample copier are:

Yearly CO_2 Emissions = wattage x hours of use x rate of CO_2/kWh

Yearly CO_2 Emissions = 1.265 kW x 400 hr/yr x 1.6 lbs/kWh = 810 lbs

2. Use the figures from earlier worksheets to complete the chart below.

MACHINE OR APPLIANCE	KILOWATTS (kW)	RATE OF CO_2/kWh	HOURS PER YEAR	CO_2/YEAR (LBS)
Copier	*1.5 kW*	*1.25 lbs/kWh*	*400 hours*	*810 lbs*

3. Gather data from other groups and calculate your school's carbon dioxide emissions from the machines and appliances used. Be sure to use each room's data only once.

School's estimated CO_2 emissions = _______________ lbs/yr

4. Use the school building electric consumption figure from before the PV system was installed to calculate your school's total carbon dioxide emissions due to using electricity.

School's CO_2 emissions = _______________ lbs/yr

5. When using an energy source that does not emit carbon dioxide to generate electricity, scientists discuss the amount of carbon dioxide emissions that were avoided. This means that instead of using a conventional fuel, which produces 1.6 pounds of carbon dioxide for each kilowatt-hour of electricity, solar energy produces zero pounds of carbon dioxide for each kilowatt-hour of electricity generated on the system. In one year, how much carbon dioxide emissions are avoided due to your school's PV system?

6. What other steps can your school take to reduce the amount of carbon dioxide emissions?

Bonus 1: How many more square feet of PV panels would you need to reduce the carbon dioxide emissions of your school by half?

Bonus 2: The DAS website indicates how many pounds of carbon dioxide production are avoided by use of the PV system. Calculate the volume of one ton of carbon dioxide in cubic meters. Calculate the volume of one ton of carbon dioxide in cubic feet. (The density of CO_2 is 1.98 kg/m^3, 1 kilogram = 2.2 pounds, 1 ton = 2000 pounds or 907.18 kilograms, and 1 foot = 0.3048 meter.)

Your Solar-Powered Cabin

Your crazy old Uncle Ed has just willed you a cabin that he has on a river near Page, AZ. The only problem is that the cabin has no electricity. Uncle Ed believes in hard work and he's specified one condition—if you are to take possession of this prime parcel, you must plan and install a PV system to support the following four specifications:

- a light for the kitchen (LED, 12 volts at 15 watts);
- a power supply for charging your laptop (12 volts at 90 watts);
- an electric pump for the well (12 volts at 100 watts intermittent); and
- a refrigerator (12 volts at 50 watts intermittent).

Before you can collect your inheritance, the lawyer will need to approve your plan. The lawyer will need to see:

- a description of the PV modules that you will use along with their ratings;
- a schematic diagram of your system design; and
- a spreadsheet detailing your budget and sources for parts.

Have fun!

Extension

When you finish your plan, design a battery system to store the electrical energy generated for use at night or during storms.

Solar-Powered Cabin Planning Page

Description of Modules:

Diagram of Design:

Budget Information:

Student Informational Text

SOLAR ENERGY

What Is Solar Energy?

Every day, the sun **radiates** (sends out) an enormous amount of energy. It radiates more energy each day than the world uses in one year. Solar energy is a **renewable** energy source.

The sun's energy comes from within the sun itself. Like most stars, the sun is made up mostly of hydrogen and helium atoms. The sun generates energy from a process called **nuclear fusion**.

During nuclear fusion, high pressure and temperature push two very small atoms together to form one larger atom. During fusion, **radiant energy** is released. Solar energy is renewable because fusion reactions are expected to generate sunlight for billions of years.

It can take 150,000 years for energy in the sun's core to make its way to the surface of the sun. It takes only eight minutes for this energy to travel the 93 million miles to Earth. The radiant energy travels to the Earth at a speed of 186,000 miles per second, the speed of light.

Only a small amount of the energy radiated by the sun strikes the Earth. Only one part in two billion! This amount of energy is still enormous. The sun provides more energy than the world can use in a year. It also provides more energy in an hour than the United States can use in a year.

About 30 percent of the radiant energy that reaches the Earth is reflected back into space. Some surfaces like ice reflect more light; some surfaces absorb more. This is called **albedo**. About half of radiant energy is absorbed by land and oceans. The rest is absorbed by the atmosphere and clouds in the **greenhouse effect**.

The sun is also the source for many different forms of energy. Solar energy powers the water cycle, allowing us to harness the energy of moving water. Solar energy drives wind formation, allowing us to use wind turbines to transform kinetic energy into electricity. Plants use solar energy in the process of photosynthesis. Biomass can trace its energy source back to the sun. Even fossil fuels originally received their energy from the sun.

History of Solar Energy

People have used solar energy for centuries. As early as the 7th century BCE, people used simple magnifying glasses to focus the light of the sun into beams so hot they could cause wood to catch fire.

In the 1860s in France, a mathematics teacher named Auguste Mouchout used heat from a solar collector to make steam to drive a steam engine. Around the same time in the United States, John Ericsson developed the first solar reflector to drive an engine using a steam boiler. With coal becoming widely used, neither of these inventions became part of the mainstream.

Early in the 1900s, scientists and engineers began researching ways to use solar energy. The solar water heater became popular during this time in Florida, California, and the Southwest.

THE SUN

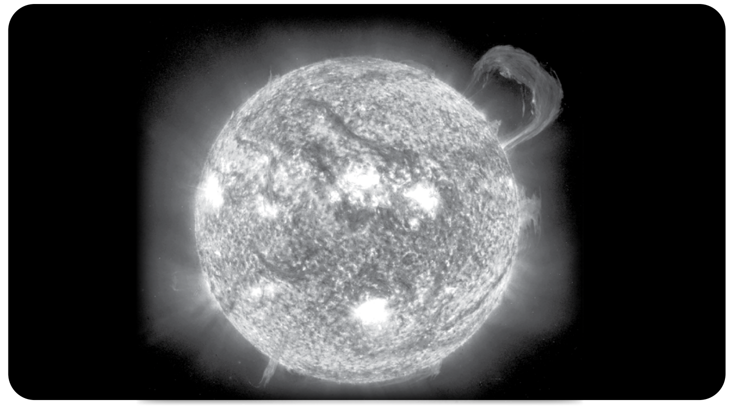
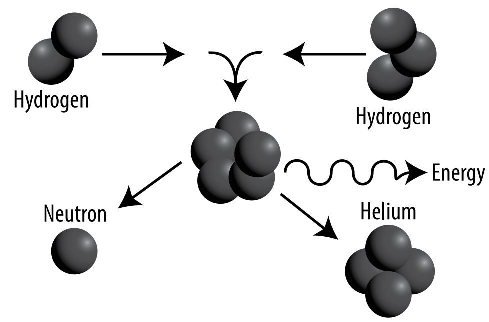


Image courtesy of NASA

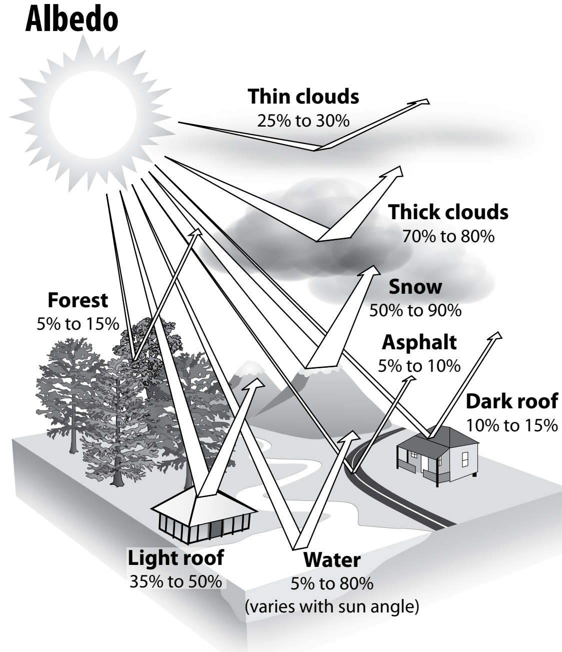
This image of our sun was captured by NASA's Solar Dynamics Observatory—a space telescope designed to study the sun.

Fusion

The process of fusion most commonly involves hydrogen combining to form a helium atom with a transformation of matter. This matter is emitted as radiant energy.



Albedo



Average reflectivity of solar radiation for various surfaces.

The industry was in full swing just before World War II. This growth lasted until the mid-1950s, when low-cost, natural gas became the primary fuel for heating homes and water, and solar heating lost popularity.

The public and world governments were not interested in solar energy until an energy crisis occurred in the 1970s. Research efforts in the U.S. and around the world since that time have resulted in tremendous improvements in solar technologies.

Today, people use solar energy to heat buildings and water and to generate electricity. In 2017, solar energy accounted for 0.79% of U.S. energy consumption – less than 1%! The top producing solar energy states include many of the sunny, warm states in the western United States.

Solar Collectors

Heating with solar energy is simple—just look at a car parked in the sun with its windows closed. Getting the right amount of heat in a certain location, however, requires more thought and careful design. Capturing sunlight and putting it to work is difficult because the solar energy that reaches the Earth is spread out over a large area.

How much solar energy a place receives depends on several things. These include the time of day, the season of the year, the latitude of the area, the **topography**, and the amount of clouds in the sky.

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 the sunlight passes through the car's glass windows, 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 do not let all the heat out. This is also how greenhouses are designed to stay warm year-round. A greenhouse or solar collector:

- allows sunlight in through the glass;
- absorbs the sunlight and changes it into heat; and
- traps most of the air inside.

Solar collectors can be either passive or active systems. **Passive systems** collect energy from the sun without specialized equipment. Passive systems use materials like glass, bricks, or stones. **Active systems** collect energy from the sun with specialized equipment like a solar panel.

JOHN ERICSSON'S SOLAR ENGINE

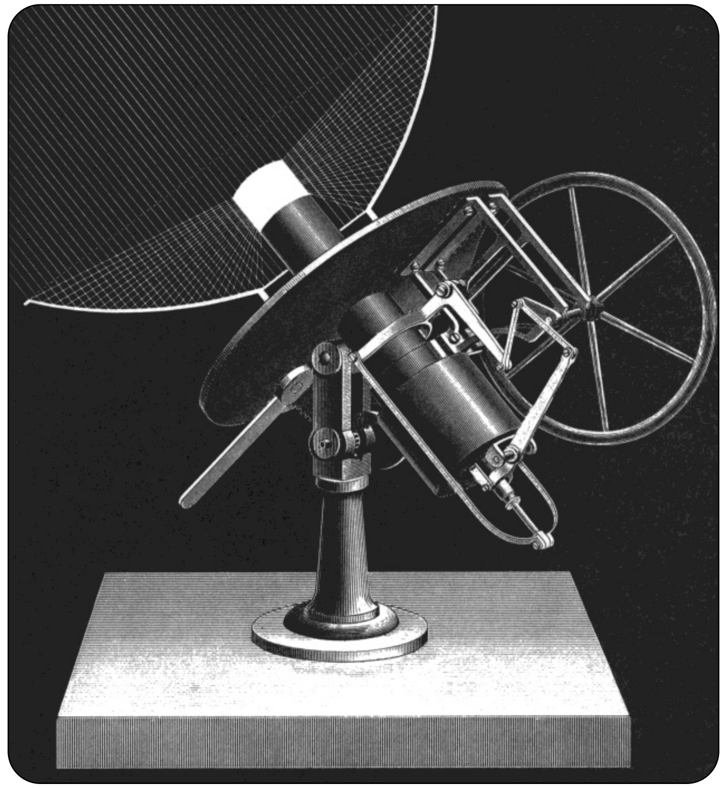
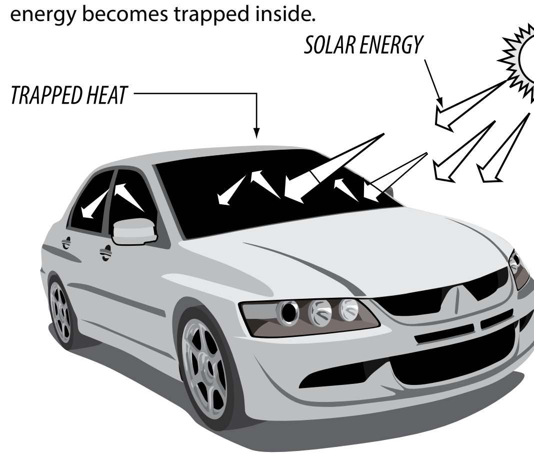


Image courtesy of www.stirlingengines.org

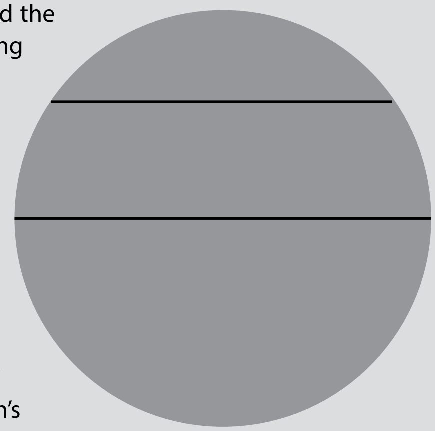
John Ericsson's Sun Motor built in New York in 1872. Ericsson had intended Californian agriculturists to take up his sun-motor for irrigation purposes, but in the end nothing came of the project.

Solar Collector

On a sunny day, a closed car becomes a solar collector. Light or solar energy passes through the window glass, is absorbed by the car's interior, and converted into thermal (heat) energy. The heat energy becomes trapped inside.



Catchin' Some Rays

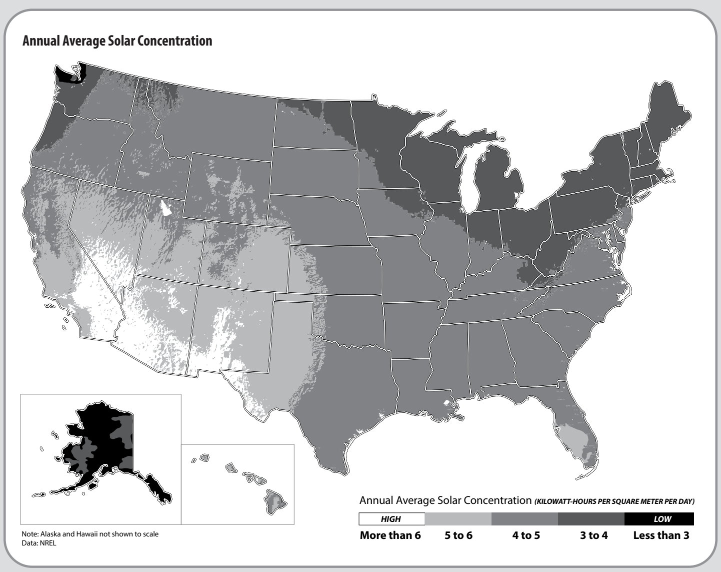


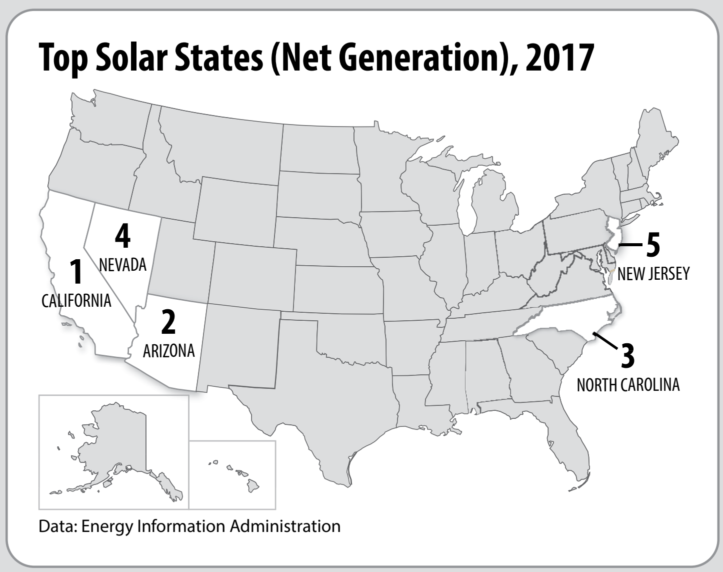
Try this: Get a large ball, like a playground ball or a beach ball. Tape a piece of string around the middle, as shown. Tape another piece of string around the ball halfway between the first string and the top, as shown. Take the ball, a lamp, and a little toy figure, like a Lego® man, into a dark room. Put the lamp on one side of the room, turn it on, and stand on the other side of the room with the ball and the figure. Hold the figure on the ball at the middle string so he is standing "on" the ball, and observe his shadow. Move the figure so he is standing on the upper string, and observe his shadow. Move the figure to the top of the ball and observe his shadow.

What did you see? Where was the smallest shadow? Where was the largest shadow? The ball is a model of the Earth in space, and the lamp models the sunlight coming from the sun. The sun is directly overhead at the Equator. This is where the middle string is on your ball. The sunlight is at the greatest angle at the North or South Pole, which is the top or bottom of your ball. In between the Equator and the poles, the angle of the sunlight reaching the Earth's surface changes. It increases as you move farther away from the Equator.

PV cells work best when the sunlight is shining on them from directly overhead. However, areas that are farther away from the Equator and the sun's direct rays can still use solar panels. We can use the sunlight in other areas by attaching PV modules at an angle rather than flat on the ground or flat on the roof of a building. The farther north you go, the greater the angle at which the panels should be mounted. Some panels will be set at the same angle all year long. Other panels can be installed in a way that they can tilt and adjust for changes in season and time of day.

The map below shows where the most solar energy is available in the United States. Lighter shading shows more solar energy, and darker shading shows less solar energy. Notice that northern states have less solar energy available than southern states, because of their latitude. The other map shows the states leading in solar energy electricity generated. Do you notice any coincidences?





Electricity

What is electricity? Electricity is simply moving electrons. Static electricity is when electrons move all at once. The electricity we use on a daily basis is different. The electrons are moving, but they aren't all moving at the same time. Imagine setting dominoes up on edge in a line. When you push over the first domino, it falls into the second, which falls into the third, and so on down the line. Now imagine the dominoes are on roller skates. The first domino moves forward and bumps into the second, which moves and bumps into the third, and so on down the line. Electricity works in a similar way. The pathway that electrons can follow is called an electrical circuit. Electrons bump or flow through the circuit, passing their energy down the line.

Electricity makes our lives easier, but it can seem like a mysterious force. Measuring electricity is confusing because we cannot see it. We may have heard such terms like watt, volt, and amp, but we do not understand what those terms mean. We buy light bulbs measured in watts, a tool that requires 120 volts, or an appliance that uses 8.8 amps. We don't always think about what those units mean when we buy these items.

If we use the flow of water as a model, we can make electricity easier to understand. The flow of electrons in a circuit is similar to water flowing through a hose. If you could look into a hose in one place, you would see a certain amount of water passing that point each second. The amount of water moving depends on the pressure, or how hard the water is being pushed. The harder the pressure, the more water passes each second. The flow of electrons in a wire depends on the electrical pressure pushing those electrons.

Voltage

The pressure that pushes electrons in a circuit is called **voltage** (V). The higher the voltage, the more pressure is pushing the electrons. Voltage is measured in **volts** (v).

AA batteries are 1.5-volts; they apply a small amount of voltage for lighting small flashlight bulbs or remote controls. A car usually has a 12-volt battery—it applies more voltage to push current through circuits to operate items like the starter, the radio, or air conditioning. The voltage of wall outlets is 120 volts. This is a dangerous voltage. Heavy duty appliances, like stoves and electric clothes dryers, are usually wired at 240 volts—a very dangerous voltage.

Current

Current is a measurement of how many electrons are flowing past a point. Current is measured in **amperes** or amps (A).

Electric Power

Electric power is how fast electricity is made or used. Measuring the electric power of a device is a combination of measuring the voltage and the current. **Power** is measured in **watts** (W).

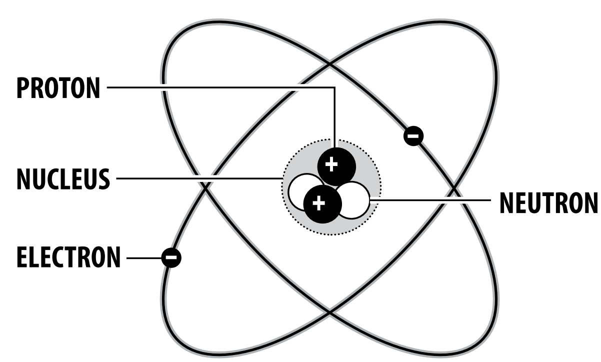
Atoms: little particles with BIG jobs!

We call atoms the building blocks of matter. Everything is made of atoms—every star, every tree, every animal. Even people are made of atoms. The air and water are, too. Atoms are the building blocks of the universe. They are very, very tiny particles. Millions of atoms would fit on the head of a pin.

An atom looks like the sun with the planets spinning around it. The center is called the nucleus.

It is made of tiny protons and neutrons. Electrons move around the nucleus in energy levels, or shells, far from the nucleus. When an atom is in balance, it has the same number of protons and electrons. It can have a different number of neutrons.

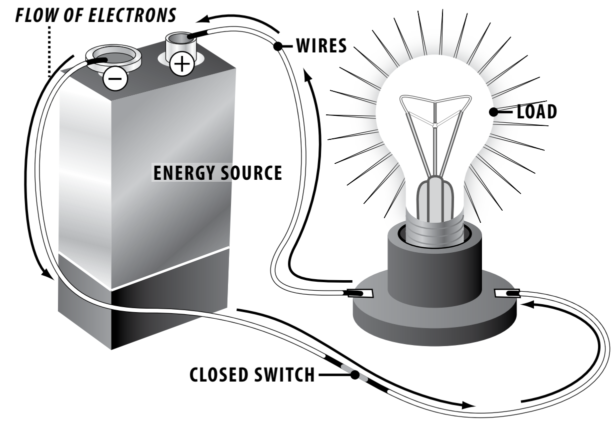
Electrons stay in their shells because a special force holds them there. Protons and electrons are attracted to each other. Protons have a positive charge (+) and electrons have a negative charge (–). Opposite charges attract each other.



Types of Circuits

Electricity travels in pathways called circuits. Circuits can be labeled as series circuits or parallel circuits. A series circuit allows only one pathway for electrons to flow. A parallel circuit allows more than one pathway for electrons to flow. Series circuits are easier to connect. Parallel circuits are better for powering many items. A flashlight is a series circuit; your house is a bunch of parallel circuits. If part of a parallel circuit is broken, the other parts will work. If part of a series circuit is broken, the entire thing will not work.

Electrical Circuits



A closed circuit is a complete path allowing electricity to flow from the energy source to the load.

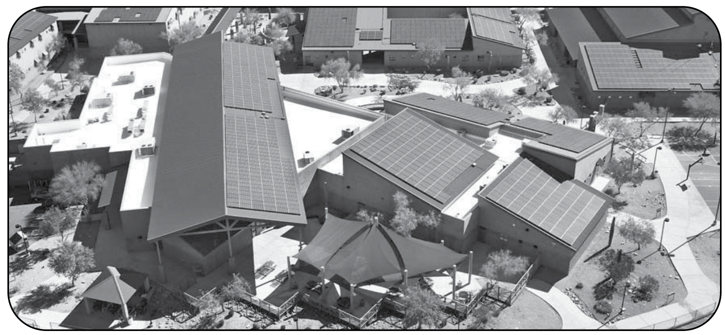
Photovoltaic Systems

Photovoltaic (or PV) **systems** change light directly into electricity. The term photo comes from the Greek phos, which means "light." The term volt is a measure of electricity named for Alessandro Volta (1745-1827), a pioneer in the development of electricity. **Photovoltaics** literally means light-electricity.

PV cells or solar cells are already an important part of our lives. The simplest PV systems power many of the small calculators and toys we use every day. Larger PV systems provide electricity for many things including factories, pumping water, radio and television equipment, and even lighting homes and running appliances. These systems are especially useful in more remote or less accessible areas.

Solar systems can be installed on roof-tops and other structures or on the ground in an open field. Some utility and electric companies are also building large solar farms to add power to the electric **grid**.

SOLAR SCHOOL



Solar systems can vary in size and in some cases can provide a significant portion of a building's or school's energy needs.

History of Photovoltaics

French physicist Edmund Becquerel first described the **photovoltaic effect** in 1839. At the age of 19, Becquerel found that certain materials make small amounts of electric current when they are put in light. In the 1870s, William Adams and Richard Day showed that light could make an electric current in a material called selenium. Charles Fritts then invented the first PV cell using selenium and gold leaf in 1883. It converted light to electricity, but his system wasted 99 percent of the light energy shined onto it. It only used one percent of the light to make electricity. This first PV cell had a very low **efficiency**.

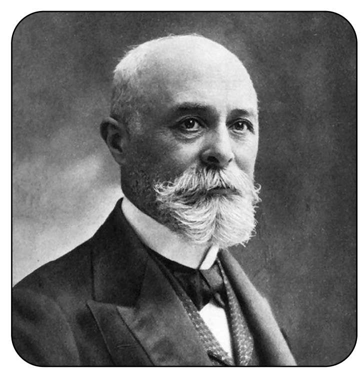
How well a PV cell converts light energy to electricity is called its **conversion efficiency**. This conversion efficiency is the amount of radiant energy turned into **electrical energy**. The conversion efficiency is always less than 100 percent.

During the second half of the 20th century, PV science and the process of making PV cells was improved. It was important for scientists to figure out how to make these cells more efficient. They needed to work with a new material and developed pure crystals of **silicon**. The first silicon PV cell was six percent efficient.

The cost of PV cells has decreased a lot over the past 25 years as the efficiency has improved. This is thanks to technology advances in PV science. Today's PV devices convert 13 to 30 percent of the radiant energy striking them into electricity. However, scientists can produce PV cells that are almost 50 percent efficient. These cells use very rare materials and are extremely expensive. More research will lead to better technologies and even better prices.

ALESSANDRO VOLTA

EDMOND BECQUEREL



SOLAR PANELS ON THE INTERNATIONAL SPACE STATION

Image courtesy of NASA

High efficiency photovoltaic cells power the International Space Station.

Photovoltaic Technology

Photovoltaic Effect

The photovoltaic effect is how PV cells are able to change radiant energy into electrical energy. When light reaches certain materials, electrons move. Electrons are tiny particles that move around the outside of an atom. PV technology works any time the sun is shining. More electricity is produced when the light is brighter and when it is striking the PV cells directly. The best rays of sunlight are perpendicular to the PV cell.

Unlike solar systems for heating water, PV cells do not produce heat to make electricity. Instead, PV cells generate electricity because light can make electrons move. Materials in the PV cell, called **semiconductors**, allow the electrons to move in a way that is useful to us.

Sunlight is composed of **photons**, or bundles of radiant energy. When photons strike a PV cell, they may be reflected, absorbed, or transmitted through the cell.

Only the absorbed photons generate electricity. When the photons are absorbed by the semiconductor, the energy of the photons is transferred to electrons in the atoms of the solar cell. The electrons have gained the energy from the photons.

With their new-found energy, these excited electrons are able to escape from their normal positions in their atoms. Think of an electron's position in an atom as a parking space in a parking lot. When the energized electrons leave their positions, they leave an empty parking space. Other electrons can move into those spaces and fill them. The movement of the electrons becomes part of the current in an electrical circuit.

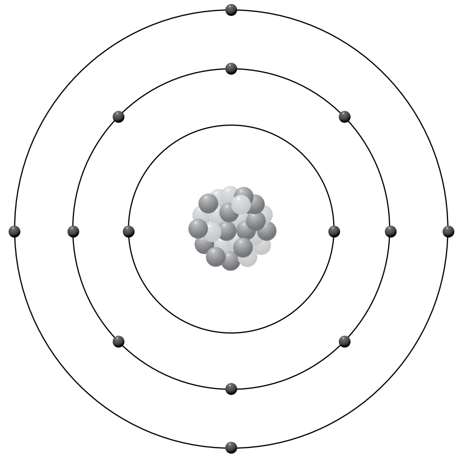
Photovoltaic Cells

The basic building block of photovoltaics is the PV cell. Different materials are used to produce PV cells, but silicon—the main ingredient in sand—is the most common material. Silicon is a semiconductor and is cheap because it is easy to find. It is used in other electronics, such as televisions, radios, and computers. PV cells, however, require very pure silicon, which can be expensive to produce.

The amount of electricity a group of PV cells makes depends on the size of the group, how efficient it is, and how bright or direct the light rays are. A typical PV cell produces 0.5 volts of electricity. It takes just a few PV cells to make enough electricity to power a small watch or solar calculator.

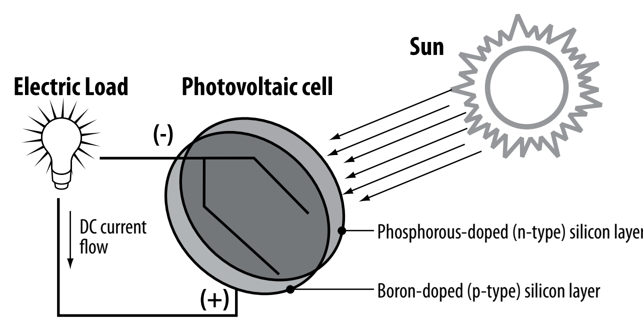
The most important parts of a PV cell are its layers where the electric current starts. There are a number of different materials suitable for making these layers, and each has benefits and drawbacks. Unfortunately, there is not a perfect material for all types of cells and uses.

Silicon Atom



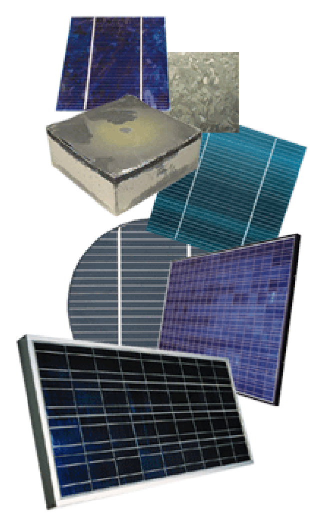
Silicon is used as a semiconductor because it has four valence electrons and does not tend to lose or gain electrons. Therefore, the electrons flow across it from the boron side to the phosphorus side without the silicon interfering with the movement.

Sunlight to Electricity



Types of PV Cells

PV cells come in many shapes and sizes. The most common shapes are circles, rectangles, and squares. The size and the shape of a PV cell, and the number of PV cells required for one PV module, depend on the material of which the PV cell is made.



PV Cells and Their Layers

Let's look more closely at how a PV cell is made and how it produces electricity.

A flat piece of pure silicon is used to make a PV cell. Other materials are added to the silicon in layers. The top layer has an element with electrons that can move easily. The bottom layer has extra places for these electrons to move. The bottom layer is 1,000 times thicker than the top.

When these layers are put together, electrons move from the top layer to the bottom layer. An **electric field** forms between them. When light strikes the PV cell, the electrons become energized and move back to where they started, moving through a circuit. A wire provides the pathway between the layers for the energized electrons to move. This wire is also connected to a **load**, such as a light, in the circuit. These moving electrons are doing work and making electricity.

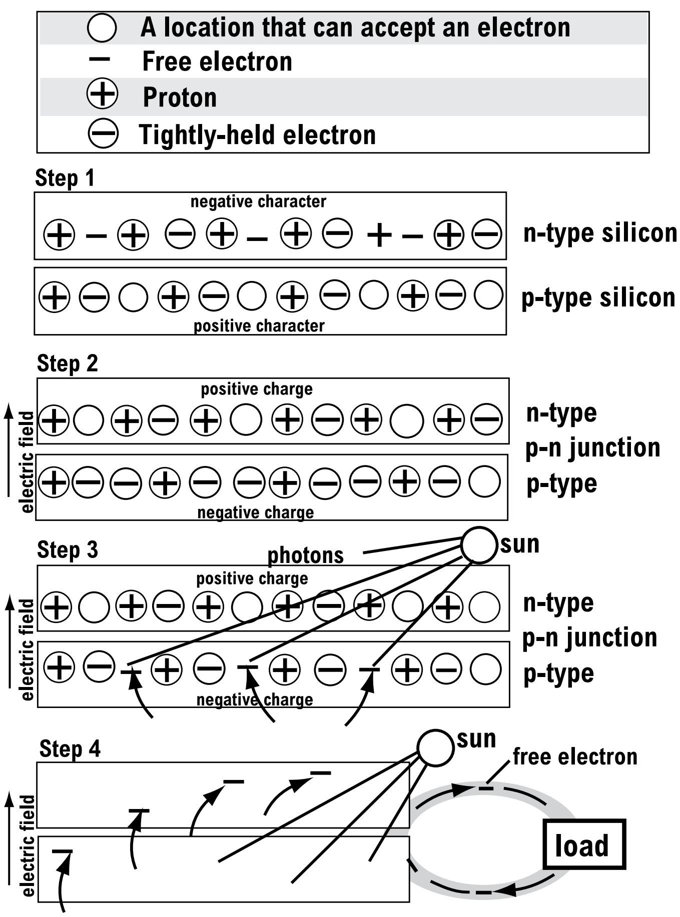
PV Modules and Arrays

PV cells are connected together to form larger groups called photovoltaic **modules**. Photovoltaic cells are connected in series and/or parallel circuits to create higher voltages, currents, and power levels. A PV module is the smallest photovoltaic you can buy. One module will not power much—sometimes not even enough for a light bulb.

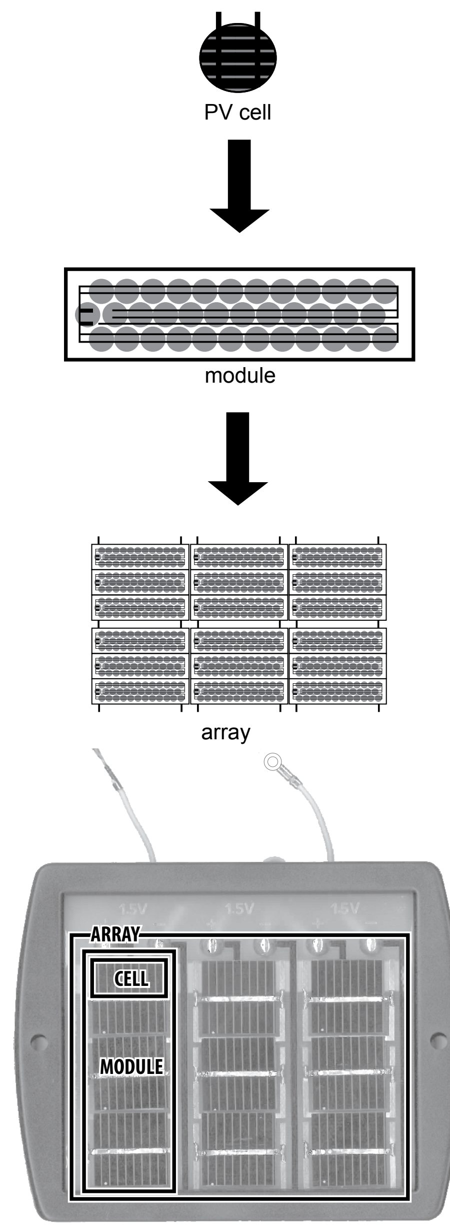
A common PV module has PV cells sandwiched between a front sheet and a back sheet. The front sheet has to be clear and is often made of glass. The back sheet can be dark in color or clear, and is usually made of plastic. These sheets protect them from breakage and from the weather. An aluminum frame can be put around the PV module so that it can be attached to structures.

Photovoltaic **arrays** include two or more PV modules. These modules are combined as one unit that is used to generate power.

Photovoltaic Cell



Photovoltaic Arrays Are Made of Individual Cells



PV Variables

There are many factors that can alter how effective a solar panel is. Installers consider the angle of the panel, the direction it faces, and the electrical needs of the consumer. One variable that is important to consider is the irradiance of the panel. **Irradiance** describes the intensity of the solar energy reaching the panel. The more intense the light is reaching the panel, the higher the power generated by the panel. Other factors to consider when installing a PV module include, local weather, seasonal angle of the sun, and even air temperature. Light often means thermal energy is created, especially if the object is dark in color. PV cells are a dark color. In areas with bright, direct rays and very high temperatures, a solar panel may sometimes become less efficient if it gets too hot.

Measuring Energy Use

Solar panels generate power in watts. We measure electrical energy used as power in a certain amount of time. Many devices switched on for a short amount of time might use the same amount of energy as one device turned on for a long time. Electrical energy is measured in watt-hours, or power x time. One thousand watts of power in one hour is a **kilowatt-hour**. The electric company bills us for our energy use in kilowatt-hours. A solar panel can reduce the amount of electricity we need to buy from the electric company. Solar panels need extra parts to be able to help us use the power they make at times when we need it.

Power Inverter

PV modules produce current called direct current. **Direct current (DC)** is electric current that flows in one direction. Many simple devices that run on batteries use direct current. **Alternating current (AC)** is electric current that changes the direction it flows in a predictable pattern of about 120 times per second. AC is the kind of electricity we get from the electric company, and the type most of our appliances and electronic devices need in order to operate.

In your calculator or a watch, DC current made by a PV module can be used right away. If AC current is necessary, a device called a power **inverter** can be added to the PV system to turn DC to AC current.

Battery System

A PV system cannot store electricity – it needs to be used right away. Batteries are often added to a PV system with an inverter. The inverter is connected to a group of batteries. It is also connected to a home, building, or other electrical load, like a road sign. During daylight hours, the PV array charges the batteries. The batteries supply power whenever it is needed.

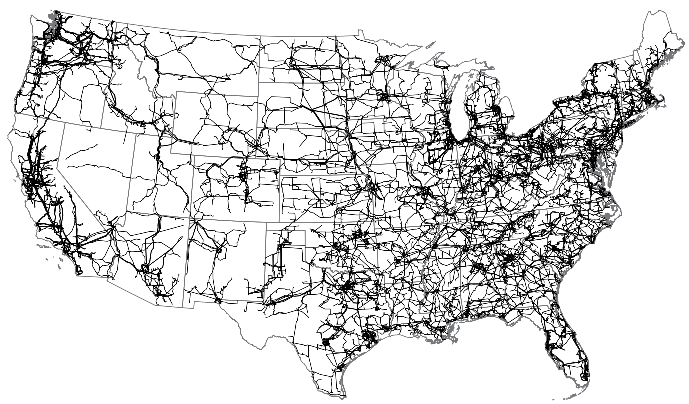
A device called a **charge controller** keeps the battery properly charged and protects it from being overcharged or completely discharged.

Net Metering and the Grid

Homes and businesses get their electricity from their electric company. All of the electricity generated is transmitted over a series of wires and power lines to those that use it. This system of power lines is often called the electric power grid. At your home you have a meter that the electric company uses to keep track of your electricity use. They monitor your meter to predict how much electricity they need to generate.

If a home or business installs a solar panel, the panel may generate more electricity than they use or need at a certain time. This can help reduce electricity costs because they will need to purchase less electricity. If their panel is connected to the electric power grid, the unused electricity may be transmitted back onto the power grid for other homes and businesses to use. Some electric companies will pay the owners of the panels back for generating extra electricity. This is often called **net metering**.

The Continental U.S. Electric Grid



Data: Energy Information Administration

PV Systems

There are two types of PV systems, grid-connected systems and stand-alone systems. The main difference between these systems is that one is connected to the power grid and the other is not.

Grid-Connected Systems

PV Array

Inverter

AC Loads

Electric Utility

Image courtesy of PG&E

PG&E's Vaca-Dixon Solar Station in California is a 2-MW grid-connected system.

Stand-Alone Systems

PV Array

Charge Controller

Energy Storage (Battery)

DC Load (Energy Use)

Inverter

AC Load

Energy Distribution

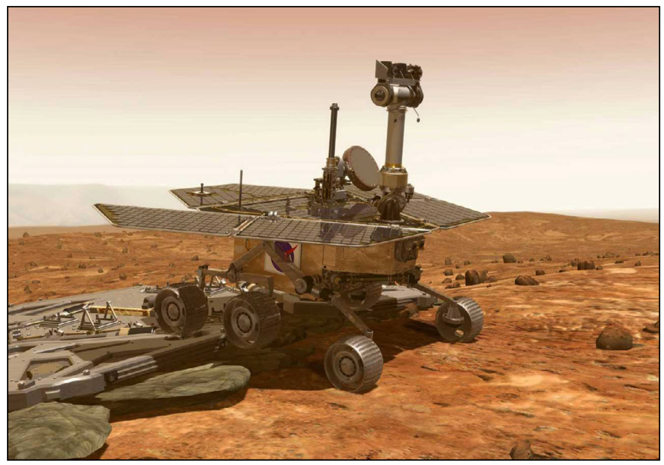


Image courtesy of NASA

The Mars Rovers, Spirit and Opportunity, are powered by stand-alone systems because they operate far away from Earth.

Grid-Connected Systems

Grid-connected systems are connected to and work with the national electric power grid. What is the grid? It is the network of cables through which electricity is carried from power stations to homes, schools, and other places. A grid-connected system is linked to this network of power lines.

A grid-connected system must have an inverter to change DC power into AC power. This allows it to meet the needs of the homeowner and the power grid. It can deliver the electricity it produces into the electricity network. A grid-connected system also allows users to draw energy from the grid when their PV system is not working.

Stand-Alone Systems

A stand-alone system works outside of the grid to generate electricity for one system. Usually a stand-alone system includes batteries with a charge controller to store the electricity.

PV systems were once used only as stand–alone systems in areas where there was no other electricity supply. Today, stand-alone systems are used for water pumping, highway lighting, weather stations, remote homes, and other uses away from power lines.

Size of PV Systems

▪ **Residential**

A residential system is used at the home. It produces electricity to run appliances like refrigerators and televisions. These systems are usually unable to provide all the power used by the homeowners. This type of system might produce enough electricity to power part, or sometimes all, of one home's electricity needs.

▪ **Commercial**

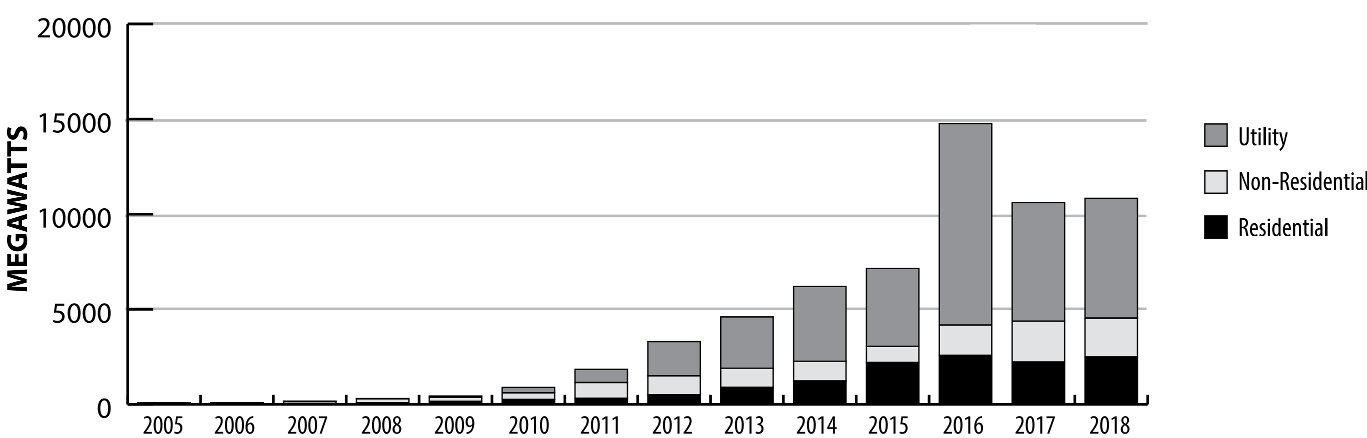
A commercial system is used at a business or industrial site, like an airport or a school. These systems are much larger than residential systems. They can produce more power because more space is available for their installation. This type of system might produce enough electricity to operate all or part of the business or industrial site.

▪ **Utility**

Utility systems are owned by energy companies to produce power for sale to consumers. Large areas of land are often needed for their installation. Utility systems are often built on land that cannot be used in other ways.

Average Size of Grid Connected Photovoltaic Systems

Annual Installed Grid-Connected PV Capacity by Sector



Data: Solar Energy Industries Association, IREC

New PV Technologies

Today there are many new PV technologies being researched and developed. Thin-film photovoltaics are flexible and do not break easily. They can be used in an area where glass is a bad idea, such as in areas that have strong storms. They can also be used on older structures where the weight of glass on the roof would cause it to collapse. Photovoltaic paints and coatings allow surfaces to be made into electricity-producing structures without adding much weight.

Multi-junction photovoltaics allow for higher efficiency. A normal PV module uses light of only one wavelength or color. Multi-junction photovoltaics are able to use three or four different colors of light to produce electricity. Because sunlight is a mixture of many different wavelengths, being able to use three or four of them instead of just one is a more efficient use of the sun's energy.

Scientists are also researching other materials for photovoltaics that are not as expensive to create or gather. Bringing the cost of PV systems down will make them more affordable to more people.

THIN-FILM TECHNOLOGY

The Schapfen Mill Tower is a flour mill in Germany. The southern facade is faced with 1,300 thin-film solar modules.

PROs and CONs of PV Systems

PROs

Photovoltaic systems offer many advantages:

- they are safe, clean, and quiet to operate;
- they are highly reliable;
- they need very little maintenance;
- they are good for areas where there is little access to electricity;
- they work well for homes and businesses;
- they can be expanded to meet growing electrical needs;
- they can act as a backup during outages; and
- the fuel is renewable and free.

CONs

There are also some limits to PV systems:

- PV systems cannot operate all the time;
- grid-connected systems are expensive to buy and install;
- large amounts of land are needed to hold enough panels that will generate a useful amount of electricity; and
- the process to make silicon for PV panels can be harmful to the environment.

Glossary

active system	a system that uses special equipment to use the sun's energy
albedo	measure of the amount of light reflected by a surface
alternating current (AC)	an electric current that changes its direction at regular intervals or cycles; in the U.S. the standard is 120 reversals per second; abbreviated as AC
ambient temperature	the temperature of surrounding air; temperature surrounding solar cells
ampere (A)	a unit of measure for an electric current; the number of electrons that pass a point in a given amount of time; abbreviated as amp
array	many photovoltaic modules connected together, working as a system
charge controller	a device that controls how much electric current is added to or removed from a battery
conversion efficiency	amount of useable energy transformed from another form; always less than 100%
current	the flow of electrons through a circuit, usually measured in amperes
direct current (DC)	an electric current that flows in only one direction through a circuit; abbreviated as DC
efficiency	the amount of useful energy created compared to the energy supplied; written as a percentage, always less than 100%
electric field	the electric force per unit charge, caused by a charged object
electric power	how quickly electrical energy is used; measured in watts; also used to describe the maximum power a power plant can produce
electrical energy	the energy of moving electrons
greenhouse effect	solar energy reflected by the Earth gets absorbed by some gases in the atmosphere, keeping the Earth warm
grid	the system of wires, poles, and towers that carry electricity from power plants to electricity users
inverter	device that changes direct current to alternating current
irradiance	the amount of power or radiation on a specific surface, watts/meter^2
kilowatt-hour (kWh)	a way of measuring electricity that describes how much energy has been used; one thousand watts used in one hour; the way electrical utilities charge for electric power
load	an item connected to the output of an electrical circuit; amount of current drawn by a circuit
module	several PV cells connected together in a larger unit
net metering	when an electricity consumer is able to sell extra electricity back to the electric company
nuclear fusion	when the nuclei of atoms are combined together; the sun combines the nuclei of hydrogen atoms into helium atoms; energy from the nuclei of atoms, called nuclear energy, is transformed into radiant energy during nuclear fusion
passive system	a system that doesn't need special equipment to use the sun's energy
photons	bundles of radiant energy
photovoltaic effect	some materials generate electric current when exposed to light transforming radiant energy into electrical energy

photovoltaic system	a group of objects that generate electric power using energy from the sun; often includes a PV module(s), batteries, inverter, and connecting wires
photovoltaics	see photovoltaic system
power	how fast energy is transferred; measured in watts
radiant energy	energy transferred in electromagnetic or transverse waves, such as x-rays, light, and radio waves
radiate	traveling in a wavelike pattern
renewable	resources that can be easily made or replenished; we can never use up renewable fuels or resources
semiconductor	any material that can conduct a small amount of electric current; semiconductors are solid crystals, such as silicon, that conduct better than an insulator but not as well as a conductor
silicon	element number 14 on the periodic table; a gray, shiny, brittle, solid semiconducting material that is the main ingredient in PV cells
solar collector	an item, like a car or greenhouse, that absorbs radiant energy from the sun and traps it inside
topography	from the Greek words *topos*, meaning place, and *graphe*, meaning written; using lines to make a map of hills and valleys; the shape of the land such as hilly, flat, mountainous, etc.
volt (V)	unit to measure voltage
voltage	the potential an electron has to move; the “pressure” behind a moving electron; the measure of the amount of energy an electron has in a circuit; measured in volts
watt	unit to measure power
watt-hour (W)	measure of electrical energy; consuming one watt for one hour

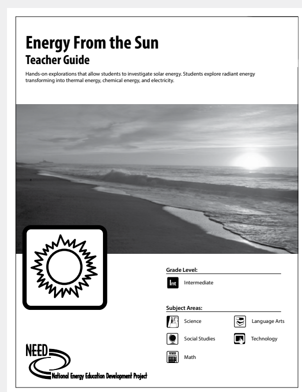
Solar Kits

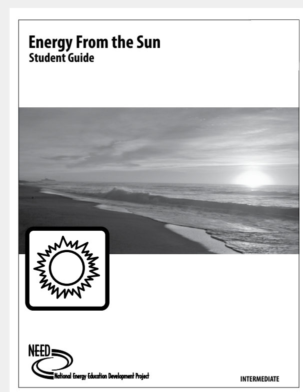
ENERGY FROM THE SUN AND KIT

Grades 6–8

Intermediate students learn about solar energy through investigations that explore radiant energy transforming into thermal energy, kinetic energy, chemical energy, and electricity. The kit includes a Teacher Guide, a class set of 30 Student Guides, and the materials necessary to conduct the activities.

Level:	Intermediate
Teacher and Student Guides	$ 5.00
Energy From the Sun Kit	$ 375.00
Class Set of 30 Student Guides	$ 50.00
Class Set of Consumables	$40.00





Visit https://the-need-project.myshopify.com/collections/solar to purchase kits.

OTHER SOLAR KITS

THE SUN AND ITS ENERGY

WONDERS OF THE SUN

EXPLORING PHOTOVOLTAICS

Schools Going Solar Evaluation Form

State: ____________ **Grade Level:** ____________ **Number of Students:** ____________

1. Did you conduct the entire unit?	❑ Yes	❑ No
2. Were the instructions clear and easy to follow?	❑ Yes	❑ No
3. Did the unit meet your academic objectives?	❑ Yes	❑ No
4. Were the activities age appropriate?	❑ Yes	❑ No
5. Were the allotted times sufficient to conduct the activities?	❑ Yes	❑ No
6. Was the unit easy to use?	❑ Yes	❑ No
7. Was the preparation required acceptable for the unit?	❑ Yes	❑ No
8. Were the students interested and motivated?	❑ Yes	❑ No
9. Was the energy knowledge content age appropriate?	❑ Yes	❑ No
10. Would you teach this unit again?	❑ Yes	❑ No

Please explain any 'no' statement below.

How would you rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor
How would your students rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor

What would make the unit more useful to you?

Other Comments:

Please fax or mail to: **The NEED Project**
8408 Kao Circle
Manassas, VA 20110
FAX: 1-800-847-1820

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National Grid
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National Ocean Industries Association
National Renewable Energy Laboratory
NC Green Power
Nebraskans for Solar
New Mexico Oil Corporation
New Mexico Landman's Association
NextEra Energy Resources
NEXTracker
Nicor Gas
Nisource Charitable Foundation
Noble Energy
North Carolina Department of Environmental Quality
North Shore Gas
Offshore Technology Conference
Ohio Energy Project
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Oxnard Union High School District
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