Energy From the Sun

Student Guide

2017-2018

NEED
National Energy Education Development Project

INTERMEDIATE

Energy From the Sun

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 in a plasma state. The sun generates energy from a process called **nuclear fusion**.

During nuclear fusion, the high pressure and temperature in the sun's core cause **nuclei** to separate from their electrons. Hydrogen nuclei fuse to form one helium atom. During the fusion process, **radiant energy** is released. It can take 150,000 years for energy in the sun's core to make its way to the solar surface, and then just a little over eight minutes 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 portion of the energy radiated by the sun into space strikes the Earth, one part in two billion. Yet this amount of energy is enormous. The sun 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. About half of the radiant energy is absorbed by land and oceans. The rest is absorbed by the atmosphere and clouds in the **greenhouse effect**.

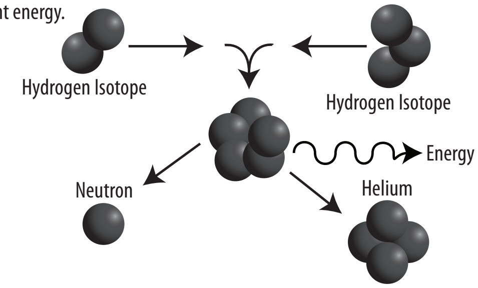
In addition to supplying a large amount of energy directly, the sun is also the source for many different forms of energy. Solar energy powers the water cycle, allowing us to harness the energy of moving water. Solar energy drives wind formation, allowing us to use wind turbines to transform kinetic 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.

How We Use Solar Energy

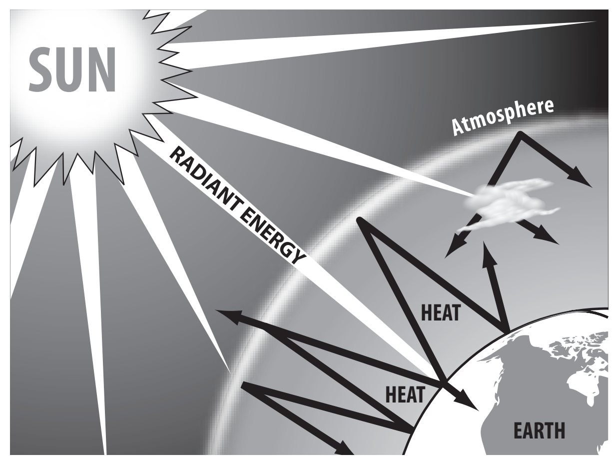
People have harnessed solar energy for centuries. As early as the seventh century BCE, people used basic magnifying glasses to focus light from the sun to make fire. Over a century ago, a scientist in France used a solar collector to make steam to power an engine. Solar water heaters gained popularity in the early 1900's in the southwest United States. Today, people use solar energy to heat buildings and water and to generate electricity. In 2015, solar energy accounted for just over 0.4 percent of U.S. energy consumption – less than one percent! The top producing solar energy states include many of the sunny, warm states in the western United States.

Fusion

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



The Greenhouse Effect

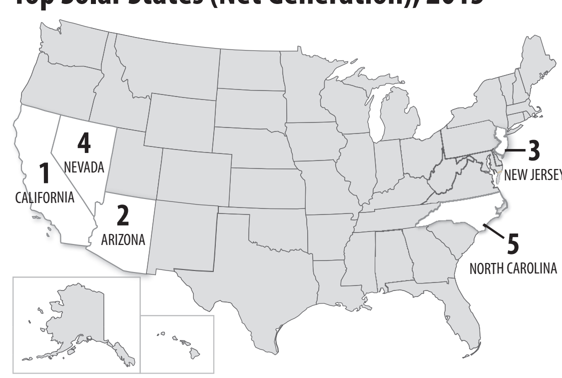


Radiant energy (light rays) shines on the Earth. Some radiant energy reaches the atmosphere and is reflected back into space. Some radiant energy is absorbed by the atmosphere and is transformed into heat (dark arrows).

Half of the radiant energy that is directed at Earth passes through the atmosphere and reaches the Earth, where it is transformed into heat.

The Earth absorbs some of this heat, but most of the heat flows back into the air. The atmosphere traps the heat. Very little of the heat escapes back into space. The trapped heat flows back to the Earth. This is called the greenhouse effect. The greenhouse effect keeps the Earth at a temperature that supports life.

Top Solar States (Net Generation), 2015



Data: Energy Information Administration

Solar Collectors

A **solar collector** is one way to capture sunlight and transform it into heat energy, or **thermal energy**. The amount of solar energy an area receives depends on the time of day, the season of the year, the cloudiness of the sky, and how far one is from the Earth's Equator. A closed car on a sunny day is a solar collector. As sunlight passes through the car's windows, the seat covers, side panels, and floor of the car absorb it. The absorbed energy transforms into thermal energy that is trapped inside the car. A greenhouse also makes a great example of a solar collector.

Solar Space Heating

Space heating means heating the space inside a building. Today, many homes use solar energy for space heating. There are two basic types of solar space heating systems: passive and active. **Hybrid solar systems** are a combination of passive and active systems.

Passive Solar Design

A **passive solar home** is designed to let in as much sunlight as possible. It is a big solar collector. Sunlight passes through the windows and heats the walls and floor inside the house. The light can get in, but the thermal energy is trapped inside. A passive solar home does not depend on mechanical equipment to move heat throughout the house. For example, awnings may be designed to let in light in the winter when the sun is lower in the horizon, yet shade the windows in the summer when the sun is higher in the sky. Passive solar buildings are quiet, peaceful places to live or work. They do not rely on machinery and heat the walls or floors rather than the air inside. Passive homes can get 30 to 80 percent of the heat they need from the sun. They store their heat energy by using thick walls and building materials that retain heat well like masonry, concrete, stone, and even water. If a passive home incorporates blowers or fans, it is then called a hybrid solar system.

Active Solar Design

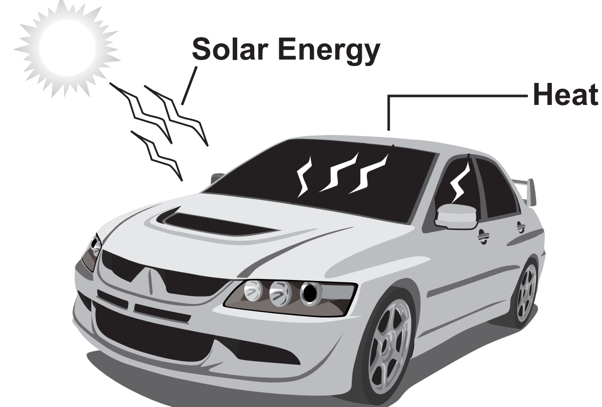
An **active solar home** uses mechanical equipment and other sources of energy to collect and move thermal energy.

One example of an active solar system consists of dark-colored metal plates inside frames with glass tops. These systems are often mounted on the roof or in a location with good solar exposure. The metal plates absorb sunlight and transform it into thermal energy, which heats up a fluid inside the collector. The warmed fluid is moved into the house via a pump and the thermal energy of the fluid is transferred to the air or water inside the home. These solar collectors are stored high on a roof where they can collect the most sunlight. They need to be placed in an area where they will not be shaded by trees or other buildings. Heat can be stored in a large tank filled with liquid, or even in rock bins underneath the house. Both active and passive designs usually include some sort of back-up system like a furnace or wood stove, in case of extreme cold or cloudy weather.

Solar Water Heating

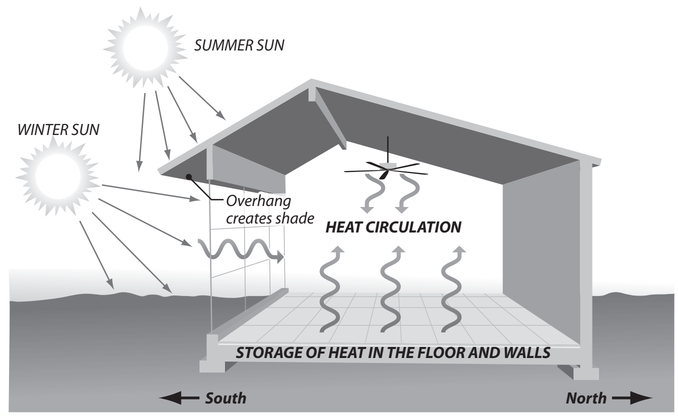
Solar energy can also be used to heat water for household use. Heating water for bathing and washing is the second largest home energy cost. Installing a solar water heater can cut that cost in half. A solar water heater works a lot like solar space heating. In our hemisphere, a solar collector is often mounted on the south side of a roof where it can capture sunlight. The sunlight heats water and stores it in a tank. The hot water is piped to faucets throughout a house, just as it would be with an ordinary water heater.

Solar Collector



On a sunny day, a closed car is a solar collector. Solar energy passes through the glass, hits the inside of the car and changes into thermal energy, which gets trapped inside.

Passive Solar Home Design



SOLAR WATER HEATER

Radiant Energy to Electricity

Solar energy can be used to produce electricity. Two ways to make electricity from solar energy are **photovoltaic** systems and systems using thermal energy.

Photovoltaic Systems

Photovoltaic comes from the words *photo,* meaning light, and *volt*, a measurement of electricity. **Photovoltaic cells** are also called PV cells or solar cells for short. Using PV cells to harness the sun's energy is a rapidly expanding science. The first practical PV cell was developed by Bell Telephone researchers. At first, PV cells were used primarily in space to power U.S. space satellites. Now PV cells are common in many different applications. You are probably familiar with photovoltaic cells. Solar-powered toys, calculators, and many lighted roadside signs all use solar cells to convert sunlight into electricity.

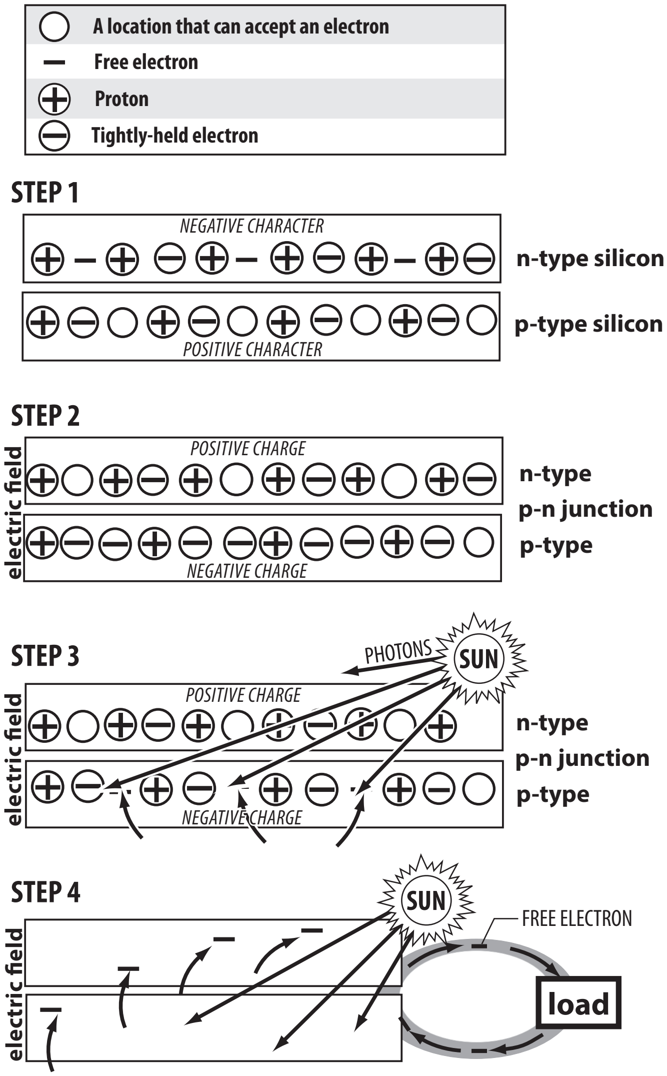
Solar cells are made of a thin wafer of **silicon**, one of the elements found in sand and the second most common element on Earth. The top of the wafer has a very small amount of phosphorous added to it. This gives the top of the wafer an extra amount of free, negatively charged electrons. This is called n-type silicon because it has a habit of giving up its electrons, a negative character. The bottom of the wafer has a small amount of boron added to it, which has a tendency to attract electrons. It is called p-type silicon because of its positive character. When both of these chemicals have been added to the silicon wafer, some of the free electrons from the n-type silicon flow to the p-type silicon and an electric field forms between the layers at the p-n junction. The p-type now has a negative charge because it gained electrons. The n-type has become positive because it lost electrons.

When the PV cell is placed in the sun, the radiant energy excites the free electrons. If a circuit is made by connecting the wafer's sides, electrons transfer their energy from atom to atom from the n-type through the wire to the p-type. The PV cell is producing electricity—the transfer of energy due to moving electrons. If a load such as a light bulb is placed along the wire forming a circuit, the electricity will do work as it flows to make the bulb light. The conversion of sunlight into electricity takes place silently and instantly. There are no mechanical parts to wear out, therefore photovoltaic systems last an extended period of time.

Photovoltaic systems can consist of small cells, like the ones that charge calculators, to systems that power individual homes, to large power plants powering many homes. The average size of a residential PV system installed is about 6.1 **kilowatts**. The average size of a **utility-scale** PV is about 4.3 **megawatts**. However, the sizes of residential, commercial, and utility-scale PV systems can vary greatly, depending on the space available for use.

New technologies are constantly being developed to make PV cells thinner and more flexible. There are now roofing shingles that are made of PV cells. Rather than putting panels on your roof, solar shingles can be used that match the conventional shingles for a more pleasing look. Scientists are developing PV cells that can be put into home windows and on thin, flexible film that can be attached to the outside of the home. There are even different types of solar paint!

From Silicon to Electricity



UTILITY-SCALE PHOTOVOLTAIC INSTALLATION

Image courtesy of Sacramento Municipal Utility District

A single PV cell does not generate much electricity. Many cells are connected to create panels that will produce enough usable electricity to power devices or be transported to consumers.

Concentrating Solar Power Systems

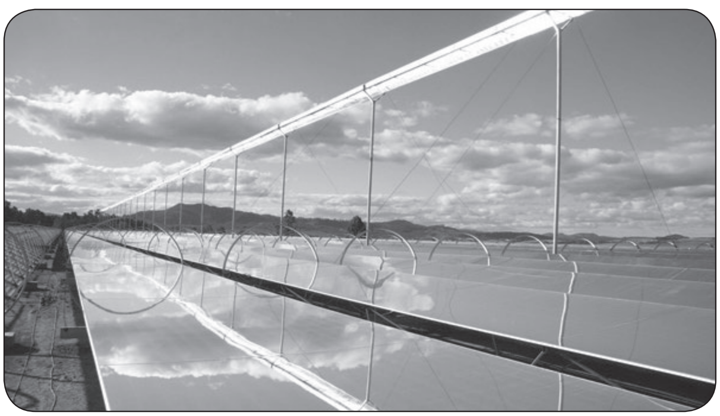
Concentrating solar power (CSP) **systems** also use solar energy to make electricity, but instead of only panels, they also use a turbine system. Since the solar radiation that reaches the Earth is so spread out, it must be concentrated to produce the high temperatures required to generate electricity using a steam turbine. There are several types of systems that use mirrors or other reflecting surfaces to concentrate the sun's energy, increasing its intensity.

Linear concentrating systems use mirrors to concentrate sunlight onto receivers located just above the mirrors. The receivers are long tubes that carry either water that is directly converted to steam or fluid that transfers energy in a **heat exchanger**, which produces steam. The steam drives a turbine that turns a generator to make electricity. Linear concentrating systems are either parabolic trough systems, or linear Fresnel reflector systems.

Parabolic trough systems use long, curved mirrors in troughs that focus the sunlight onto a pipe located at the focal line. A fluid circulating inside the pipe collects the energy and transfers it to a heat exchanger, producing steam to drive a conventional turbine. The world's largest parabolic trough system is located in the Mojave Desert in California. The SEGS facility consists of several sites that together have a total generating capacity of 354 megawatts. Five to ten acres of parabolic troughs are needed to produce one megawatt of electricity. Arizona houses another one of the world's largest facilities of this type. The Solana plant near Phoenix can generate 280 megawatts.

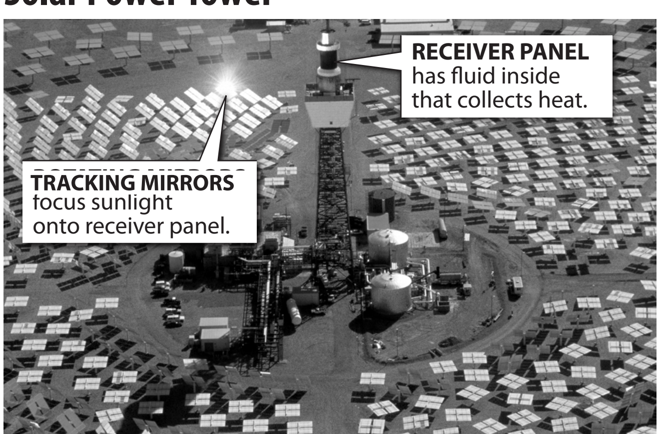
DISH/ENGINE SYSTEM

LINEAR FRESNEL REFLECTORS



Photos courtesy of National Renewable Energy Laboratory

Solar Power Tower



Linear Fresnel reflector systems use several flat mirrors in groups to concentrate the sun onto a tube receiver above them. This arrangement allows the mirrors to better track the sun's position for maximum reflection. The first linear Fresnel reflector system in the U.S. generates 5 megawatts of electricity in Bakersfield, CA.

While parabolic trough systems are the most common in the United States, there are advantages and disadvantages to both systems. Parabolic trough systems are proven and have excellent performance. However, the parabolic mirrors are expensive to manufacture and the power plants require large amounts of land. Linear Fresnel reflector systems use mirrors that are easier and cheaper to manufacture. However, the performance of linear Fresnel reflector systems does not yet match that of parabolic troughs.

A **solar power tower** consists of a large field of sun-tracking mirrors, called **heliostats**, that focus solar energy on a receiver at the top of a centrally located tower. The enormous amount of energy in the sun's rays focused at one point on the tower can produce temperatures over 500 degrees Celsius. The thermal energy is used for heating water or molten salt that saves the energy for later use. In a heat exchanger, the hot water or molten salt heats the water and changes it to steam that is used to move the turbine generator. The largest solar power tower system in the world is found in California. The Ivanpah Solar Electric Generation System uses three towers with over 170,000 heliostats and has a generating capacity of over 390 megawatts.

Dish/engine systems are like satellite dishes that concentrate sunlight rather than signals, with a heat engine located at the focal point to generate electricity. These generators can be small, mobile units that can be operated individually or in clusters, in urban and remote locations.

Hybrid Electric Power Plants

Martin Next Generation Solar Energy Center, Indiantown, FL

One of the challenges with generating electricity from solar energy is that people consume electricity 24 hours a day, but the sun only shines a portion of that time. One strategy to overcome that challenge is to build a hybrid facility. A hybrid facility is an electric generating plant that uses both renewable and nonrenewable energy sources in order to meet the electrical demand of the local community.

Florida Power and Light Company (FPL) has a combined-cycle natural gas power plant in Indiantown, FL. In 1989, a portion of the site was licensed for a coal-powered generation unit that was not constructed. Instead, ground was broken in 2008 to use 500 acres of the site for a solar-thermal array that transforms the sun's energy into electricity.

The center uses more than 190,000 parabolic mirrors to harness the sun's energy. Using motors, the mirrors rotate to track the sun and take full advantage of daylight hours. At full peak, estimated electricity generation each year is 155,000 megawatt-hours, enough to power 11,000 homes. This makes the Martin Next Generation Solar Energy Center the largest solar thermal power plant in the eastern United States.

The FPL Martin Next Generation Solar Energy Center is the first hybrid solar facility in the world to connect a solar plant to an existing combined-cycle natural gas power plant. Steam produced by the concentrated solar thermal system is transferred to the same steam turbine that the natural gas plant uses. The electricity generated in this process is then sent out onto the grid through existing transmission lines. Connecting the solar plant to the natural gas plant reduced the cost to build the solar facility. This will allow FPL to reduce its natural gas use by 1.3 billion cubic feet each year, saving customers $178 million in fuel costs over the life of the solar facility. Over its lifetime, the center will also prevent 2.75 million tons of greenhouse gases from entering the atmosphere—the equivalent of removing more than 18,500 cars from the road every year for 30 years.

When constructing any energy facility, engineers and planners must take many things into account. When building the Martin Next Generation Solar Energy Center, plant engineers had to consider Florida's hurricane season. The motors that move the mirrors also allow the mirrors to flip upside down for protection. The mirrors are built on an advanced aluminum truss system that can sustain winds up to 130 miles per hour.

The FPL Martin Next Generation Solar Energy Center showcases how utilities are bringing all energy sources into their generation plans and finding ways to connect renewable and nonrenewable energy sources to provide the electricity needed night and day.

PARABOLIC TROUGH SYSTEM

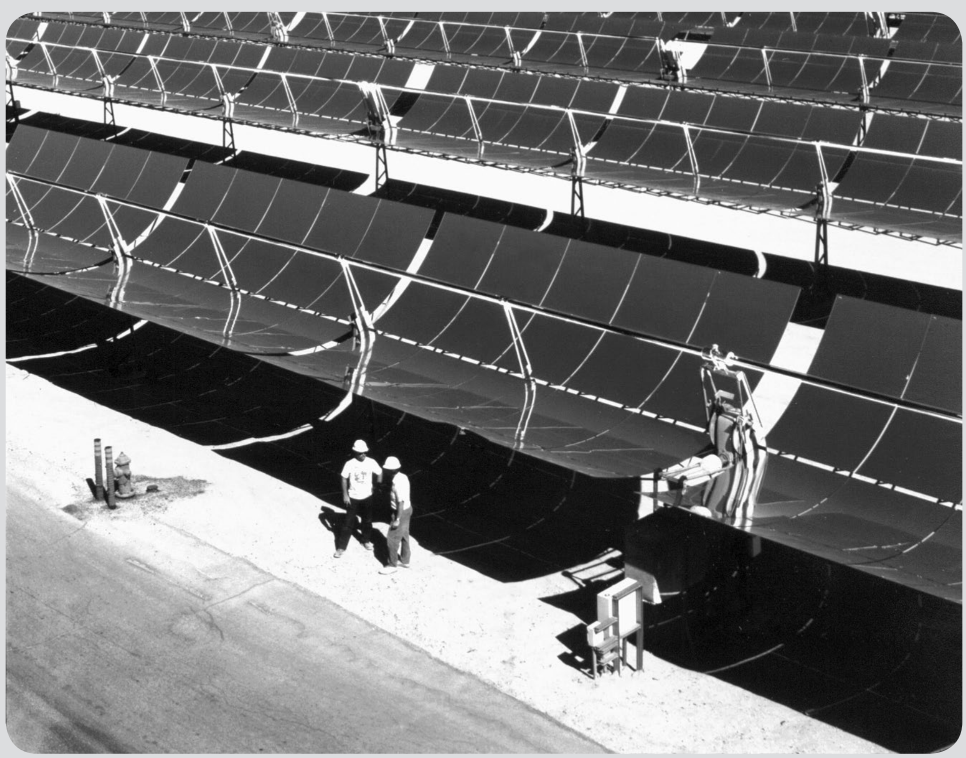


Image courtesy of U.S. Department of Energy

Benefits and Limitations

Solar energy has great potential for the future. Radiant energy from the sun is free and its supplies are unlimited. It cannot be controlled by any one nation or industry. The electricity generated by photovoltaics does not pollute the environment; however, the manufacturing of the PV cell does have an environmental impact. As we improve the technology to harness the sun's enormous power, we can work toward a sustainable energy future.

Benefits of Solar Energy

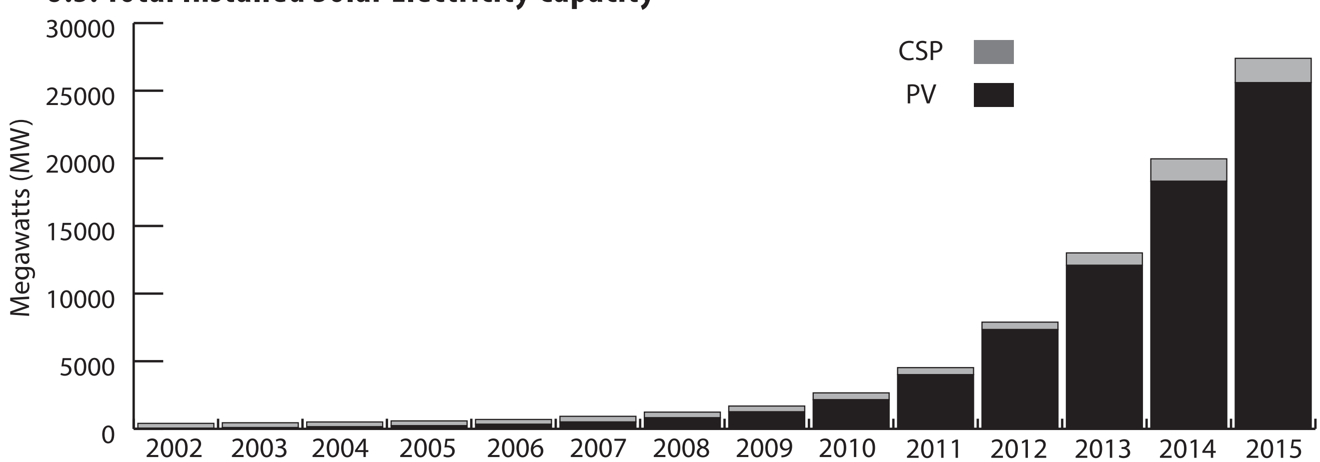
- Solar electric systems are safe, clean, and quiet to operate.
- Solar systems are highly reliable.
- Solar systems require very little maintenance.
- Solar systems are cost-effective in remote areas and for some residential and commercial applications.
- Solar systems are flexible and can be expanded to meet increasing electrical needs for homes and businesses.
- Solar systems can provide independence from the **grid** or backup during outages.
- The fuel is renewable and free and domestically produced.
- Harnessing solar energy spurs economic development.
- Using solar energy to generate electricity produces no greenhouse gases.

Challenges of Solar Energy

- PV systems are not well suited for energy-intensive uses such as heating.
- Grid-connected systems are often expensive, except in areas with high electricity rates where local incentives are offered.
- We cannot harness solar energy at night.
- To be used around the clock, solar systems require battery or thermal storage.
- Utility scale systems require a large amount of land.
- The highest solar concentration is found in areas far from population centers.
- Systems are affected by shading, cloudy weather, and dirt accumulation.
- Large utility-scale concentrated solar systems require large amounts of water in areas where there is very little water.
- Due to the cost per kilowatt-hour to generate electricity from PV, power companies often opt for cheaper sources for generation.
- The process to make some solar electric technologies can have harmful effects on the environment.
- CSP facilities can affect wildlife in an area.

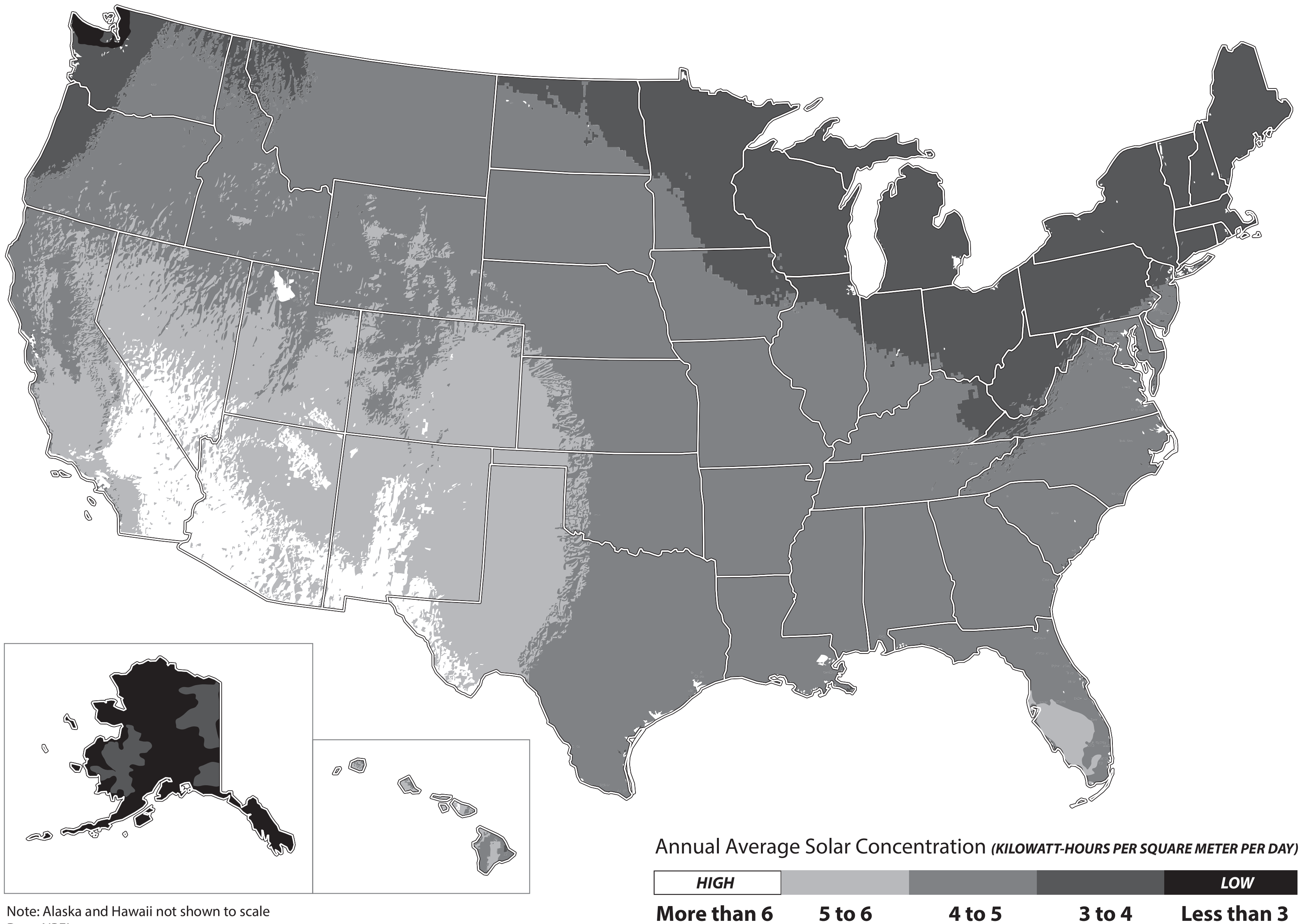
Average Size of Photovoltaic Systems, Grid Connected, 2015

U.S. Total Installed Solar Electricity Capacity



Data: DOE EERE Renewable Energy Data Book, IREC

Solar Resources in the United States



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

KWL Organizer for Solar Energy

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

Radiation Cans

Question

What happens to the sun's radiant energy when it comes in contact with a black can or a shiny can?

Hypothesis

In your science notebook, write your hypothesis in an "If…then…because…" format.

Caution

Do not look directly at the sun or its reflection; doing so can be harmful to your eyesight.

Materials

- 1 Set of radiation cans (one black and one shiny)
- 2 Thermometers
- 1 Beaker
- Room temperature water
- Light source (sunny day or bright artificial light)
- Timer

Procedure

1. Put thermometers into the empty black and shiny cans and replace the lids. Position the thermometers so they are not touching the bottoms of the cans. Record the starting temperature of both cans.
2. Place the cans in a sunny place or under the light source. Record the temperature every minute for fifteen minutes using the data table on the next page.
3. Calculate the change in temperature for each can and record it in the ΔT column of the data table.
4. Remove the cans from the direct light. Take the lid off of each can and allow the air inside to return to room temperature.
5. Fill both cans with 150 mL of room temperature water and record the temperatures.
6. Place the cans under the same light source. Record the temperature every minute for 15 minutes.
7. Calculate the change in temperature for each can and record it in the ΔT column of the data table.

Conclusions

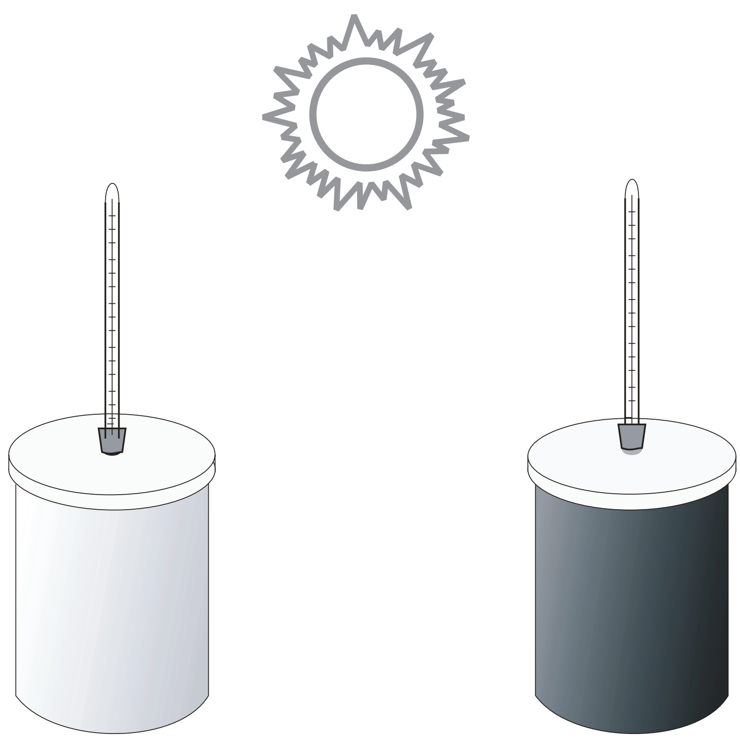
1. What have you learned about converting radiant energy into heat? How does that relate to reflection and absorption of radiant energy in the black and shiny cans?
2. Compare the results of measuring temperature change in cans with air and cans with water. What did you notice? Use data to explain what happened in each trial.
3. What color should a solar water heater be and why? Use data to support your answer.

Data

Use or re-create the tables below in your science notebook for your data.

Air Only																	
	Starting Temperature	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ΔT
Black Can																	
Shiny Can																	

Room Temperature Water																	
	Starting Temperature	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ΔT
Black Can																	
Shiny Can																	



Solar Concentration

Question

What effect do reflectors have on the amount of solar radiation collected?

Hypothesis

In your science notebook, write your hypothesis in an "If…then…because…" format.

Caution

Do not look directly at the sun or its reflection; doing so can be harmful to your eyesight.

Materials for each group

- 1 Set of radiation cans (one black and one shiny)
- Clay
- 2 Thermometers
- Cold water
- 1 Beaker
- Light source (sunny day or bright artificial light)
- Ruler

Materials for specific groups

- Group B—2 Concave mirrors
- Group C—4 Concave mirrors
- Group D—2 Flat mirrors
- Group E—4 Flat mirrors

Procedure

1. Fill the silver and black radiation cans with 150 mL of cold water.
2. Put a thermometer into each can and position them so the thermometers are in the water but not touching the bottoms of the cans. Replace the lids. Record the temperature of the water on your data table in the starting temperature column.
3. Place the cans in the light source. If using a lamp, make sure all cans are equidistant from the lamp.
4. Position the mirrors for your group using the following instructions:
    - Group A: The control—cans without mirrors.
    - Group B: Position one concave mirror behind each can so that the mirrors focus sunlight onto the cans. The mirrors should be about seven centimeters (7 cm) from the outside edge of the can. Use pieces of clay to hold the mirrors in the correct position.
    - Group C: Position two concave mirrors behind each can as described above.
    - Group D: Position one flat mirror behind each can as described above.
    - Group E: Position two flat mirrors behind each can as described above.
5. Record the temperatures of the water in your group's cans every minute for 15 minutes.
6. Calculate the change in temperature and record it in the ΔT column on the data table in your science notebook.
7. Share your data with the other groups and record their findings in your data table in your science notebook.

Conclusions

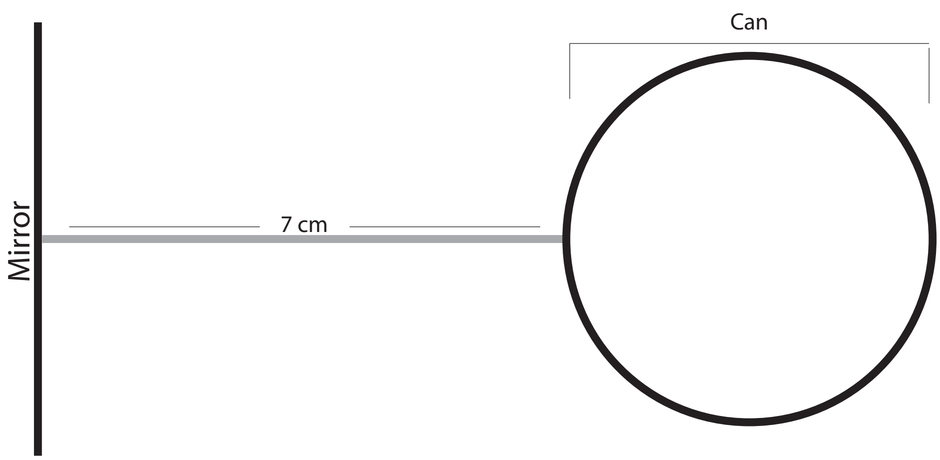
1. Compare and contrast how the shape of the mirror and the color of the container influence the amount of heat energy absorbed. Use data to support your answer.
2. How does the solar industry use concentrated solar power to produce electricity?

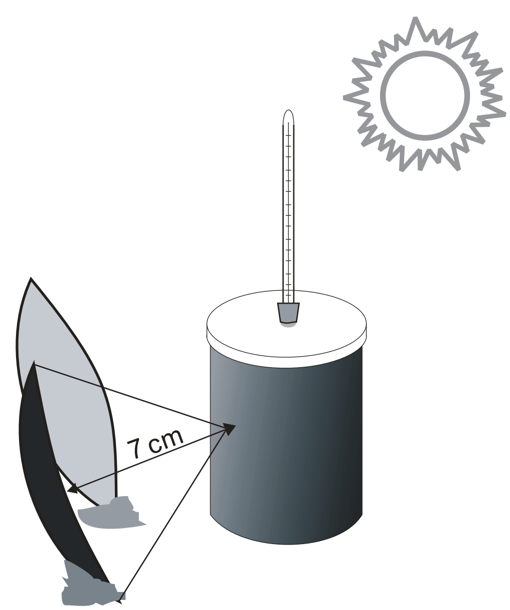
Data

Use or re-create the table below in your science notebook for your data.
Put your initials by the cans you are responsible for and record your data.
When you are done, share your data with the class, and fill in the rest of the data based on other groups' results.

	Starting Temperature	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ΔT
Black Can with no mirror																	
Shiny Can with no mirror																	
Black Can with one concave mirror																	
Shiny Can with one concave mirror																	
Black Can with two concave mirrors																	
Shiny Can with two concave mirrors																	
Black Can with one flat mirror																	
Shiny Can with one flat mirror																	
Black Can with two flat mirrors																	
Shiny Can with two flat mirrors																	

Use this guide to place the mirror 7 cm away from the can.





Solar Distiller

Question

What happens when colored water evaporates?

Hypothesis

In your science notebook, write your hypothesis in an "If…then…because…" format.

Materials

- 1 Large container (e.g., cake pan, glass bowl, disposable aluminum pan)
- 1 - 100 mL Beaker (or small glass bowl shorter than the depth of your larger dish)
- 1 Marble
- Clear plastic wrap
- Large rubber band
- Water
- Food coloring
- Sunny day or bright light source

✔ Procedure

1. Measure and pour 50 mL of water into the large container.
2. Add four (4) drops of food coloring to the water and mix. Record the color of the water.
3. Set the small beaker/bowl in the center of the large plastic container. Weigh it down if it is floating.
4. Place the plastic wrap over the top of the large plastic container leaving a depression in the center over the small beaker/bowl. Secure the plastic wrap with the rubber band, making sure no air is able to flow in or out of the model.
5. Place a marble in the center of the plastic wrap over the small beaker/bowl.
6. Place the container in the full sun, or bright light.
7. Observe the container after 30 minutes.

Data

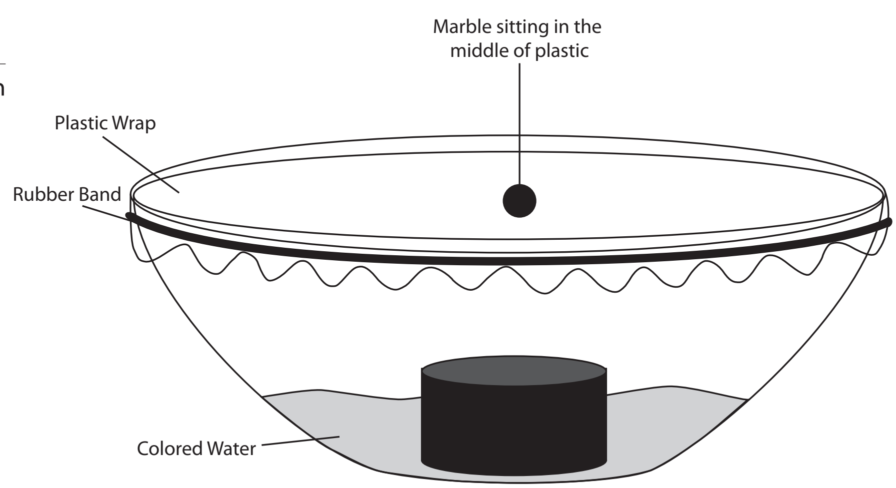
Record your observations using pictures and words in your science notebook.

Conclusions

1. What did you observe in the center small beaker/bowl?
2. Draw and label the solar distiller. Explain the processes of evaporation and condensation in the solar distiller.
3. Draw and label Earth's natural water cycle. Explain the processes of evaporation and condensation in the water cycle. Compare and contrast how they are the same and how they are different.

Extension

Test a variety of liquids to find out which ones contain water.



Photovoltaic Cells

Question

How does changing the amount of radiant energy reaching the solar panel affect the panel's electrical output?

Hypothesis

In your science notebook, write your hypothesis in an "If…then…because…" format.

Materials

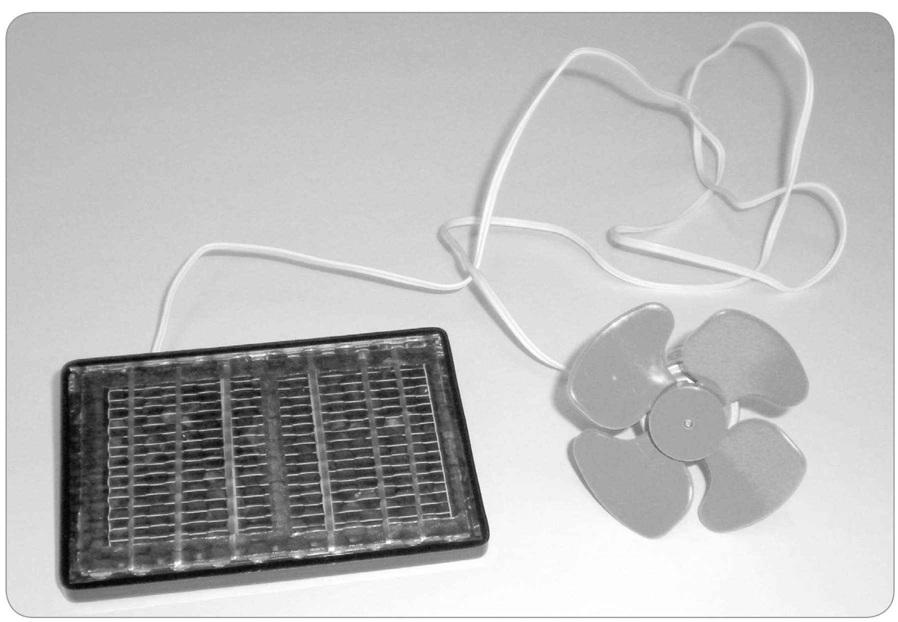
- 1 PV module
- 1 Motor
- 1 Fan
- Paper
- Bright light source

✔ Procedure

1. Attach the motor to the PV module by removing the screws on the posts of the PV module, sliding one connector from the motor onto each post, then reconnecting the screws.
2. Attach the fan to the stem of the motor so that you can see the motion of the motor.
3. Place the module under a bright light source. Record your observations in your science notebook.
4. Cover ¼, then ½, then ¾ of the module using a piece of paper and observe what happens to the spinning of the fan. Record your observations in your science notebook.
5. Hold the PV module at different angles to the sun. Estimate the angles you use. Observe and record your observations.
6. Cover part of the PV module and change its angle. Observe and record your observations.
7. Observe and note the direction of the spin of the fan. Remove the wires from the PV module posts and connect them to the opposite posts. Observe and record your observations.

Conclusions

1. What have you learned about PV cells and their ability to convert radiant energy into electricity?
2. How does changing the area of sunlight exposure on the PV module affect the amount of electricity produced?
3. How does changing the angle of the PV module to the sunlight affect the amount of electricity produced?
4. Which angle and exposure of the PV module produced the most electricity?
5. Explain the results of reversing the wires on the PV module posts.



Temperature and UV Beads

Question

Does temperature affect the rate at which UV beads change colors?

Background

UV stands for ultraviolet light, a type of electromagnetic radiation that travels in a wave-like pattern. UV light is found within sunlight but is invisible. You are probably aware of the effects of UV radiation because you wear sunscreen and sunglasses to protect you from it. UV light produces chemical reactions that can cause a substance to glow or fluoresce, or your skin to burn or tan. It also causes the formation of Vitamin D, an essential vitamin for humans and other organisms. A good amount of harmful UV radiation gets blocked by the ozone layer, but the little amounts that get through will lead to these chemical changes. UV beads contain special color-changing pigments that are sensitive to UV light from the sun and other sources.

Hypothesis

In your science notebook, write your hypothesis in an "If…then…because…" format.

Materials

- 4 Foam cups
- UV beads
- 4 Thermometers
- Ice—a few cubes
- Beaker (250 mL or 100 mL)
- Permanent marker
- Timer, clock, or watch with second hand
- Sunny day
- Hot, cold, and room temperature water

✔ Procedure

1. Gather four UV beads of the same color.
2. Use the marker to label each of the cups as follows:
    - Cup 1—room temperature water
    - Cup 2—hot water
    - Cup 3—ice water
    - Cup 4—room temperature water
3. Add 1 UV bead to each cup.
4. Add 100 mL of room temperature water to Cup 1.
5. Add 100 mL of hot water to Cup 2.
6. Add ice and 100 mL water to Cup 3.
7. Add 100 mL of room temperature water to Cup 4. Cup 1 will remain indoors as the control.
8. Take a temperature reading of each of the cups and record it on the data chart.
9. Record the color of the beads.
10. Take Cups 2, 3, and 4 outside into the sunlight for one minute.
11. Record your observations after one minute of UV exposure and be as specific with the color observations as you can.
12. Return to your classroom and wait one minute. Record your observations in the data chart. Compare the beads you took outside to the bead you left in the classroom. Record your observations.
13. Wait two more minutes and compare the beads again. Note the color and record your observations.

Data

Use the table below or re-create it in your science notebook to record your data.

		Cup 1 - Control Room Temp. Water	Cup 2 Hot Water	Cup 3 Ice Water	Cup 4 Room Temp. Water
Beginning	Temperature				
	Color of Beads				
1 minute of UV exposure	Temperature				
	Color of Beads				
1 minute indoor exposure	Temperature				
	Color of Beads				
3 minutes indoor exposure	Temperature				
	Color of Beads				

Conclusions

1. What happened to the beads when exposed to UV light outside?
2. What happened to the beads one minute after returning back inside?
3. Which temperature of water affected the beads the most? How?
4. Did the water temperature affect the rate at which the UV beads lost their color?

Extension

Test multiple colors of beads at the same time. Do the beads change colors at different rates?

Solar Balloon

Question

What will happen when the solar balloon is filled with air and taken outside on a sunny day?

Hypothesis

In your science notebook, write your hypothesis in an "If…then…because…" format. Be sure to support or explain your hypothesis using the concepts you explored in previous activities. Incorporate at least five words from the word bank below in your explanation. Circle the words you chose to use!

Materials

- Solar balloon
- Fishing line or lightweight string
- Sunny day

Word Bank

- absorbs
- air
- converts
- gas
- heat
- light
- radiant energy
- reflection
- transforms
- thermal energy

✔ Procedure

1. Take the solar balloon outside. Tie one end of the balloon and fill it with air. When the balloon is full, tie the open end closed. Tie fishing line or lightweight string to the balloon and let it sit in the sunlight. Observe what happens. Record your observations.

Conclusion

1. Do you support or reject your hypothesis? Explain why using evidence from your observations. Use words from the word bank above to explain what happened to the balloon.

Solar Oven Challenge

Question

How does the design of a solar oven affect the transformation of radiant energy to thermal energy?

Hypothesis

In your science notebook, write your hypothesis in an "If…then…because…" format.

Materials Used in Teacher Sample

- 1 Small pizza box
- Plastic wrap
- Aluminum foil
- 1 Wooden skewer (12"-18")
- Marker
- Scissors
- Ruler
- Masking tape
- 1 Paper plate*
- Black construction paper
- Oven thermometer
- Food to cook
- Various materials provided by your teacher

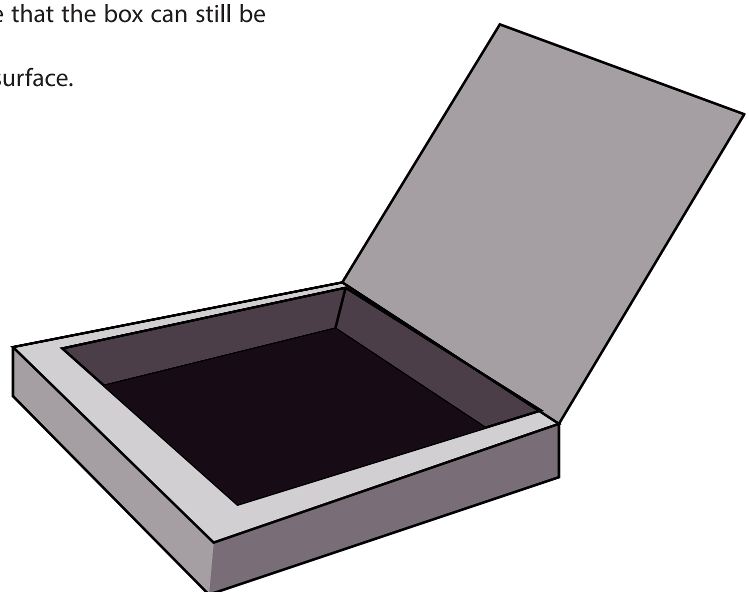
***NOTE*:** Dark-colored paper plates work best, if available.

✔ Procedure

1. Read over the general solar oven directions below and look at the materials provided by your teacher.
2. List all of the possible variables you could change in your solar oven design.
3. In your science notebook, or using the next page, sketch possible designs. Discuss with your group all of your different ideas. Choose one solar oven design to build.
4. Gather the materials you need.
5. Build your solar oven and test its efficiency using the oven thermometer.
6. Make any needed design changes that will enable your solar oven to cook food efficiently.

General Directions to Build a Solar Oven

1. On the top of the pizza box, use your marker to draw a square with edges spaced 1" from all sides of the box.
2. Use scissors to cut along the sides and front edge of the lid, leaving the fourth side along the box's hinge uncut.
3. Tape aluminum foil to the inside surface of the new flap you just cut, shiny side visible. This is to reflect sunlight into the box. Smooth out any wrinkles that might occur.
4. Tape plastic wrap to the original box flap so that it covers the hole you cut into the flap. Seal all four of the edges with tape.
5. Tape black construction paper to the bottom inside of the box. This will help absorb the incoming sunlight.
6. Cover any air leaks around the box edges with tape, making sure that the box can still be opened to place food inside or remove it later.
7. Go outside in the sunlight and place the solar oven on a level flat surface.
8. Place food items on a paper plate and place it inside the oven. Put the oven thermometer inside the oven where you will be able to see it without moving the oven.
9. Tape one end of a wooden skewer to the reflector lid, attach the other end to the box to adjust reflector.
10. Let the food cook and periodically check the reflector angle to make sure sunlight is getting inside the oven.



⁂ Conclusions

1. What factors contributed to the successful cooking of the food?
2. What effect did changing the variable(s) have on converting radiant energy to thermal energy? How could you improve your design?
3. What are the practical applications where solar ovens could be used?

Solar Oven Challenge

A solar oven needs to let radiant energy in, convert that radiant energy to thermal energy, and keep the thermal energy inside to cook the food. Use this page to brainstorm solar oven design possibilities.

Step One: Sketch

Brainstorm possible solar oven designs. Label the materials you will use and explain why.

Step Two: Compare

Share your design with the other members of your group. What is similar? What is different?

Step Three: Final Design

Choose one design that your group will use. Sketch the design here. Label the materials you will use and explain why you think this is the best design.

Designing a Solar House

You have been commissioned by The National Energy Education Development Project to design a home using passive and active solar design principles. You will be expected to present the solar home design to potential buyers (your peers). You will need to explain what the solar features are, how they work, and why they are beneficial to the energy efficiency of your home.

Guidelines

- Sketch at least two designs, and choose one to develop completely.
- Draw the design on graph paper.
- Indicate cardinal directions (north, south, east, west) on your drawing.
- Label all components including windows, doors, type of solar systems, and any other information that will help explain your design.
- Include landscaping plans and label those on your drawing as well.
- Write a paragraph about your house design explaining the choices you made.
- Use the topic organizer on page 22 to develop a short presentation about your design.

Planning

Presentation Topic Organizer

Important Information	Additional Information Needed

Topic

Graphics Needed	Design of Presentation

Glossary

active solar home	using specialized pumps, fans, and/or equipment to move heated air or power a home
concentrating solar power system	technologies that focus the energy from the sun onto one smaller area creating high temperatures that can produce electricity
dish/engine system	a type of solar collector that uses satellite-like dishes and an engine to track and focus the sun's rays to a focus point
Fresnel lens	a lens designed to capture light using concentric circles in sections on its surface
greenhouse effect	the trapping of energy from the sun by the atmosphere, due to the presence of certain gases; the atmosphere acts like a greenhouse
grid	the layout of the system of electrical distribution lines
heat exchanger	any device that transfers heat from one fluid to another, or to the environment
heliostat	a sun-seeking or tracking mirror that changes its direction to follow the sun's rays
hybrid solar system	using a combination of active and passive solar designs to heat and power a home; see active solar home; see passive solar home
kilowatt	a unit of power, usually used for electric power or energy consumption; 1,000 watts
linear concentrating system	a system of mirrors in a line that focus sunlight onto receivers that carry liquid to a heat exchanger
linear Fresnel reflector system	a system using groups of flat mirrors to focus sunlight onto a receiver; lenses capture light at angles to better focus light onto the receiver; see Fresnel lens
megawatt	unit of electric power equal to 1,000 kilowatts or one million watts
nuclear fusion	when the nuclei of atoms are combined or "fused" together; the sun combines the nuclei of hydrogen atoms into helium atoms during fusion
nuclei	more than one nucleus; nuclei are the centers of atoms that hold protons and neutrons
parabolic trough system	a type of solar collector that has a parabolic shaped reflector to focus radiant energy
passive solar home	a means of capturing, storing, and using heat from the sun without using specialized equipment
photovoltaic	from the words photo and volt; means energy from light; see photovoltaic cell
photovoltaic cell	a device, usually made from silicon, which converts some of the energy from light (radiant energy) into electric energy; another name for a solar cell
radiant energy	any form of energy radiating from a source in electromagnetic waves
renewable	fuels that can be easily made or replenished; we can never use up renewable fuels
silicon	an element commonly found on Earth that is frequently used for semiconductors, PV cells, and electric equipment
solar collector	an item, like a car or greenhouse, that absorbs radiant energy from the sun and traps it within
solar power tower	a device that focuses solar energy on a single spot using reflection, producing high temperatures that can create steam to turn turbines
space heating	heating the interior of a building or home
thermal energy	the energy contained within a substance due to the random motion of atoms and molecules of the material
utility-scale	term used to describe an electric generation device that provides megawatts of power for distribution
watt	a unit of power, usually for electric measurments; describes the rate at which work is done or energy is used

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