4-H STEM Toolkit

The Sky's the Limit: **Solar Energy Project Toolkit**

The Sky's the Limit 4-H Science curriculum was created to increase awareness and scientific literacy about solar energy. Activities in this toolkit use engineering design principles to develop an understanding of solar energy. Participants will become familiar with the how and why of using solar energy. The activities focus on the transfer of energy, circuits, capturing solar energy, and engineering design. Lessons scaffold from the basic understanding of circuits and include building design challenges such as building a solar oven, constructing a solar-powered boat, and exploring elements that impact solar cars.

The activities are designed for middle school students (grades 6-8), but may be adapted for other-age learners. These lessons require access to direct sunlight or a high-power spotlight.

If you need assistance with these activities please email us: 4-HScience@maine.edu.

Information about additional 4-H STEM Toolkits is available on the 4-H STEM Toolkits page: extension.umaine.edu/4h/stem-toolkits/

- Activity 1: What is a Circuit?
- Activity 2: Capture the Sun
- Activity 3: Series and Parallel Circuits
- Activity 4: Solar S'mores
- Activity 5: Design and Build a Solar Car
- Activity 6: Engineering Solar Powered Boats

Acknowledgments

This 4-H Science toolkit was created for the University of Maine Cooperative Extension with generous support from RLC Engineering and the Maine 4-H Foundation.

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- **Michelle Snowden**, Web Professional, University of Maine Cooperative Extension
- **Peter Zack**, Founder, Maine Junior Solar Sprint

Special thanks to the staff at the University of Maine Cooperative Extension Bryant Pond 4-H Camp and Learning Center for their contributions of activity and lesson ideas.

Activity 1: What is a Circuit?

Activity 2: Capture the Sun

Activity 3: Series and Parallel Circuits

Activity 4: Solar S'mores

Activity 5: Design and Build a Solar Car

Activity 6: Engineering Solar Powered Boats

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4-H STEM Toolkit

The Sky's the Limit: **Activity 1: What is a Circuit?**

Time: This lesson should take approximately 60 – 75 minutes minutes to complete.

Learning Targets

- Understand how electricity flows through a circuit.
- Demonstrate how to light a bulb with wire and a battery.
- Utilize the circuit to determine if materials conduct electricity or insulate.

Essential Questions

1 How do the parts of an electrical circuit work together?
2 What makes a good circuit design?

Enduring Understandings

1 All electrical circuits must include a power source, a load, and a path for electricity to flow. Electricity only flows through a complete circuit.
2 Conductors and insulators help in designing circuits.

NGSS Standards

- 4-PS3-2, 4-PS3-4
- 5-ESS3-1
- MS-PS3-3

Background for Facilitator

Electricity is a type of energy (EXPLAINTHATSTUFF! website: wexplainthatstuff.com/energy.html) that can build up in one place or flow from one place to another. When electricity gathers in one place it is known as static electricity (does not move); electricity that moves from one place to another is called current electricity. For an electric current to happen, there must be a circuit. A circuit is a closed path or loop around which an electric current flows. Linking electrical components together with pieces of wire cable usually makes a circuit. Thus, in a flashlight, there is a simple circuit with a switch, a lamp, and a battery linked together by a few short pieces of copper (EXPLAINTHATSTUFF! website) wire. When you turn the switch on, electricity flows around the circuit. If there is a break anywhere in the circuit, electricity cannot flow. If one of the wires is broken, for example, the lamp will not light. Reference the EXPLAINTHATSTUFF! website for more background information as needed.

This activity has youth explore what objects may conduct electricity (conductors) and which objects do not conduct electricity (insulators). Metals are generally good conductors of electricity, for example, the washer provided in this activity. Insulators do not conduct electricity, for example, glass marbles, wood, plastic, and most rocks.

Many youth may not have had any formal exposure to electricity or circuits. Be sure to let them know it is ok if they have not had any experience with this before, and if they have, this will hopefully be a new approach for them. Building a circuit with these materials, while seemingly simple, requires everyone to be open to a new challenge and discovery. It may also require some grit to keep trying if the light bulb does not light easily.

Vocabulary List

- **Circuit:** A device that provides a path for electric current to flow.
- **Voltage:** The force or "pressure" pushing the electricity through the circuit; measured in volts.
- **Conductor:** Material that allows the flow of electricity.
- **Insulator:** Material which does not allow the flow of electricity.
- **Power:** The rate of doing work, measured in watts.
- **Resistance:** A material's opposition to the flow of electric current; measured in ohms.

Materials

- 2-AA batteries
- 1.5V bulbs
- Wires
- LED lights
- Tape
- 5 objects (marble, washer, wood, plastic, rock)
- Pencils
- *What is a Circuit Data Sheet* (PDF) (to download and print from: extension.umaine.edu/4h/stem-toolkits/skys-the-limit-solar-energy-project-toolkit/activity-1-what-is-a-circuit/

What is a Circuit? Data Sheet

Insulate or Conduct

Draw the complete circuit:

Variables	Predict I or C	Actual I or C
Acorn		
Paperclip		
Glass Marble		
Bead		
Aluminum Foil		
Paper		

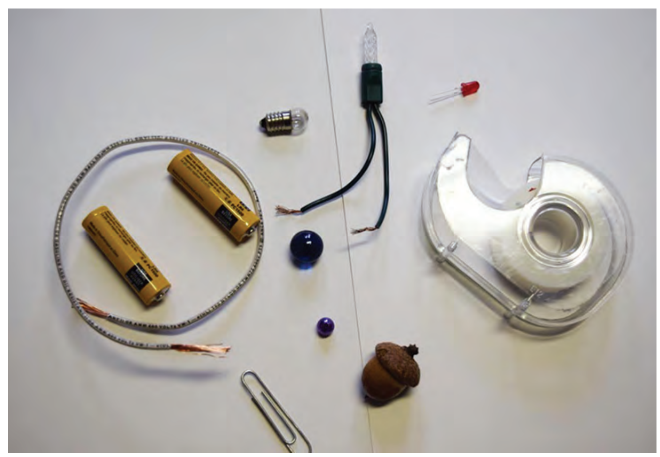

Figure 1.1: What is a Circuit? materials. Goal: Help students visualize how electricity flows through a circuit. (UMaine Extension 4-H Photo: Sarah Sparks)

Methods

Engage

Begin by playing a few rounds of the game Have You Ever? Facilitators should designate one side of the room as "yes" and one side of the room as "no." Tell youth that you will be reading statements out loud and they should go stand on the side of the room that best describes their answer to that question. Read these out loud, one at a time, and allow youth to move appropriately. Where youth stand can help serve as an indication of what their own experience is with renewable energy and energy consumption.

- Have you ever left the room and not turned out the light?
- Have you ever seen a wind turbine?
- Have you ever used energy captured from a wind turbine?
- Have you ever seen a solar panel?
- Have you ever used energy captured from a solar panel?
- Have you ever left the sink on while you brush your teeth?
- Have you ever walked or ridden a bike to avoid driving somewhere?
- Have you ever used data on your cell phone instead of using wi-fi (when it was available)?
- Have you ever used a device powered by a battery (stored energy)?
- Have you ever unplugged something when you were done using it?
- Have you ever recycled something?
- Have you ever used a clothesline (or hung clothes outside to dry)?
- Have you ever used an air conditioner in the summer or heated your home in the winter?

After youth have played Have You Ever, ask them what they know about how energy is directed to things like lights, cell phone chargers, etc? Help them connect what they brought up in Have You Ever to what they might already know.

Explore

1 Begin by letting youth know that today they are going to build a circuit. Provide each team of students with a set of materials. Before starting, make sure they know that the wire is insulated in the middle, but the open ends can get hot and are sharp.

2 Explain that each team should construct a working circuit with 2 wires, the 1.5V bulb, and the battery. Challenge them – how many different ways can you put the circuit together to get the light to shine? Reference additional information and diagram below.

3 Have each participant draw a sketch of the completed circuit in the results table.

4 After they have completed steps 1-3, let groups know their next step is to construct a working circuit using the LED lights, battery and wires (lights will illuminate).

5 As groups work on their working circuits, introduce the concept of polarity testing. Polarity testing the LED bulbs can be a way to reinforce concepts of the circuit. Youth can test the polarity by matching the positive and negative terminals of the bulb to the appropriate positive/negative terminals of the batteries. (**Tip: in typical LEDs, the longer wire terminal is generally positive**).

Safety Consideration: *Do not leave the wires attached to the battery (completed circuit) any longer than to see the light illuminate, as the wire could become warm.*

Explain

1 As a large group, have a sharing discussion about what each group did that successfully completed a circuit.

2 What did they discover that did not work to make a complete circuit? Tip for facilitator: taking time to reflect together can help all groups have some foundational knowledge for the second half of this activity.

3 Discuss how energy flows through a circuit.

4 Now it's time to introduce some key vocabulary for circuitry. Explain that today we learned about circuits, insulators, and conductors. These can be questions

brainstormed as a whole group, or in small groups and then reported out.

- Tell what you know about circuits.
- Tell me what you think an insulator is. What are examples of insulators in the circuits you built?
- Tell me what you think a conductor is. What are examples of conductors in the circuits you built?

Elaborate

1 Now groups will be given five sample objects to test. Each participant should predict which of the test objects they think can conduct electricity and which cannot. Examples of sample objects could include metal coins, washers or tinfoil, wooden items (acorn/toothpick), and rocks or marbles.

2 Now using your completed circuit, test your hypotheses. Place one of the other objects between the battery and the bulb. Write in the data table if the object conducts (bulb lights up) or insulates (bulb does not light up).

3 Look around the classroom and try to find 3 insulators and 3 conductors. Discuss what makes you believe they are insulators and what makes them conductors.

Evaluate

As a group, take time to reflect on the experience you just had. Here are some questions to get you started.

- How did you feel when you were building your circuits?
- What did you think was going to happen when you put the wire, battery and light together the first time? How about when you tried the LED lights and test objects?
- What process or method did you use to design your circuit?
- How did you decide what to do to build your circuit? Who did what?
- Did everyone design their circuit the same way? Did your background knowledge impact how you designed your circuit? What did you already know before this activity that you used in designing your circuit?
- How did you make your circuit light up the bulb?
- Can you think of objects in a house that conduct and those that insulate?
- What would happen if the wires in your house were not insulated?
- Why might it be important for us to know about how energy flows in circuits?
- How might you explain circuits to someone else?

Extension Ideas

- Try a bigger or multiple batteries and see what happens.
- Try adding a longer length of lights and see what happens.
- Test other objects.
- Try a lemon battery.
- Try adding a switch.

Additional Information

Figure 1.2: Here are some of the different orientations of the circuit with the 1.5V bulb.
(UMaine Extension 4-H Graphic, D.O. Neill)

Figure 1.3: Here is how you need to set up the circuit for the LED light (tape the batteries together to keep them from separating)
(UMaine Extension 4-H Graphic, D.O. Neill)

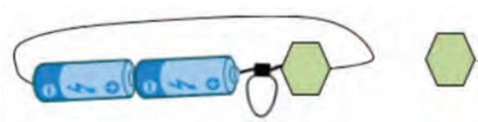

Figure 1.4: Here is how you need to set up the circuit to test conductivity (tape the batteries together to keep them from separating) (UMaine Extension 4-H Graphic, D.O. Neill)

Additional Resources

- Electric Circuits Lesson Plan (PBS Learning Media | MPBN) mainepublic.pbslearningmedia.org/resource/phy03.sci.phys.mfe.lp_electric/electric circuits/#.Ww6xc0gvzIU

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What is a Circuit?
Data Sheet

<u>Insulate or Conduct</u>

Draw the complete circuit:

Variables	**Predict I or C**	**Actual I or C**
Acorn		
Paperclip		
Glass Marble		
Bead		
Aluminum Foil		
Paper		

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The Sky's the Limit: **Activity 2: Capture the Sun**

2

Time: This lesson should take approximately 40 – 50 minutes minutes to complete.

Learning Targets

- Learn about renewable resources versus nonrenewable resources, and how conservation and new technologies are needed to prevent the complete elimination of nonrenewable resources.
- Construct a circuit using the solar panel as the power generator.
- Compare panel power output under different conditions.
- Understand how to use solar panels in the best way to capture solar energy.

Essential Questions

1 What are the best conditions for the panel to produce maximum power?

2 What are the benefits of solar power?

3 What are the limitations of solar power?

Enduring Understandings

1 Electricity can be produced from solar energy using a solar panel.

2 Solar power can be used as a renewable resource; but has limitations.

NGSS Standards

- 4-PS3-2, 4-PS3-4
- 5-ESS3-1
- MS-PS3-3

Background for Facilitator

It takes millions of years for the radiant 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. For example, energy from the sun travels through space, through the earth's atmosphere and weather forces before reaching the earth's surface. Yet this amount of energy is enormous. Every day enough energy from the sun strikes the United States to supply the nation's energy needs for one and a half years. About 15 percent of the radiant energy that reaches the earth is reflected back into space. Another 30 percent is used to evaporate water, which is lifted into the atmosphere and produces rainfall. Plants, the land, and the oceans also absorb radiant energy. Capturing sunlight and putting it to work is difficult because the solar energy that reaches the earth is spread out over a large area. 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 close you are to the earth's equator. More information that may be useful is available in the **Exploring Solar Energy Student Guide (Seven Activities) (PDF)**, U.S. Department of Energy/Energy Efficiency & Renewable Energy website: www1.eere.energy.gov/education/pdfs/solar_exploringsolarenergystudent.pdf

If you are doing this curriculum as a series, youth in Activity 1 learned what a circuit is. It is not necessary to have done Activity 1 in order to do this activity. Either way, be sure to let youth know it is ok if they were not successful in lighting the light bulb or have never had experience with solar energy. This will hopefully be a new approach for them. Building a circuit with these materials, while seemingly simple, requires everyone to be open to a new challenge and discovery. It may also require some grit to keep trying if the fan does not spin easily.

Standard electrical circuits use red wires as positive and black wires as negative. These are used to indicate electrical polarity or the flow of energy in a circuit. Electricity flows from the positive pole to the negative pole. It will be important to explain the colors of the wires (black and red) to youth, so they match them correctly when building circuits.

This activity wraps up with a discussion around the pros and cons of solar energy, as well as how it might be utilized in real-world applications. This is not a complete list but provided as a reference for facilitators in case it is useful when engaging with young people in this discussion.

Table 1: Example Benefits and Challenges of Solar Energy

Benefits of Solar Energy	Challenges of Solar Energy
• It captures energy from the sun and converts it to energy and provides an alternative to fossil fuel-based energy sources. • Solar energy is environmentally friendly because it is a renewable source of energy with limited emissions that are harmful to the atmosphere, like those released by energy conversion with fossil fuels. • Solar energy is less likely to impact the environmental conditions of an area, leaving energy in the area for the surrounding ecosystem (ex. plants can still grow). • Solar energy is readily available. It does not have a significant conversion process to create energy, which is different from other processes used to generate energy, such as photosynthesis.	• Actually producing solar cells has a high energy cost because the materials used to create cells are likely to be produced in a way that is not environmentally friendly. • Sun and solar energy are not always available. Factors that influence this intermittent production include daylight hours, the angle of the sun, weather/clouds, and other influences. • There is some maintenance required of cells to be most efficient. A common example is due to weather interference and clearing snow or dust from the panels to maximize efficiency. • Efficiency of panel designs are evolving. Engineers are currently working on bi-facial cells that would collect solar energy from both sides of panels.

Facilitators and youth may also watch the video Maine 4-H Solar Energy Project with RLC Engineering 5422 (YouTube). youtube.com/watch?v=H23iWucMDeM

Limitations of solar energy are highlighted at minute marker 10:31-12:49 and benefits of solar energy are highlighted from marker 12:49-13:48.

Solar panels are absorbing energy from the sun. Solar panels do not radiate light from them or generate energy on their own, as they require an input of visible light.

Potential uses of solar energy include powering cars, boats, homes, and businesses. Solar energy can also be utilized to power smaller items, such as lights, heat, and the things created in this kit.

Safety tip: *Youth should be told not to look directly at the sun or any area where the rays are concentrated.*

Vocabulary List

- **Non-renewable resource:** A resource that is not able to be replenished in a human lifetime
- **Renewable resource:** A resource that is able to be replenished in a human lifetime
- **Solar energy:** Energy that comes directly from the sun
- **Photovoltaic cell:** A small part of a solar panel that converts energy from sunlight; many photovoltaic cells make up a solar panel.

Materials

- Solar panels
- Wires with alligator clips
- Motor with fan
- Multi-meter
- **Capture the Sun Solar Panels Data Sheet (PDF)** (to download and print) extension.umaine.edu/4h/wp-content/uploads/sites/38/2022/03/Capture-the-Sun-Solar-Panels-Data-Sheet_2022.pdf

Capture the Sun Solar Panels Data Sheet

Variables	Voltage	# of Times Fan Revolves/Speed
No Light		
Indoor Light		
Flashlight		
Direct Sunlight		
Shadowed Sunlight		
Angled Sunlight		

- Pencils
- Flashlight
- Protractor
- Graph paper
- One small bag of "resources" per group (this includes a Ziploc bag containing 45 red kidney beans and five white lima beans for a total of 50 beans per bag.)
- One large bag of "resources" per group (this includes a Ziploc bag containing 90 red kidney beans and ten white lima beans for a total of 100 beans)
- One copy of the worksheets for each group member:
  - Renew-a-Bean Activity: Table 1 for a small bag of beans (PDF)
  - Renew-a-Bean Activity: Table 2 for a large bag of beans (PDF)
- Large paper or plastic cup for holding "used resources"

Goal: To practice producing electricity from a solar panel.

Methods

Engage

The electricity that we use every day comes from two different kinds of resources, **renewable resources**, and **nonrenewable resources**. Renewable resources are resources that can be used again, that regenerate, or that are available in an almost never-ending supply. Nonrenewable resources, on the other hand, are resources that can be used only once and are then used up completely.

Take a moment to brainstorm some examples of renewable and nonrenewable energy resources. How many can the youth come up with?

The point of this part of the activity is to demonstrate the consequences of relying too heavily on nonrenewable energy resources. The red beans represent the nonrenewable resources and the white represents the renewable resources.

1. Have one person in the group pick 5 beans out of the bag without looking.
2. Count how many red beans and how many white beans were removed from the bag and record the information on the datasheet.
3. Once the beans have been counted and the number of each color removed has been recorded, place the red beans in the cup and put any white beans back in the bag. Since the red beans represent nonrenewable resources, after they have been removed from the bag they are considered "used up" and are no longer viable. Since the white beans are renewable, they can go back into the bag to be used again.
4. Continue this pattern until you have drawn from the bag 20 times or until you are left with only white beans in the bag.

Once all the youth have finished the activity, have them put the beans back in the bags and regroup. The previous activity was great to demonstrate the differences between renewable and nonrenewable energy resources at a constant rate, but as we know, the consumption of electricity is ever on the rise. Therefore, this model the youth just worked with is not applicable to the real-life model.

Next, each group of youth will need the next size up, the bags with 100 beans in them.

1. Same as before, have one group member remove five beans from the bag without looking.
2. Record how many of each color of bean was removed from the bag.
3. Once the numbers of each bean have been recorded on the data sheet, put the red kidney beans in the cup and any white beans that were removed back in the bag.
4. Here is where it's different from before: since electrical demand is always on the rise, we will increase the amount of "energy resources" used by two each subsequent turn. For example, instead of picking out five beans on the second turn, the youth will now pick out seven.
5. Repeat steps two to three.
6. Youth will then remove nine beans from the bag.
7. Repeat this pattern until either all of the nonrenewable resources have been used up or until the group has removed beans from the bags 30 times.

Questions to Discuss

1. How many turns did it take for your group to deplete the nonrenewable resources when consumption remained constant?
2. Did you notice a pattern as you took more turns? Around what turn did you start to see an increase in the number of white beans you removed from the bag each turn? Did the same thing happen when you increased the number of beans you drew each turn? Around what turn did you see the increase in part two?

3 What does this activity show about our consumption of nonrenewable energy resources?

Can we continue to consume high levels of nonrenewable energy resources like we have been for many years to come?

– Courtesy U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy.

Explore

Be sure to be in the sunlight (or a high-power spotlight) when testing.

Today youth are going to explore ways to harness the energy of the sun. Divide youth into cooperative learning groups.

1 Provide groups with a solar panel, a set of alligator clips, motor, and a plastic fan. If you have other materials, such as LED lights or buzzers, consider offering those as well. Introduce all the materials to youth so they know what they are called.

2 Tell groups their challenge is to make the fan spin (or light up or make sound). Allow youth time to explore different ways to assemble the materials to complete the task.

3 Once they are successful, encourage youth to explore the following conditions: darkness, indoor light, direct sunlight, shadowed light, and angled light.

4 What happens to the direction of the fan's rotation when they reverse the connections of the wires to the panel?

5 What predictions do youth have about if they were to connect the fan to a battery? What do they think would happen?

Explain

Ask each group to share what they observed. Here are some questions that could be used as discussion prompts:

- What designs did they discover that worked?
- What designs did not work?
- What evidence supports designs that worked or did not work?

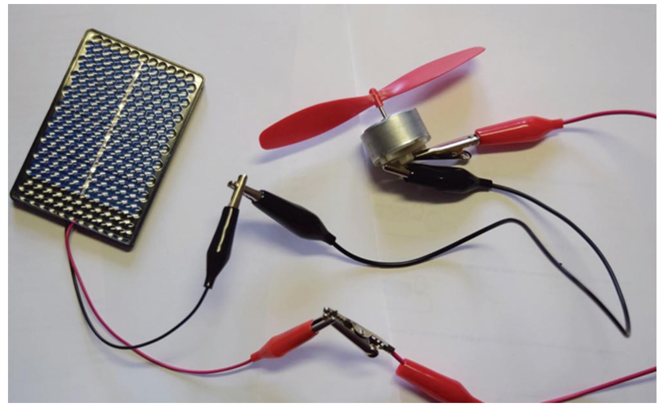

Figure 2.1: Sample set up of solar panel with motor and fan. (UMaine Extension 4-H Photo, Sarah Sparks)

- Were there other factors that influenced whether the fan moved?
- Facilitators may want to have each group introduce their design.
- What patterns emerge?
- Did everyone use a common design to make their fan spin or are there different methods that worked?
- Are there places that consistently capture more energy than others? For example, did the fan spin faster in the darkness or outside? Why do they think that happened?

The more direct the sunlight is to the panel the more energy is produced. Solar panels work best if they can track the movement of the sunlight throughout the day. This is correlated between the solar radiance (energy per square foot) and the angle of the sun relative to the angle of the solar cell. Demonstrate this using a flashlight, graph paper, and a protractor. The paper represents the earth's surface, the edge of the paper represents the horizon and the flashlight represents the sun. Mimic the sun rising and setting and see how many squares are covered in light at different points during the day.

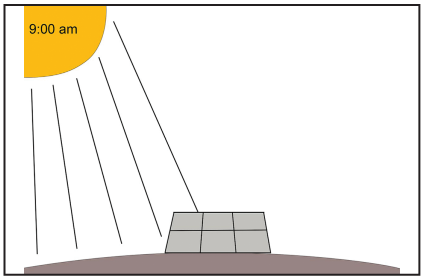

Figure 2.2: The sun at 9:00 a.m.

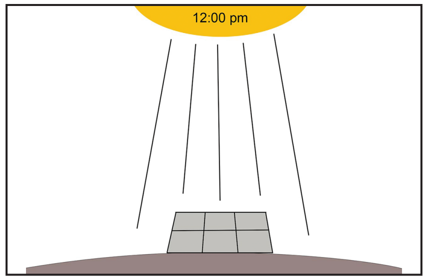

Figure 2.3: The sun at 12:00 p.m.

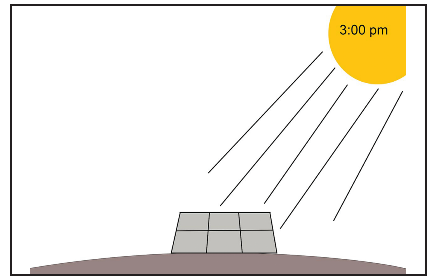

Figure 2.4: The sun at 3:00 p.m.

(UMaine Extension 4-H Graphics, Jessy Brainerd)

Elaborate

As a group, discuss how you might be able to know what design or factors work best (generate the most energy). Explain that next you are going to use a scientific tool, a multi-meter, to measure the energy generated in voltage.

1. Provide groups with a multimeter, solar panel and a set of alligator clips. Groups will need to follow directions carefully to get started, but will have time to explore after the first few steps.
2. Turn the dial of the multi-meter until it points to 20V.
3. Touch the red probe to the positive (+) end of the battery and the black probe to the negative (-) end of the battery. Record the voltage reading (see image below).
4. Repeat with the black probe on the positive and the red on the negative. Record the voltage reading.
5. Connect the solar panel to the multimeter using the alligator clips (see image below).
6. Measure the solar panel's voltage under the following conditions: darkness, indoor light, direct sunlight, shadowed light, and angled light.
7. Shut off the multimeter when finished.

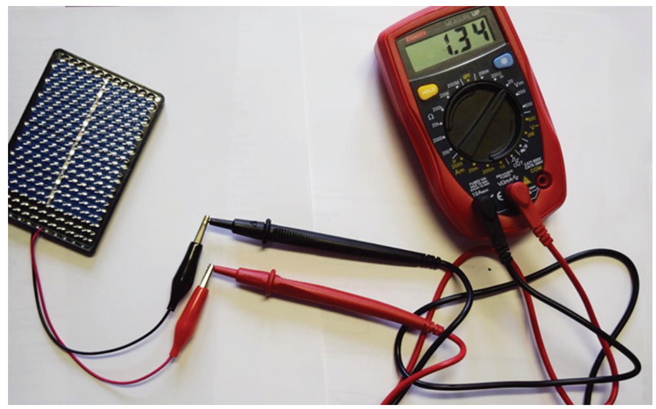

Figure 2.5: Sample set up of solar panel with multi-meter. (UMaine Extension 4-H Photo, Sarah Sparks)

Evaluate

As a group, take time to reflect on the experience you just had. Here are some questions to get you started.

1. How did you feel when you were testing the solar panels?
2. What did you think was going to happen when the solar panel was in direct sunlight? Indoor light? Darkness? What did you think was going to happen
3. When you attached the motor/fan to the solar panel?
4. What did you observe happening when you attached the motor/fan?
5. What challenges did you run into?
6. How did you troubleshoot problems when your design did not work like you thought?

7 How could you take what you discovered today and apply it to using larger solar panels?

8 What are some of the benefits of solar energy?

9 What are some of the concerns with solar energy?

10 What are the potential uses for solar energy?

Extension Ideas

1 Try a bigger motor and see what happens.

2 Try moving the solar panel higher and lower in the sky.

3 Try different angles of the solar panel, different times of day, or different compass bearings.

Additional information: You could do this experiment without the motor and examine bulb brightness by using LED lights or 1.5V bulbs in holders.

Additional Resources

- **Exploring Solar Energy Student Guide (Seven Activities) (PDF)**, U.S. Department of Energy/Energy Efficiency & Renewable Energy website
- **Renewable Solar: Solar Basics, Energy from the sun, Energy KIDS** | U.S. Energy Information Administration: www.eia.gov/kids/energy-sources/solar/

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Capture the Sun
Solar Panels Data Sheet

Variables	Voltage	# of Times Fan Revolves/Speed
No Light		
Indoor Light		
Flashlight		
Direct Sunlight		
Shadowed Sunlight		
Angled Sunlight		

Renew-a-Bean Activity: Table 1 (for small bag of beans)

Turn	Red Beans	White Beans
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Renew-A-Bean Activity: Table 2 (For large bag of beans)

Turn	Number of beans removed	Red Beans	White beans
1	5		
2	7		
3	9		
4	11		
5	13		
6	15		
7	17		
8	19		
9	21		
10	23		
11	25		
12	27		
13	29		
14	31		
15	33		
16	35		
17	37		
18	39		
19	41		
20	43		
21	45		
22	47		
23	49		
24	51		
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26	55		
27	57		
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30			

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4-H STEM Toolkit

The Sky's the Limit: **Activity 3: Series and Parallel Circuits**

3

Time: This lesson should take approximately 40 – 50 minutes minutes to complete.

Learning Targets

- Construct a circuit using multiple solar panels as the power generators.
- Compare solar panel power output under different conditions.
- Understand how to use solar panels in the best way to capture solar energy.
- Recognize the potential for larger power – voltage and current – output that comes from the large solar panel arrays for scale power production.

Essential Questions

1 What is the difference between renewable and nonrenewable resources?

2 What happens to power output when you add more panels?

3 What happens to power output when the circuit is wired in series?

4 What happens to power output when the circuit is wired in parallel?

5 How much energy can we capture from the sun? What does this depend on? What solar panel system designs capture the most power?

Enduring Understandings

1 Understand how groups of solar panels can be used to create larger amounts of energy.

2 Materials found in nature that are used by living things to meet their needs are called natural resources. Resources that can be replaced quickly are called renewable resources. Resources that take thousands or millions of years to be replaced are called non-renewable resources. We use both types of resources to generate power for our everyday needs. Humans require a lot of energy to get through the day and depend largely on utility companies to provide that energy. We have the technology to capture a lot of energy from renewable resources which would have positive impacts on the environment.

NGSS Standards

- 4-PS3-2, 4-PS3-4
- 5-ESS3-1
- MS-PS3-3

Background for Facilitator

This activity introduces the concepts of different types of circuits, series circuits, and parallel circuits. Facilitators might want to reference diagrams in the Elaborate section. A series circuit must have all items functioning for it to work. An example of this is a string of lights. If one light in the circuit does not work, then none of the lights will work. Another common example is a power strip with multiple plug-ins. Everything in the power strip is connected in a series circuit, with no way to make one outlet plug in work and others not work. A series circuit aims to have the same amount of current flow through all the components placed inline. It is called a 'series' because of the fact that the components are in the same single path of the current flow. For instance, when components such as resistors are put in a series circuit connection, the same current flows through these resistors, but each will have different voltages, assuming that the amount of resistance is dissimilar. The voltage of the whole circuit will be the sum of the voltages in every component or resistor.

A parallel circuit may have similar components, but each item has its own circuit. An example of this is a light fixture that has multiple light bulbs. One light bulb can go out, but the other lights will still work. Another example is electrical outlets in common house wiring. Each outlet can power a unique item that can be turned on/off independently of another item in the outlet. When in parallel, the components are wired in separate loops. This circuit splits the current flow, and the current flowing through each component will ultimately combine to form the current flowing in the source. The voltages across the ends of the components are the same; the polarities are also identical.

Parallel circuits are more complex than the simple circuits built earlier in this curriculum. As with any engineering problem, as more pieces of the puzzle are added, it is important to remind youth that this is a new challenge and is expected to be more complicated. As a group, we will need to work together as it is to be expected that the first design may not be successful. Maybe even the second or third – keep trying! If youth (or facilitators) get frustrated, reference some of the additional resources and videos at the end of this lesson. Refer to other members of the group, what have they tried that did or did not work.

Let's draw out the same example given in the series circuit, and assume that the resistors are connected in parallel. The other term for 'parallel' circuits is 'multiple', because of the multiple connections. Additional resources that may be helpful are available on the Difference Between Series and Parallel Circuits page (DifferentBetween.net website).

The strength of sunlight, or light source, can impact the success of this activity. If not enough voltage is generated from one solar panel, consider adding a second panel to the circuit to harvest more energy and successfully light up the light bulb. It is important to be sure the positive and negative wires are correctly matched or the circuit will not flow. It is also important to pay careful attention to the circuits when assembled – it could be easy to damage products not connected correctly.

Safety Consideration: *Youth should be told not to look directly at the sun or any area where the rays are concentrated. If youth are collecting their own materials (panels, light bulbs, fans, etc.), be sure to consider safety by not overloading systems or using materials that could put youth at risk.*

Vocabulary List

- **Solar energy:** Energy that comes directly from the sun
- **Photovoltaic cell:** A small part of a solar panel that creates energy from sunlight; many photovoltaic cells make up a solar panel.

- **Series Circuit:** A closed circuit in which the current follows one path.
- **Parallel Circuit:** A closed circuit where the current is divided into two or more paths.
- **Polarity:** the direction of electric or magnetic field.
- **Resistance:** A material's opposition to the flow of electric current; measured in ohms.
- **Voltage:** The force or "pressure" pushing the electricity through the circuit; measured in volts.

Materials

- Solar panels
- Wires with alligator clips
- LED lights (colored lights are easier to see in bright sunlight)
- Series/Parallel Circuits Data Sheet (PDF) (to download and print)
- DC motor
- Small Plastic Fan
- Pencils

Goal: Help students visualize how to wire a circuit to maximum power output.

Variables	Voltage	Brightness
1 Solar Panel		
2 Solar Panels		
1 Bulb		
2 Bulb in Series		
Remove 1 Bulb from the Circuit		
2 Bulbs in Parallel		
Remove 1 Bulb from the Circuit		

Methods

Engage

Begin by accessing the youth's prior knowledge and discussing these key concepts:

1 What does renewable mean? (something that can be replenished in a human lifetime)

2 What kinds of energy are renewable? (solar, wind, geothermal, water)

3 How can we use renewable energy sources? (power for houses, cars, run machines)

4 What are some of the limitations to renewable energy? (winter sunlight reduction, money for solar panels or wind turbines, unreliable, expensive, etc.)

5 Why does everyone not have a solar panel or wind turbine to power their home?

Explore

Be sure to be in the sunlight (or a high-power spotlight) when testing.

1 Let youth know that today we are going to explore different types of circuits that are built with renewable energy. The purpose of this is to help them understand how solar energy is collected and becomes usable energy for things we use in our everyday lives, such as fans.

2 Youth should have access to materials, including a Series/Parallel Circuits Data Sheet (PDF) (to download and print or view the "Series/Parallel Circuit Data Sheet" table, above, under "Materials").

3 Have youth attach the DC motor to the plastic fan. Then they should connect one solar panel to the wires from the motor. Ask what they see happening as they are doing this. How could you increase the speed of the fan with the materials available?

4 Allow youth to work together and test out their ideas. Have them make predictions about what changes they will see when they

connect the fan to test. How will they know Now that youth have tested out working with the solar panels and fans, have them connect one solar panel to the multimeter. Measure the voltage generated in the direct sun. What happens when they move into the shade? Remind them to make sure to write it down on their data sheet. Have groups predict how much it will go up if they add another group's solar panel to their circuit.

5 Have youth test out adding solar panels to their initial circuit. This should turn into groups working together, as they will need to work together to have access to materials. Remind them to write down the voltage on their data sheets.

Explain

Ask groups to discuss these questions. Encourage them to use the data they collected when making a claim to answer these questions.

1 What happened to the energy captured with one solar panel? Use evidence to support your claim.
2 How about when you added a second solar panel? Use evidence to support your claim?
3 Why might this happen?
4 How does changing how the solar panels are connected impact the amount of energy captured?

By linking the solar panels together this way, you created different types of circuits. Explain series circuits and parallel circuits using models created by the youth. Wiring in parallel produces the most power, because of reduced resistance.

Elaborate

Now let's try a new way to use the energy. Instead of measuring the voltage/energy collected, we will test the energy capture with solar panels using light bulbs.

1 Remove the multi-meter and add a light. Test the brightness. Tip: when using the smaller LED bulbs, typically the longer wire is the positive (red) and the shorter wire is the negative (black).
2 Predict what will happen to the brightness of the light if you add another bulb directly to the first one (series).
3 Try it out. How many bulbs can you light with a series circuit using one panel? How about two panels?
4 Using the series circuit diagram, connect two bulbs to the circuit and describe the brightness.
5 Predict what will happen to the brightness of the light if you add another bulb directly to the panel (parallel).
6 Using the parallel circuit diagram, connect two bulbs to the circuit and describe the brightness. How many bulbs can you light with a parallel circuit using one panel? How about two panels?

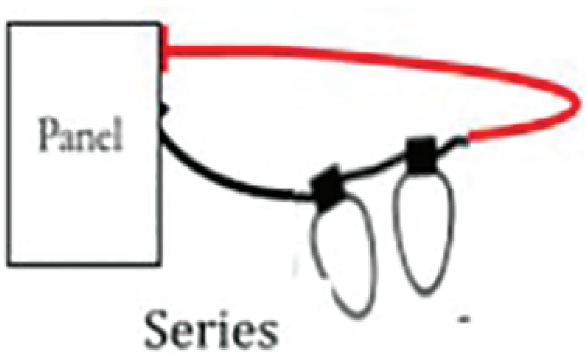

Figure 3.1: Series Circuit (Graphic, D.O. Neill)

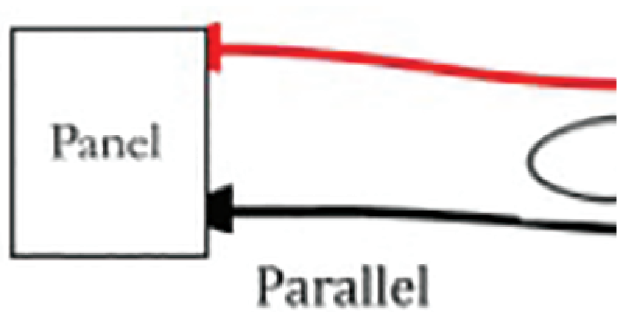

Figure 3.2: Parallel Circuit (Graphic, D.O. Neill)

Series Circuits:

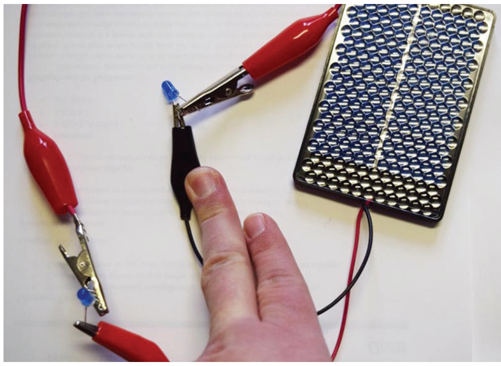

Figure 3.3: Series Circuit (UMaine Extension 4-H Photo, Sarah Sparks)

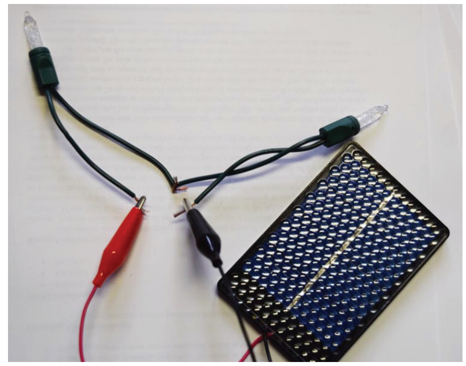

Figure 3.4: Series Circuit (UMaine Extension 4-H Photo, Sarah Sparks)

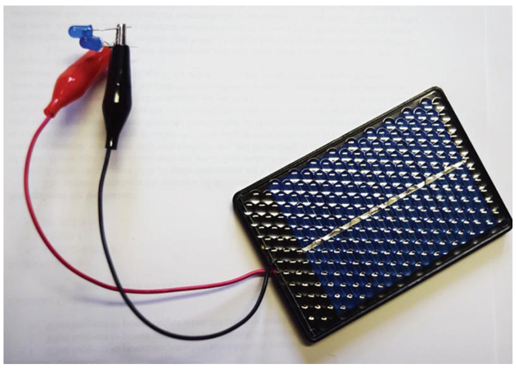

Figure 3.5: Parallel Circuit (UMaine Extension 4-H Photo, Sarah Sparks)

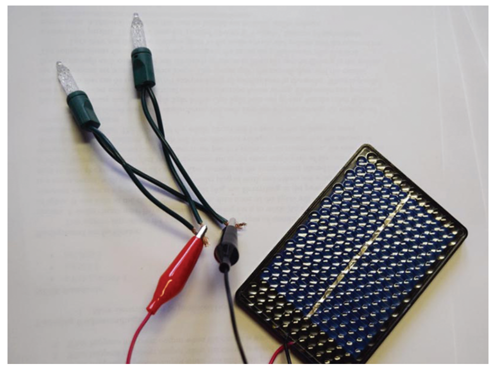

Figure 3.6: Parallel Circuit (UMaine Extension 4-H Photo, Sarah Sparks)

Evaluate

As a group, take time to reflect on the discoveries just made. Here are some questions to get you started:

1 How did you feel when you were adding solar panels and light bulbs?

2 What did you think was going to happen when you added a second solar panel? How about a second light bulb?

3 How did you decide how to add a second solar panel or second light bulb?

4 What did you observe?

Encourage youth to use observations and data collected with the Series/Parallel Circuits Data Sheet to support their claims by answering these questions:

1 What happens when one of the light bulbs is removed from the series circuit?

2 What happens when one of the light bulbs is removed from the parallel circuit?

3 What effect did series circuits have on the light bulbs?

4 What effect did parallel circuits have on the light bulbs?

5 How might you use different types of circuits in the real world? Can you think of an example where you use these every day?

6 In which setup did you get the most power output? Use evidence to support your claim.

7 How do you think engineers decide whether to use series or parallel circuits in large solar arrays? Why do you think they design them that way?

8 How could what you learned to be valuable in the future? How might this apply to the world around us?

Extension Ideas

Try with 1.5V bulbs in holders or buzzers and measure speed or sound intensity.

How many solar panels would you need to meet your household energy needs? How could you figure this out?

Additional Resources

- **Electric Circuits – Lesson 4 – Circuit Connections, Two Types of Connections** (the Physics Classroom website) physicsclassroom.com/class/circuits/Lesson-4/Two-Types-of-Connections
- Video: **Series and Parallel Circuits** (PBS Learning Media | Maine Public website) mainepublic.pbslearningmedia.org/resource/rr10.sci.phys.energy.sources.seriespar/series-and-parallel-circuits/#.Ww_zc0gvzIU
- **Renewable Solar, Solar Basics** (energy KIDS | U.S. Energy Information Administration website) eia.gov/kids/energy-sources/solar/

MAINE 4-H FOUNDATION

RLC ENGINEERING

This 4-H Science toolkit was created for the University of Maine Cooperative Extension with generous support from RLC Engineering and the Maine 4-H Foundation.

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Series/Parallel Circuit Data Sheet

Variables	Voltage	Brightness
1 Solar Panel		X
2 Solar Panels		X
1 Bulb		
2 Bulbs in Series		
Remove 1 Bulb from the Circuit		
2 Bulbs in Parallel		
Remove 1 Bulb from the Circuit		

THE UNIVERSITY OF MAINE Cooperative Extension

4-H STEM Toolkit

The Sky's the Limit: **Activity 4: Solar S'mores**

4

Time: This lesson should take approximately 60 – 80 minutes minutes to complete.

Learning Targets

- Understand how solar ovens capture the sun's heat.
- Design and construct a working solar oven.
- Use the engineering design process to determine the best design and potential modifications.

Essential Questions

- How can you capture the sun's heat?
- How do properties of different materials impact heat capture?

Enduring Understandings

- Solar energy is not just light/electrical, but also heat/radiant.
- Some materials capture heat better than others.

NGSS Standards

- 3-5-ETS1-1, 1-2, 1-3
- 4-PS3-2, 4-PS3-3
- MS-PS3-3, ETS 1-2, 1-2, 1-3, 1-4

Background for Facilitator

In this activity, participants will build their own solar ovens and use them to cook s'mores. Using the engagement and appeal of food, in particular s'mores, youth will become engineers to build and test their designs. It will be important to check with your group to make sure there are no food allergies before proceeding. This activity uses everyday materials, such as cardboard, aluminum foil, and the sun. Constructing the ovens themselves will require youth to be open to the challenge, positive emotionality, and teamwork in order to be successful. As the facilitator, be sure to tell youth this upfront. Let them know that while they will be working in small groups, everyone is a team and it's ok to ask for help. For example, if you get frustrated using the packing tape, ask someone else to take a turn or lend an extra hand.

Several scientific phenomena are involved in making your oven the best heater it can be. **Heat** is the form of energy (sometimes called **thermal** energy) that is transferred by a difference in temperature. You want to transfer the sun's heat to your solar oven. **Reflection** is the throwing back of light, heat, or sound by a body or surface, like a mirror. The shiny foil you'll use in your oven will reflect the sun's light and heat inside your oven. During **absorption**, energy is taken into material rather than reflected. You will line the inside of your oven with black paper so it can absorb the light and heat being reflected into it. Another energy process you should be familiar with for this project is convection, which is the transfer of heat by the movement of a gas or liquid. You'll use plastic wrap to make your oven airtight so the air warmed by the sun doesn't leave your oven through convection. One final energy term important to this project is insulation. Insulating materials prevent heat from leaving your oven through radiation. That's why you are going to line the inside of your oven with a cheap and effective insulator — newspaper!

Science Project: How to Make a Solar Oven (Education.com website) education.com/science-fair/article/design-solar-cooker/

Safety Consideration: *Youth should be told not to look directly at the sun or any area where the rays are concentrated.*

Vocabulary List

- **Thermal Energy:** heat energy
- **Radiant Energy:** light energy
- **Reflection**: bouncing energy back without absorbing it
- **Absorption:** take in heat energy
- **Convection:** move heat through the air
- **Engineering Design:** a series of steps to create a product, including ask, imagine, plan, create, improve

Materials

- Cardboard
- Aluminum foil
- Plastic food wrap
- Packing tape
- Glue
- Scissors
- Newspaper
- Black paper or markers
- Ruler
- Paper
- Pencils
- S'Mores fixings

Goal: Help students visualize how solar energy can be captured and transferred.

Methods

Engage

Begin by accessing the youth's prior knowledge:

- Have you ever gotten into a car after it sat in a sunny spot? What did you notice about the interior of the car? Why do you think this happened?
- What does the Sun provide for the Earth system?
- How can we capture the Sun's energy?
- What is a solar oven and how does it work?
- What are two objects that reflect light? (ex. mirror, aluminum foil, white walls or paper)
- What are two colors that absorb heat well? (ex. dark colors such as black and purple)

Explore

1 Explain that today they will be constructing an oven that is heated using energy from the sun. Let participants know what materials will be made available to them in building their oven, but do not give them the materials yet. Explain that their oven can be any shape, but must have a door that can open and a "window" space on the top.

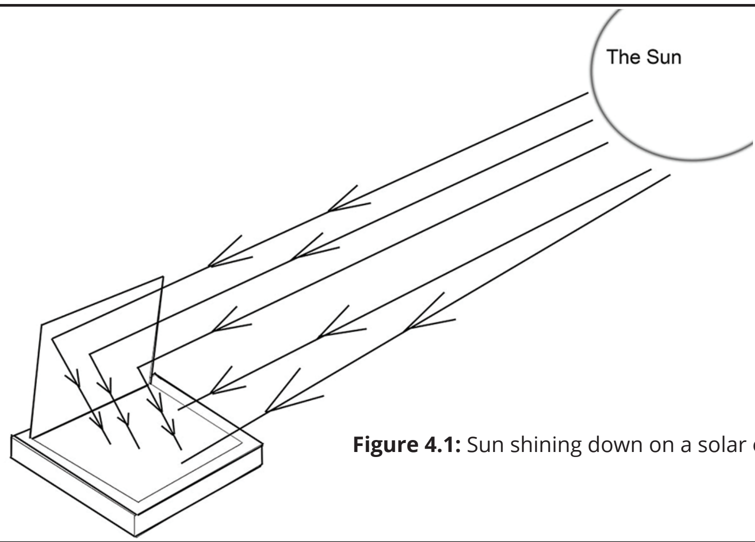

Figure 4.1: Sun shining down on a solar oven (UMaine Extension 4-H Graphic, Jessy Brainerd)

2 First, they will be asked to discuss and sketch their design in small groups. Before breaking into groups, ask if anyone has ideas about how this might work? Has anyone seen a solar oven before? If yes, have them explain what they remember. The facilitator may want to show youth image 4.1 or replicate it on a whiteboard to help the imagination process get started. Explain that this image is one example of how the sun's energy might reach inside their oven, but there have been many other successful designs.

3 Divide youth into cooperative learning groups. Groups should begin by discussing how they might use the materials. Give participants access to paper and pencils to sketch their ideas. Remind them that everyone in their group needs to have a voice in how the oven is designed. Challenge them to include at least one idea from each person.

4 Explain they can be as creative as they want, but they need to be able to explain how the sun's energy will be captured into the oven. Have them draw a creative, one-of-a-kind solar oven.

Explain

Have groups present their design to either the facilitator or the whole group if time allows. Have groups explain why they chose certain materials and what they anticipate the function of those materials to be.

As a group, discuss the purpose of the foil, window, and reflector. Why might these features be important? Review some of the key concepts in the elaborate phase as well, such as rolled-up newspapers as an insulator. After sharing oven designs and some of the important pieces of the oven design, give groups a few minutes to discuss what they might want to change or modify from their original design. The facilitator should be ready to prompt discussion or ideas that promote some key factors that generally lead to success. These include:

- Covering the entire inside of the oven with aluminum foil
- Adding insulation to the sides of the box (rolling up newspaper into tubes works well)
- Having a covered window at the top of the oven (2 layers of packing tape or plastic wrap works)
- Create a sun reflector to direct the sun into the oven's window (example: using cardboard, glue, and foil)
- Consider the outside of the oven. Dark colors absorb the sun's energy, so covering it with black construction paper is one approach.

Example images of assembled ovens:

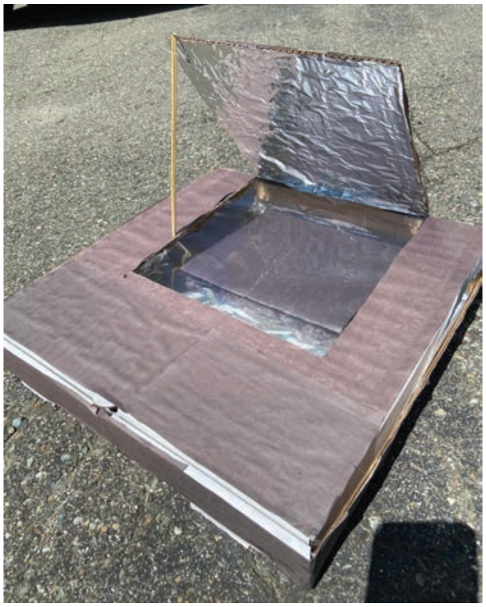

Figure 4.2: A sample of a solar oven set-up
(UMaine Extension 4-H Photo, Jessy Brainerd)

Figure 4.3: Solar Oven Examples
(UMaine Extension 4-H Photo, Sarah Sparks)

Facilitator Tip: *While s'mores are baking, this might be a good time to move into discussion for the evaluate section.*

Elaborate

Allow groups to select their materials and build their ovens. Remind them to work together as the materials can be difficult to manipulate. When groups have their ovens constructed, it's time to test them out! Follow these steps to get your s'mores recipe baking.

1 Preheat the solar oven by placing it in a sunny spot for up to 10 minutes.
2 Place a square of graham cracker in the oven and top with a marshmallow.
3 Close the oven door and place the reflector on the top.
4 Heat until the marshmallow is squishy.
5 Gently place a piece of chocolate and another square of graham cracker on top.
6 Heat it up for a few minutes more, just to melt the chocolate a bit.

Evaluate

Based on their experience and observations, engage is a group discussion. Here are some suggested topics to get started.

- How did you feel when you were drawing and designing your oven?
- How did you actually build your oven?
- How did you decide who would do what?
- How did you actually build your solar oven?
- What challenges did you encounter?
- What are the key components of the most effective design of a solar oven? Why are those designs effective?
- How do you know if your solar oven is working? What evidence do you have to support that claim?
- Discuss the importance of the engineering design process.
- How else might you use a solar oven?

Facilitators may want to have youth sketch their solar oven design to label or aid in the discussion of how the energy was captured.

Extension Ideas

- Use a full-sized solar oven and prepare something more complicated.
- Use a thermometer and measure how hot different colored objects get in the sun.
- Use a thermometer to measure how the temperature differs for a solid, liquid, and gas.
- Use a thermometer in each oven to determine the design that gets the hottest.
- Try each oven to see if they can melt a solid piece of candy.

Additional information: This experiment should be done in pairs or small groups, in order to maximize 21st Century skill building-communication, teamwork, and problem-solving skills.

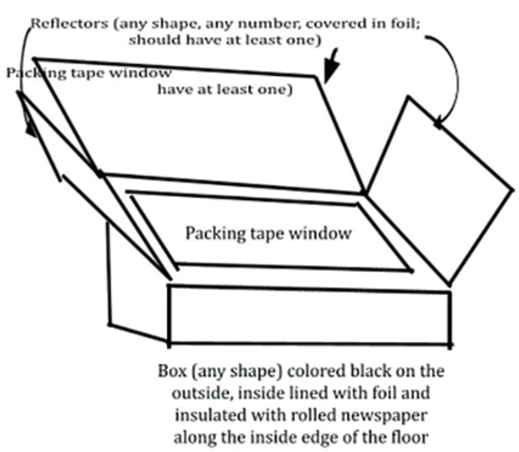

Figure 4.3: Box (any shape) colored black on the outside, inside lined with foil and insulated with rolled newspaper along the inside edge of the floor. Indicators point to Reflectors (any shape, any number, covered in foil, should have at least one); Packing tape window (have at least one); and the packing tape window is indicated. (Graphic, D.O. Neill)

Additional Resources

- **Science Project: How to Make a Solar Oven** (Education.com website) education.com/science-fair/article/design-solar-cooker/
- **Make S'Mores With a Solar Oven!** (NASA Climate Kids website) climatekids.nasa.gov/smores/
- **NASA STEM Engagement, Engineering Design Process** (NASA website) nasa.gov/audience/foreducators/best/edp.html

This 4-H Science toolkit was created for the University of Maine Cooperative Extension with generous support from RLC Engineering and the Maine 4-H Foundation.

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4-H STEM Toolkit

The Sky's the Limit: **Activity 5: Design and Build a Solar Car**

5

Time: This lesson should take approximately 90 – 120 minutes minutes to complete.

Learning Targets

- Understand how solar panels convert electrical energy from the sun to mechanical energy in a motor.
- Design and construct a working solar car.
- Use your experiences to create the fastest car.

Essential Questions

1 What elements can impact the speed of a solar car?

Enduring Understandings

- How solar panels capture light/electrical energy from the sun.
- Some car designs are faster than others.
- The engineering design process is an effective way to find a solution to a problem.

NGSS Standards

- 3-5-ETS1-1, 1-2, 1-3
- 4-PS3-2, 4-PS3-3
- MS-PS3-3, ETS 1-2, 1-2, 1-3, 1-4

Background for Facilitator

This activity has youth construct a solar-powered car. These cars use solar photovoltaic systems to power them. Solar photovoltaic systems convert sunlight into electricity. Solar photovoltaic (PV) devices, or solar cells, change sunlight directly into electricity. Small PV cells can power calculators, watches, and other small electronic devices. Arrangements of many solar cells in PV panels and arrangements of multiple PV panels in PV arrays can produce electricity for an entire house. Some PV power plants have large arrays that cover many acres to produce electricity for thousands of homes.

- The two main benefits of using solar energy are: Energy systems do not produce air pollutants or carbon dioxide. Solar energy systems on buildings have minimal effects on the environment.
- The main limitations of solar energy: The amount of sunlight that arrives at the earth's surface is not constant. The amount of sunlight varies depending on location, time of day, the season of the year, and weather conditions.
- The amount of sunlight reaching a square foot of the earth's surface is relatively small, so a large surface area is necessary to absorb or collect a useful amount of energy.

While templates are provided for the cars to start, youth should have the opportunity to engage in the engineering design process and modify their design if they choose.

View either video:

- **Video: Maine 4-H Solar Energy Project with RLC Engineering 5422** (YouTube) youtu.be/H23iWucMDeM
- **The Engineering Design Process: A Taco Party** (YouTube) youtu.be/MAhpfFt_mWM

As the facilitator, it will be especially important to ask purposeful questions about their designs, such as why they chose a certain modification and what the function of that modification might be. Encourage youth to explain why they are making design choices. If a design does not work how they expect, what might they change? This will encourage independence and discovery.

Safety Consideration: *Youth should be told not to look directly at the sun or any area where the rays are concentrated.*

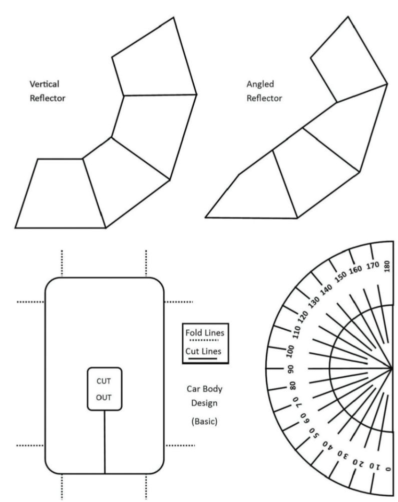
Vocabulary List

- **Thermal Energy:** heat energy
- **Radiant Energy:** light energy
- **Reflection:** bouncing energy back without absorbing it
- **Absorption:** take in heat energy
- **Solar panel:** collect sunlight and change radiant energy into electricity
- **Engineering Design:** a series of steps to create a product, including ask, imagine, plan, create, improve
- **Chassis:** The frame that holds the body and motor of an automobile together.
- **Axle:** The supporting shaft on which the wheels revolve.
- **Transmission:** The part of the car that transfers the power from the motor to the wheels.
- **Aerodynamics:** design of car to allow air to flow smoothly and quickly around it to decrease drag and increase speed

Materials

- Mini Solar Cars
- **Solar Car Design Template (PDF)** (to download and print)
- Copies of Car Design (best on cardstock)
- Scissors
- Meter stick
- Stopwatch
- Colored Filters
- Protractor
- Double Stick Tape
- Reflector Outlines
- Aluminum Foil
- Flashlight
- **Solar Cars Data Sheet Template, Part A (PDF)** (to download and print), view sample below.

Goal: Have students go through the engineering design process to create a solar car that utilizes alternative energy.



Solar Car Design Template is included in the PDF link under the "Materials" list.

Solar Cars Data Sheet Template: Part A: Calculating Speed

Speed = distance/time	Speed = 1 meter/ X seconds
Trial 1: My car took _______ seconds to travel 1 meter. The speed my car traveled at for trial 1 is:	1 meter/ ______ seconds = ______ speed
Trial 2: My car took _______ seconds to travel 1 meter. The speed my car traveled at for trial 2 is:	1 meter/ ______ seconds = ______ speed
Trial 3: My car took _______ seconds to travel 1 meter. The speed my car traveled at for trial 3 is:	1 meter/ ______ seconds = ______ speed

Figure 5.1: Solar Car Materials
(UMaine Extension 4-H Photo, Sarah Sparks)

Methods

Engage

Tell the youth that today they are going to become engineers and build a car powered by the sun.

Begin by brainstorming with young people what they already know about solar power and the engineering design process.

Explore

- Ask youth to explain what they already know about solar energy.
- Facilitator note: focus on how sunlight is captured and transferred into usable energy.
- Reflect on some of the activities youth have already done related to solar energy. How can the heat of the sun be captured?
- How can engineers capture energy from the sun and what might impact the amount of energy they capture?
- How can solar energy be used? Can youth think of examples you have seen locally?
- What limits exist for solar energy?
- What do youth know about engineers and what they do?
- What role do youth think engineers play in relation to solar energy?
- Why would it be a good idea to build a solar car?

Explain to participants that today you are going to look at different factors that affect a solar-powered car. In order to do that, everyone will become an engineer for the day. Watch this video as a group, as a way to introduce the engineering design process:

Video: The Engineering Design Process: A Taco Party, KQED QUEST (YouTube): youtube.com/watch?v=MAhpfFt_mWM

Explore

Be sure to be in the sunlight (or a high-power spotlight) when testing.

The purpose of this activity is to maximize the use of solar energy, using engineering design to move a small car. Briefly discuss how we will know we have achieved this goal? Begin by showing youth the materials they will use to construct a basic car. Facilitators should decide if youth will work independently or with a small group. Each youth/group will have a mini solar car, a template, and scissors. Model how to construct the car and then give youth the materials to build their own cars. They will cut out the car body design provided and place it on the mini car chassis.

Once cars are built, identify a safe place to take the group outside and test the cars. You may want to set up a runway or test track. Masking tape on the pavement is one way to do this. Have youth work with a partner or small group and begin gathering data about their cars. They should:

- Measure the time it takes for the car to travel over a 1-meter distance while in the sun or using the flashlight.
- Calculate the speed; 1 meter divided by the time in seconds. Use the Solar Cars Data Sheet part A to help aid in this (provided as an appendix in this curriculum).
- Discuss the results before moving on. What did the youth find during this testing phase?

After collecting some baseline data, it's time to use the creative part of being an engineer. Challenge them to do one of the following:

- Create a different shape for the front end of the car and test the speed.
- Create another shape for the front end of the car and test the speed.
- Create another shape for the body and test the speed.

Before testing, discuss as a group if there are any other data we should be collecting before we test? Refer to the **Solar Cars Data Sheet Template, Part B (PDF)** if needed. If a whiteboard or flipchart are available, this would be a good time to generate a group datasheet, where collective results are displayed. Test the modified designs and measure the time and speed again.

Explain

Have youth share their modified car design. They can do this in small groups, or with the whole group as time allows. What changes did they make to the original design? What impact did their modification have on how their car worked? As a whole group, some themes will likely emerge (such as aerodynamics). Explain that now that the group's car designs are complete, we are going to add some other factors to our designs and see how they can impact the movement of the cars. A summary of factors that influence the function of these solar cars is below. During the discussion, encourage youth to use evidence to support their claims. As these themes emerge, help guide youth into understanding the science behind their discoveries.

1. **Aerodynamics:** the lower the air resistance, the faster the car. Prior discussion may have introduced this vocabulary term. If it has not already been discussed and named, now is the time. What does it mean to be aerodynamic? What factors maximize aerodynamics in our car designs? Use evidence to support claims related to car design.

Solar Cars Data Sheet Template: Part B: Collected Data

Variables	Time	Speed	Star the Fastest
Square Original			
Design 1			
Design 2			
Design 3			
Red Filter			
Orange Filter			
Yellow Filter			
Green Filter			
Blue Filter			
Purple Filter			
10 Degrees			
30 Degrees			
60 Degrees			
90 Degrees			
120 Degrees			
150 Degrees			
Vertical Reflector			
Angled Reflector			
Our Designed Reflector			

Describe the fastest car based on design, filter, sun angle, and reflector shape.

As a group, discuss which design created the fastest car? When answering this question, youth should use evidence to support their claims. Refer to the group and/or individual data sheets during this discussion. What patterns did you see? What differences did you see?

2 **Filters**: only certain colored light can be converted into mechanical energy in the panel. While filters are not used in real practice with solar panels, they can simulate real-world scenarios that impact the light absorbed by the panels. Filters hold radiant wavelengths out and the color is different radiation frequencies. Explain that filters can reduce the radiance, or energy, reaching the panel.

   Colored filters can mimic real-life scenarios. For example, shade from a cloud or surrounding tree or structure would still allow indirect light to reach the panel but would limit the direct sunlight. Another example might include light reflected off snow or grass, which is absorbed differently by solar panels than the direct rays of sunlight. The science behind which filters mimic which can be complex. The key here is to determine which color filter impacts their cars going faster or slower. Additional resources are provided at the end of this lesson with more information about filters.

3 **Angles**: the more directly the sun hits the panel, the faster the car.

4 **Reflectors:** by concentrating the sun energy onto the panel, the faster the car.

Elaborate

Reflecting at 90 degrees, with respect to the sun, is best; ask participants to explain this. Use a flashlight to create a model of the sun at various angles in relation to the reflector. Regardless of how you point it, the flashlight is always producing the same amount of light. Draw a circle around the area the beam is lighting up. Now move the flashlight to a lower angle and outline the area, repeat. Now draw a square in the first circle about the size of the circle; this represents a solar cell that is collecting all the power the flashlight is producing. Now compare the situation when the angle is 45 degrees. The solar cell is only covering half of the area that light is shining on. Therefore it must be collecting less than half the power of the flashlight. At the lowest angle, the beam is covering a huge area but the solar cell is only catching a small portion of the light.

The straight version, of the reflector, is good for noon sun directly overhead. The tilted one is good when racing towards a low sun. The ideal reflector angle and size direct all the light coming in the opening towards the target.

Explain to the youth that the first test we will perform is with color filters. There are several colored filters. The key here is to determine which color filter impacts their cars going faster or slower. Ask everyone to predict a color they think will make the car go faster, and a color they think will go slower. Ask youth to explain why they predict that color will make that difference.

After making predictions, have youth test the color filters with their cars. As a group, make sure that all the colors are tested at least once. If time allows, everyone could test all the colors. If limited in time, testing can happen as a whole group, using only the fastest car design.

Place the red filter over the panel and calculate the speed (measure the time it takes for the car to travel over a 1-meter distance).

1 Repeat for each colored filter.

2 Did any filter make the car faster? Use data and evidence to support your claim.

3 Which color reduced the speed the most? Use data and evidence to support your claim.

Be sure to remind youth that they can use data collected in past trials as evidence in making comparisons. Thinking about the types of data that are needed and how to capture data is an important skill. If time allows, and materials are available, as a group generates their own (or group) datasheet. Use the **Solar Cars Data Sheet Template, Part B (PDF)** to continue to collect data if needed.

The facilitator should explain after cars have been tested that white light is composed of all colors mixed together but we don't see them separately. A rainbow (or rainbow diffraction stickers) splits the white light into its colors so you can see different kinds of light there. Objects can absorb and reflect the light of different colors. If an object is white it means it is reflecting all the colors equally, if it is red that means that it is reflecting back only red light but is absorbing the others. A black object is absorbing all colors equally. The filters work the same way except the filter is transparent. A red filter lets red light through but blocks all other colors. A blue filter makes the red colors behind disappear. Colored filters will block some light so unfiltered light is always the strongest. Solar cells are sensitive to the color (wavelength) of light they are exposed to; it doesn't work very well below 450 nm which is blue to violet light. Note to facilitator: filters closest to the color of natural light generally work best (ex. yellow and red), while those similar to darkness achieve fewer results (ex. blue).

Now it's time to test light angles. Use the white from the protractors provided to reflect light onto the car's solar panel. The facilitator can determine if this is best done as a whole group, or in small groups.

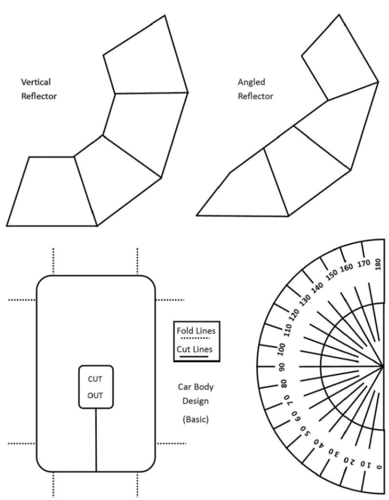
1 Using a protractor shine light on the solar panel at a 10-degree angle, have youth test the speed over a 1-meter distance.
2 Repeat for the following angles: 30, 60, 90, 120, and 150.
3 Ask participants as they are testing, which angle of light produces the fastest car? Ask youth to use data and evidence to support their claim.

The final phase is to build reflectors onto the cars. Use the templates in **Solar Car Design Template (PDF)** designed to attach reflectors. Everyone should test at least one type of reflector. The following directions should be explained to youth participants.

1 Put out the vertical reflector and put it on the car.
2 Test the speed over a 1-meter distance.
3 Repeat with the angled reflector.
4 If time allows, add aluminum foil to the inside of the reflector.
5 Ask participants, which type of reflector affected the speed of the car the most? Ask youth to use data and evidence to support their claim.

Ask the group why do solar arrays change positions instead of being stationary?

In this discussion, tie in concepts of energy transfer when answering these questions. For example, "I know my car is going the fastest because…." Or "My car is using the following factors to generate energy…"



Solar Car Design Template is included in the PDF link under the "Materials" list.

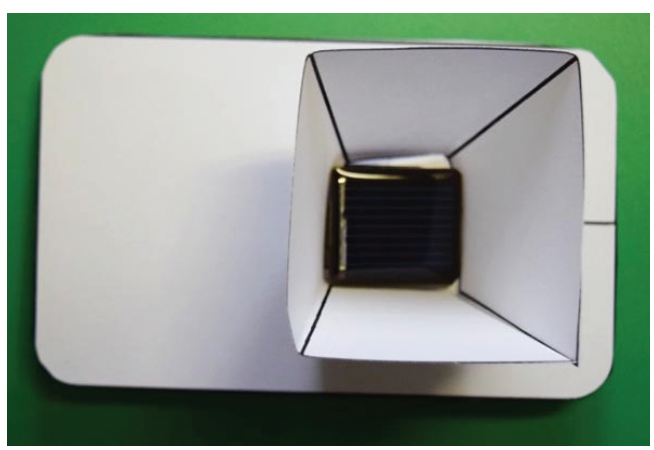


Figure 5.2: Example of a mini solar car with vertical reflector attached. (UMaine Extension 4-H Photo, Sarah Sparks)

Evaluate

Using observations and data collected on their **Solar Cars Data Sheet Template, Part A (PDF)** and **Solar Cars Data Sheet Template, Part B (PDF)**, engage in a group discussion on these topics. Encourage participants to use evidence when making their claims in response to the following questions.

- How did it feel when you were testing your car?
- What did you think would happen when you tested your car the first time?
- What did you think would happen when you added color filters? Reflectors?
- How did you design your car?
- What challenges did you have in building and/or testing your car?
- What design seemed to work the best? Why do you think that was? Use data and evidence to make your claim.
- What did you learn about solar energy? What are some of the limitations for solar energy? What design for a solar car might be used as evidence to support this claim?
- What did you learn about car design? How can you connect this to engineering design?
- How might you use what you learned today and apply it to future possibilities?
- Based on data and evidence collected today, what can we infer the perfect car to be?

Extension Ideas

1 Using your fastest car based on design, filters, angles, and reflectors, race the cars over a 2-meter track, 3 at a time. Continue to race until the fastest car is determined.

2 Test the cars on a full sun, partial sun, and overcast day.

3 Have students create Junior Solar Sprint cars.

Additional information: Students can participate in the University of Maine Junior Solar Sprint competition in June. More information about the solar sprint is available at the end of this curriculum.

Additional Resources

- **Teacher Guide for SunDawg Bag Lessons, Teacher Edition (PDF)** (Clean Energy Institute, University of Washington)
- **SunDawg Bag, Bring Solar to the Classroom, Mini-Cars and Lessons, Youth Edition (PDF)** (Clean Energy Institute, University of Washington)
- **Renewable Solar, Solar basics** (energyKIDS U.S. Energy Information Administration website) eia.gov/kids/energy-sources/solar/
- **Junior Solar Sprint: An Introduction to Building a Model Solar Car – Student Guide to Junior Solar Spring Competition (PDF)** (NREL website)
- **Education, Junior Solar Sprint** (Florida Solar Energy Center website) fsec.ucf.edu/en/education/k-12/energywhiz_olympics/jss/rules.htm
- **Teacher Guide for SunDawg Bag Lessons (PDF)** (Clean Energy Institute, University of Washington website)

MAINE 4-H FOUNDATION

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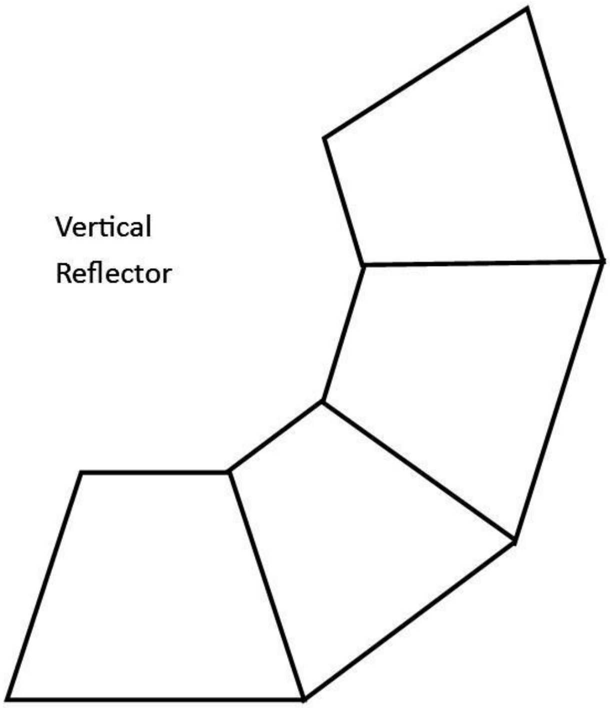
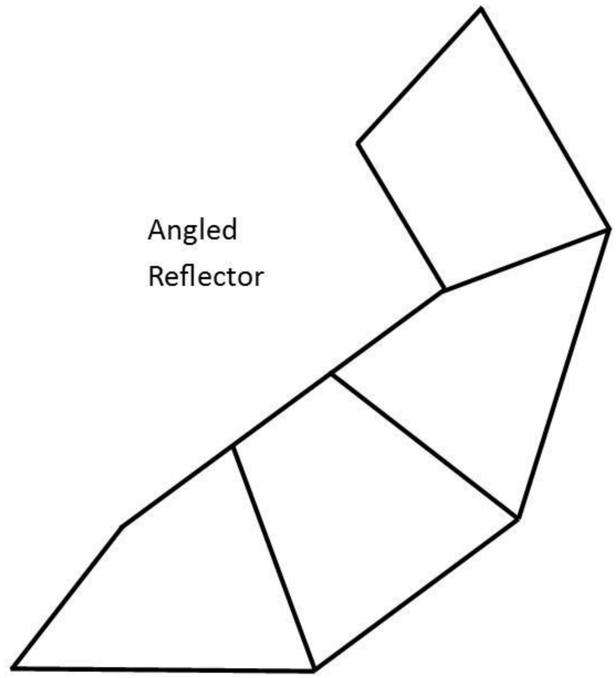
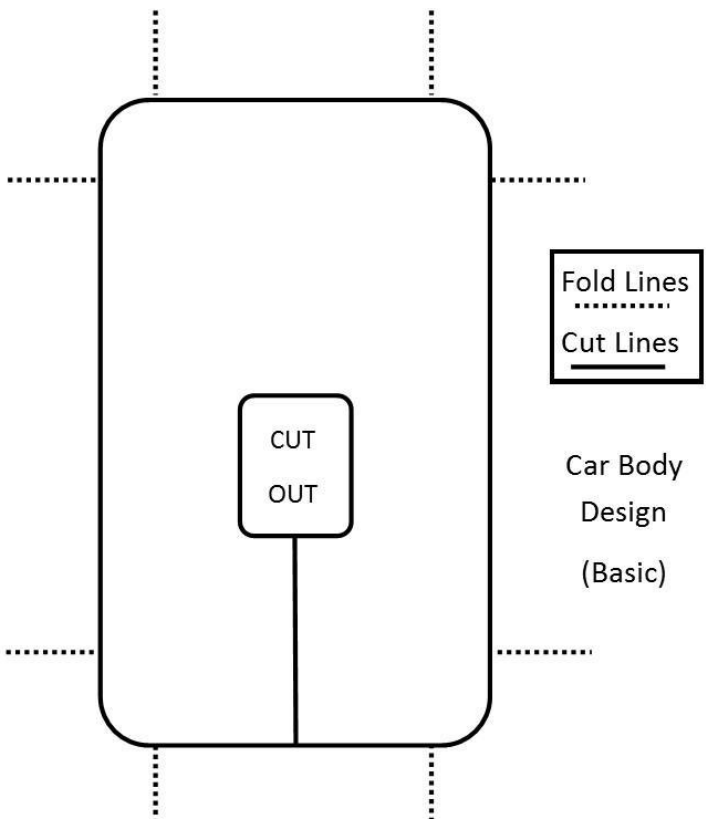
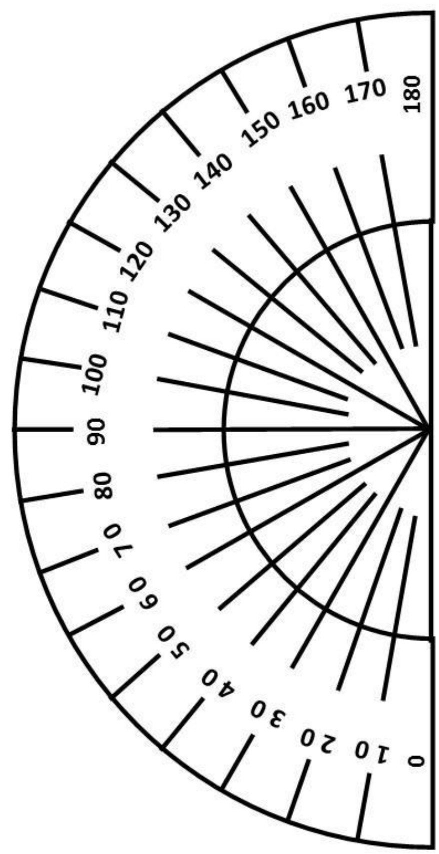
Car Design Template









Solar Cars Data Sheet

Part A: Calculating Speed

Speed = distance/time Speed = 1 meter/ X seconds

Trial 1: My car took_______seconds to travel 1 meter.
The speed my car traveled at for trial 1 is: 1 meter/_______seconds =_______speed

Trial 2: My car took_______seconds to travel 1 meter.
The speed my car traveled at for trial 2 is: 1 meter/_______seconds =_______speed

Trial 3: My car took_______seconds to travel 1 meter.
The speed my car traveled at for trial 3 is: 1 meter/_______seconds =_______speed

Solar Cars Data Sheet

Part B: Collected Data

Variables	Time	Speed	Star the Fastest
Square Original			
Design 1			
Design 2			
Design 3			
Red Filter			
Orange Filter			
Yellow Filter			
Green Filter			
Blue Filter			
Purple Filter			
10 Degrees			
30 Degrees			
60 Degrees			
90 Degrees			
120 Degrees			
150 Degrees			
Vertical Reflector			
Angled Reflector			
90 Our Designed Reflector			

Describe the fastest car based on design, filter, sun angle, and reflector shape:

4-H STEM Toolkit

The Sky's the Limit: **Activity 6: Engineering Solar Powered Boats**

6

Time: This lesson should take approximately 60 – 80 minutes minutes to complete.

Learning Targets

- Understand how energy from the sun transfers into electrical and mechanical energy.
- Design and construct a solar-powered boat.
- Use the engineering design process to determine the best design and potential modifications for optimal design.

Essential Questions

1 How can solar energy be transferred to another form of energy?

2 How does engineering design impact maximum energy collection?

3 How can we construct a model boat that is propelled by solar energy?

Enduring Understandings

1 The engineering design process is an effective way to find a solution to maximize power for building a boat.

2 Solar energy can be captured and transferred to mechanical energy to move a boat.

3 Solar energy collection can be maximized through the engineering design process.

NGSS Standards

- MS-PS3-3, MS-ETS1-1, MS-ETS1-2, MS-ETS1-4

Background for Facilitator

This activity introduces using solar energy to move a boat across the water. This activity can be done in sequence with the rest of this curriculum, or as a stand-alone activity. If water is not easily accessible, you may consider testing designs on another flat, even surface. You may want to have youth work in small groups, or independently.

These boats use solar photovoltaic systems to power them. Solar photovoltaic systems convert sunlight into electricity. Solar photovoltaic (PV) devices, or solar cells, change sunlight directly into electricity. Small PV cells can power calculators, watches, and other small electronic devices. Arrangements of many solar cells in PV panels and arrangements of multiple PV panels in PV arrays can produce electricity for an entire house. Some PV power plants have large arrays that cover many acres to produce electricity for thousands of homes.

The two main benefits of using solar energy: Energy systems do not produce air pollutants or carbon dioxide. Solar energy systems on buildings have minimal effects on the environment. The main limitations of solar energy: The amount of sunlight that arrives at the earth's surface is not constant. The amount of sunlight varies depending on location, time of day, the season of the year, and weather conditions. The amount of sunlight reaching a square foot of the earth's surface is relatively small, so a large surface area is necessary to absorb or collect a useful amount of energy.

Facilitators and youth may also watch the video **Maine 4-H Solar Energy Project with RLC Engineering 5422** (YouTube). youtu.be/H23iWucMDeM

Limitations of solar energy are highlighted at minute marker 10:31-12:49 and benefits of solar energy are highlighted from marker 12:49-13:48.

Youth should have the opportunity to engage in the engineering design process and modify their design if they choose. As the facilitator, it will be especially important to ask purposeful questions about their designs, such as why they chose a certain modification and what the function of that modification might be. Encourage youth to explain why they are making design choices. If a design does not work how they expect, what might they change? This will encourage independence and discovery.

Safety Consideration: *Youth should be told not to look directly at the sun.*

Vocabulary List

- **Circuit:** A device that provides a path for electric current to flow
- **Thermal Energy:** heat energy
- **Radiant Energy:** light energy
- **Reflection:** bouncing energy back without absorbing it
- **Absorption:** take in heat energy
- **Solar panel:** collect sunlight and change radiant energy into electricity
- **Engineering Design:** a series of steps to create a product, includes ask, imagine, plan, create, improve
- **Solar Energy:** Energy that comes directly from the sun
- **Voltage:** the difference in energy between two points
- **Engineering Design:** a series of steps to create a product, includes ask, imagine, plan, create and improve

Materials

- Blank paper
- Markers
- Multimeter and alligator clips (optional)
- ProtractorSolar Panel cell (or appropriate for the motor), with wires
- Foam trays (~4"x10" per boat)
- Mirror
- Solar Boats Observation and Data Sheet
- Clipboards
- Pencils
- Access to direct sunlight
- Scissors
- DC motor (1 per boat)
- Small plastic fan (to attach to each boat)
- Duct tape
- Large aluminum trays or small pool
- Access to water
- Graph paper
- Pencils

Figure 6.1: Solar Boat Materials
(UMaine Extension 4-H Photo, Sarah Sparks)

Methods

Engage

Discuss as a group what was discovered during Activity 1, Introduction of Solar Energy. What do participants remember about testing solar panels – what designs captured the most energy and what designs captured the least amount of energy?

> ***Note:*** *if using this as a stand-alone activity and youth have not done Activity 1 instead ask youth what they know about solar energy? Have they seen solar panels before? Have them describe where they've seen them, what they look like and what they think they might be used for. What are some of the benefits of using solar? What might be some of the challenges?*

Explain that during this session we are going to use what we learned about solar cells and the transfer of energy to build a boat that will be powered by a single solar cell.

Explore

Be sure to be in the sunlight (or a high-power spotlight) when testing.

1 Explain to the youth that today they are going to build a boat powered by solar. The goal is to have the boat travel the greatest distance across the water (or flat surface if water is not available). Introduce participants to the materials that will be available to them. Each person (or team of two) will get materials to build one boat. Basic materials include foam insulation, motor, propeller, solar panel, wires to attach the panel to the motor, and adhesive tape.

2 Provide youth with graph paper and pencils and ask them to sketch their boat design.

3 When they are done sketching, have the youth explain their design to the facilitator, who can ask reflection questions about attachment, placement of pieces, and overall design. When the facilitator approves the design, participants may get their materials and move on to constructing their boat.

4 Provide youth with time to build their initial design. Encourage individuals and teams to share with others their designs as they build.

5 Designs will be tested for the first time as a whole group. Ask youth how they will know

if their boat is successful? Are there any data that should be collected as they test? Take time to brainstorm this and ask youth to take note of the data for their individual design when it's tested. A sample data sheet is provided in the appendix to be used if there is no time to generate one with the group.

6. When groups are ready to test the initial design, have individuals introduce and explain their boat design to the entire group. After explaining, they may test in the water. Be sure your water test system (foil pan or small pool) is in the direct sun, or the solar panels may not work.
7. Ask individuals to identify what they observe after testing their initial boat design. Are there any similarities or differences between boat designs? How will they know if they are able to improve their designs? Is there additional data that could be collected to support this?
8. Youth should connect their design to the multimeter to measure voltage output from the fan.

Elaborate

As time permits, allow youth to redesign their boats to meet maximum energy production. It is important as the facilitator to let youth guide their own redesign as much as possible. Facilitators can use questions about design to provide guidance as needed (ex. What is the challenge you are trying to address? Tell me what you see there now? What could you change? What did you notice about X person's design? Is there something you could use from observing that)? Common challenges might include a limited collection of solar energy (adjust solar panel angle, height, or attachment), boats that spin in one direction, and/or boats that do not sit level on the water. Facilitators can highlight to groups that the fan is directly affected by the light brightness. The strength of the light is proportional to the motor's response.

Evaluate

Engage youth in a discussion about their experience. Encourage youth to use evidence from their observations or the data sheet when making their claims. Questions might include:

- How did you feel when you tested your boat?
- What did you think was going to happen when you tested your boat?
- Did anything surprise you during this activity?
- How did you decide who was going to do what in your group?
- What did you observe?
- What did you discover about capturing energy? Were there designs that worked better than others?
- Did your background knowledge influence your design?
- How did the sunlight or darkness impact the fan or any other use for the solar-powered motor? Use evidence to support your claim(s).
- What designs seemed to have the fastest boat? Why do you think that those boat(s) were faster than others? What could have impacted speed and design function? Use evidence to support your claim(s).
- What skills did you discover or use while working on this?
- How might you use the idea of solar power to apply to another design or real-world application?

Extension Ideas

- Design a 'course' in the water testing pool. The course should allow the student to race the boats. The variance in the course will be compensated by the angle of the cells on the boats. Through the course, different surfaces can be used to affect the boat's performance. The students then can figure out the best mounting to take advantage of the conditions.

The course can be short plastic-lined wooden troughs. The course would be set up similarly to the following sketch. The boats should have criteria that limit the contestants but allow for variations in size, shape, etc. however they should be small.

- Use the boat and modify it for better performance for a second run.
- Test the boats with various filters on the solar cells to modify power output.
- How important was direct sunlight – diffused light – reflected light?
- How well did the design allow for brief moments of blocked or filtered sunlight (artificial clouds)Use shaded filters (define these) to put over the panel and see how they impact the function of the solar panel. While filters are not used in real practice with solar panels, they can simulate real-world scenarios that impact the light absorbed by the panels. Filters hold radiant wavelengths out and the color is different radiation frequencies. Explain that filters can reduce the radiance, or energy, reaching the panel For example, if shade from a cloud or surrounding tree or structure would still allow indirect light to reach the panel, but would limit the direct sunlight. Another example might include light reflected off snow or grass, which is absorbed differently by solar panels than the direct rays of sunlight.

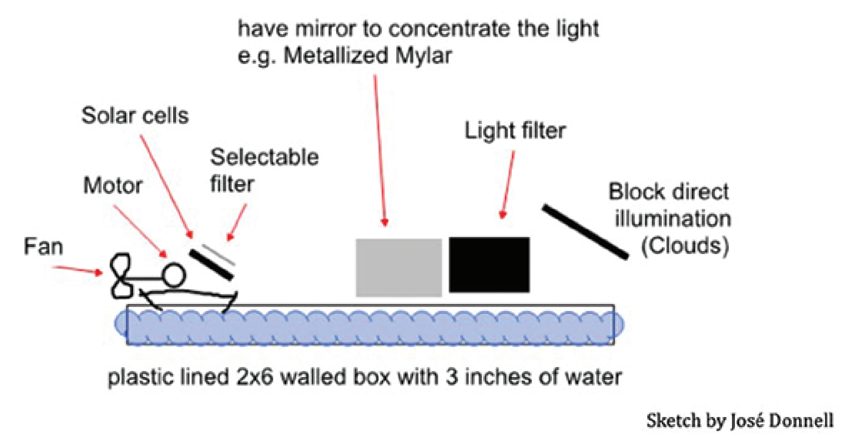


Figure 6.2: Boat Design Sketch (Graphic Sketch, Jose Donnell)

This 4-H Science toolkit was created for the University of Maine Cooperative Extension with generous support from RLC Engineering and the Maine 4-H Foundation.