HAWAI`I STATE ENERGY OFFICE

RENEWABLE ENERGY LABS

GRADES: 3-5

State of Hawaiʻi

Department of Business, Economic Development, and Tourism

Hawaiʻi State Energy Office

CLEAN ENERGY EDUCATION CURRICULA and TOOLKITS

The purpose of the Hawaiʻi State Energy Office (HSEO) is to promote energy efficiency, renewable energy, and clean transportation to help achieve a resilient clean energy economy by 2045. HSEO is developing a statewide clean energy public education and outreach program to empower teachers', students', and their families' participation in Hawaiʻi's transition to a decarbonized economy; and to encourage Hawaiʻi's K-12 students to become the next generation of clean energy leaders.

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Developed by Maui Economic Development Board, STEMworks on contract for the Hawaiʻi State Energy Office

Curriculum at a Glance	
Grade Levels	3rd - 5th
Time Required	5 - 8 Class Periods
Activity Group Sizes	2 - 4
NGSS Performance Expectations	3-5-ETS1-2, 3-PS2-2, 4-ESS3-1, 4-PS3-1, 4-PS3-2, 4-PS3-4, 5-ESS3-1
Activity Title	**Example Questions**
Lab 1: Crazy Circuits!	What is a circuit and how does it work?
Reading Exercise 1: How Does My Home Work?	What things need electricity to work? How can solar energy or kinetic energy be converted into electrical energy?
Lab 2: Crazy Circuit Science	How is electrical energy transported from one location to another? What materials are conductors (conductive)? What materials are insulators (non-conductive)?
Reading Exercise 2: Time to Shine	What do engineers do? What can solar energy be used for? What are the pros and cons of solar power?
Lab 3: Solar Rover Racing & Engineering	How can sunlight be used to create electricity and to do work? What is the engineering design process (EDP)? How can I use the EDP to improve my product designs?
Online Extension: Renewable and Nonrenewable Resources	What are renewable and nonrenewable energy resources? What are some of the environmental impacts of fossil fuels? Why is it important to transition to renewable energy resources?
Action Challenge: Energy Reduction Pledge	How can we use less energy in the classroom? How can we conserve energy at home?
At Home Extension Lessons: Cookie Mining	Most technologies use metals and minerals mined from the earth. How does mining for materials impact our land and environment?

Summary

What is energy? Energy is all around us. It is the power that brings nature, humans and machines to life. The purpose of this renewable energy curriculum is to provide young learners (Grades 3-5) the opportunity to begin building **energy literacy** through *exploration*, *experimentation*, *engineering*, and *hands-on fun*. In the pages that follow, you *and your students* will explore different types of energy; consider sources of energy including renewable and non-renewable energy sources; experiment with creating **circuits** by testing conductors and insulators; discover how energy is used to power different objects in a home; and engineer a solar powered rover that harnesses energy from the sun all the while learning how to **think like scientists and engineers.**

The classroom toolkit for this curriculum includes two books for building literacy and critical thinking skills; these readings set the stage for the hands-on laboratory activities that follow and encourage your students to identify gaps in their knowledge. The toolkit also includes essential materials for the three, hands on laboratory exercises: 1) Crazy Circuit 2) Crazy Circuit Science, and 3) Solar Rover Engineering and Racing. In these three labs, students will make hypotheses, collect data, analyze their data, and review results just like real scientists. They will also use a solar rover kit to explore the process of **engineering design**, how to test strengths and weaknesses of their designs, and how to make modifications to their designs, if needed, to improve their rover's performance. We have also included several online extension activities that can be done in the classroom or at home, as well as an at home extension activity on mining to engage other members of the household in discussions about renewable and nonrenewable resources. *This renewable energy curriculum and the inquiry-based labs are aligned to both Physical Science and Engineering Next Generation Science Standards (NGSS).*

Growth Objectives: Science and Engineering Practices

Asking Questions and Defining Problems: A practice of **science** is to **ask** and **refine questions** that lead to empirically tested descriptions and explanations of how the natural and designed world(s) works. **Engineers** generate questions to **clarify problems** to **determine criteria for successful solutions** and **identify constraints** to **solve problems** about the designed world. After completing this curriculum, we hope your students learn better how to think and ask questions like scientists and engineers. These lessons herein will help your students to:

- Ask questions about what would happen if variables were changed. *This can apply to both the crazy circuit (test different materials) and solar rover (test different configurations, designs, and vehicular weight) activities. Students can make predictions and test how different variables affect performance.*
- Ask questions that can be investigated *(What would happen if…?)* and predict reasonable outcomes based on patterns such as cause and effect relationships. *In the crazy circuit activity, students may discover patterns in terms of what types of materials are conductive and what types of materials are not. For example: What would happen if I used scissors to try to complete the circuit?*

- Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success, and constraints on materials, time or cost. In the solar rover activity, students may need to troubleshoot their rovers if they do not at first work. *The constraints for these labs are up to you and are likely the materials your students have on hand in the classroom. In the Solar Rover lab, students will be challenged to design a modified rover that is more efficient in terms of speed and or distance traveled.*

Planning and Carrying Out Investigations: Scientists and engineers plan and carry out investigations in the field or laboratory, working **collaboratively** as well as individually. Their investigations are **systematic** and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the **effectiveness, efficiency,** and **durability of designs under different conditions.**

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled, and the number of trials are considered. *In both the Crazy Circuit and Solar Rover activities, your students will need to work collaboratively as a team to produce data and to record data in the tables provided.*
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. *In both the Crazy Circuit and Solar Rover activities, your students will make and record observations, note any patterns that they see, and make predictions about future tests. From their data, they should be able to present an explanation based on the evidence they collected. For example, based on their observations and data, they can argue what kinds of materials work best to transport energy.*
- Make predictions about what would happen if a variable changes. *The Crazy Circuit activity will have students predict if a material is a conductor or insulator based on their past observations. In the Solar Rover activity they will have the option to change a variable, such as front- or back-wheel drive and make predictions about how the rover might perform differently.*
- Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success. *Students will employ the engineering design process to alter their solar rovers (modified design) to determine which model worked best.*

Analyzing and Interpreting Data: Scientific investigations produce **data** that must be **analyzed** in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include **analysis of data collected in the tests of designs**. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.

- Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships. *In the Crazy Circuit labs, students will*

record their data in a table to uncover patterns in materials that are conductors and insulators. In the Solar Rover lab, they will take quantitative measurements and calculate the average.
- Use data to evaluate and refine design solutions. *In the Solar Rover lab, students will collect and record data for their rover's distance and speed to evaluate their design solutions.*

Using Mathematics and Computational Thinking: In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.

- Describe, measure, estimate, and/or graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems. *In the Solar Rover lab, students will collect and record data for their rover's distance and speed to evaluate their original and modified design. They may also test how changing the weight of the rover changes the rover's performance.*

Constructing Explanations and Designing Solutions: The end-products of science are explanations and the end-products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.

- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem. *Students will use their solar rover performance data as supporting evidence for explaining why their modified rover performed better or worse, and what variables caused it to perform the way that it did.*
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. *Students will consult with other groups in the class to compare their solar rover designs and to determine which group best engineered a design solution.*

Engaging in Argument from Evidence: Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims.

- Construct and/or support an argument with evidence, data, and/or a model. *The online extension activity on renewable and nonrenewable resources will require students to gather* *information about various energy resources and to construct an argument for which resource types are renewable, and which are nonrenewable, based on the evidence they gathered. This will require that they can identify reliable resources and they can* distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation. *This also ties into the next practice:*

Obtaining, Evaluating, and Communicating Information: Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

- *Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.*

Career Connections

Earth Scientists, Geologists

Scientists are people who make observations, ask questions, and use scientific tools, technologies, and software to do research in an effort to find answers to many questions that few people know much about. T*here are more than 50 kinds of scientists*. Earth Scientists and Geologists are scientists who study the earth, earth resources, natural hazards, and climate patterns as recorded in the rock record. They often work in academia (universities), for environmental engineering companies, governmental organizations like NASA and NOAA, conservation operations, mining companies, and energy companies (both renewable and non-renewable).

Engineers

Engineers are problem solvers who design and create products, buildings, machines, instruments, and more, for human use and benefits. During the creation of these things, all engineers go through the process of design, prototyping, and modifying their designs (sometimes many iterations of this) until there is an optimal product or solution. Oftentimes, engineers need to work in teams made up of people with different subject matter expertise.For example, *Electrical Engineers* are experts on electricity generation while *mechanical engineers* are experts on mechanical applications (how to get the parts of the machine to work). During the three laboratory activities herein, students will have the opportunity to select roles, practice teamwork, and put on their engineer hats to build a solar rover to harness the energy of the sun to race their rovers.

Green Jobs

Green jobs are jobs that people do to benefit the environment, or to conserve natural resources. Solar installers, solar technicians, marketers for solar companies, manufacturers that produce renewable energy equipment, project managers that oversee renewable energy operations, artists that promote going green, some chemical engineers, some data analysts, and environmental scientists are all examples of green jobs. Check out the outlook for green jobs here: Where the Green Jobs Grow | U.S. Department of Labor Blog (dol.gov)

Introduction

Aloha e Energy Explorers!

Welcome to this adventure into the world of **energy**. Throughout these lessons and hands-on laboratory activities, you will discover the answer to questions like these*:

- **What is energy?**
- **Where do we get energy from?**
- **How does energy power our homes and communities?**
- **What sources of energy are renewable?**
- **What sources of energy are nonrenewable?**
- **What role do scientists and engineers play in the energy field?**

**Take a minute to pose these questions to your students and let them share some of their ideas. For now, focus on what is energy?"*

And **more importantly**, you'll **learn how to ask questions** and **investigate the answers to your own questions about energy.**

So *what is energy*? Well, energy is all around us! It is the power that brings things to life. Let's do a crazy activity together to kick off our discovery of how energy works.

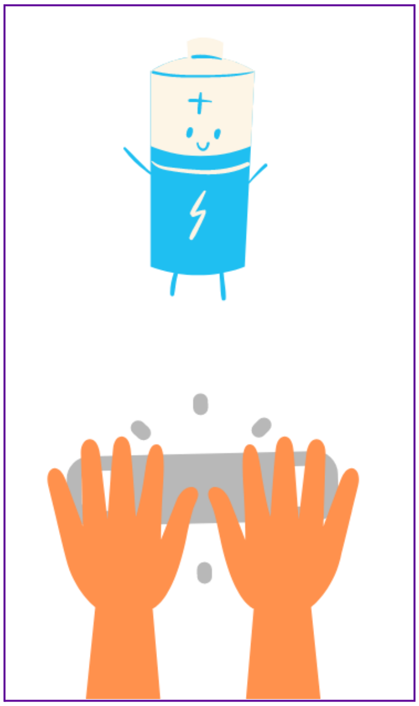
Lab 1: Crazy Circuits Exploration *(~15 minutes)*

Before we begin, what do you think energy is?

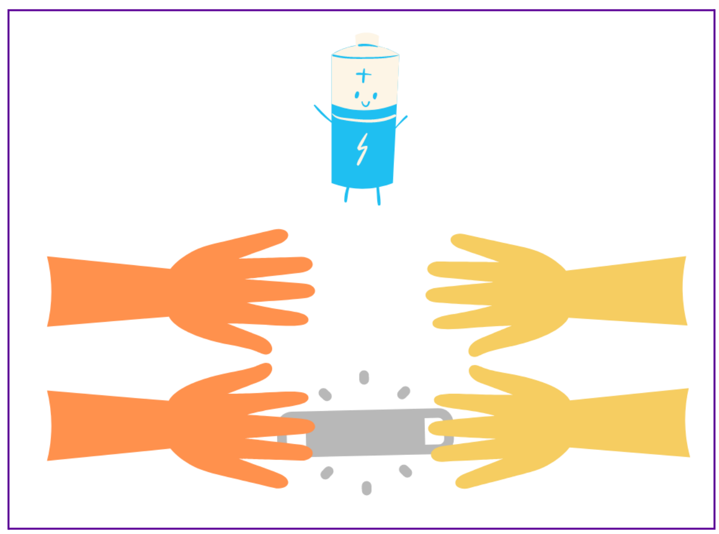
How does energy get from one place to another like from the wall to your computer?

Explore Phenomena

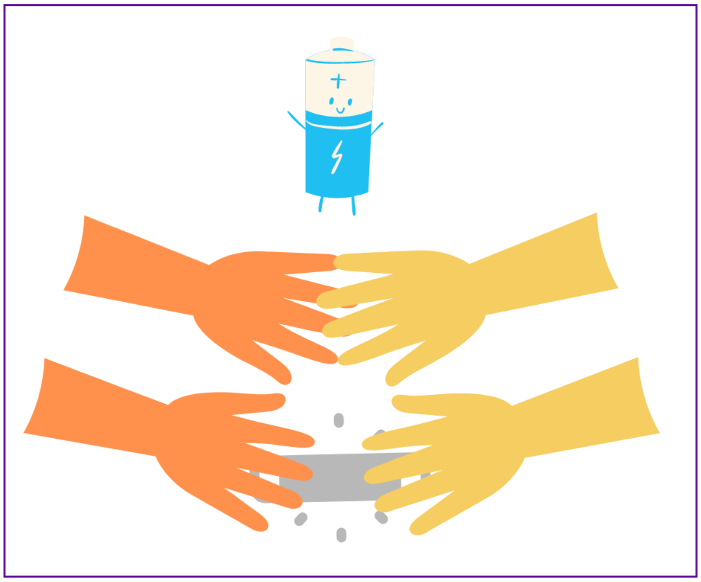
1. **Explore** - Pick up your energy stick. What do you notice? Have one person grab the silver ring on each end of the stick. Does it light up? Why or why not?



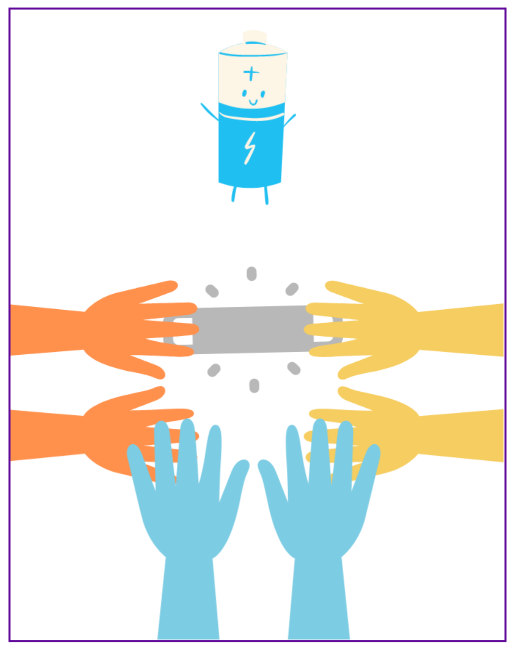
2. **Ask** - What happens if one person holds onto one of the silver rings and a second person holds onto the other silver ring? Does it light up? Why or why not?



3. **Test** - What happens if one person holds onto one end, another person holds onto the other end, and these two people hold hands? Does it light up? Why or why not? Try it out.



4. **Hypothesize** - What happens if a third person stands in the middle and holds hands with the two people holding the ends of the energy rod? Does it light up? Why or why not?



5. **Summarize** your observations:

6. How does the crazy circuit work?

   Most students will not <u>*really*</u> *know how the circuit works. At this point, you are presenting them with a phenomenon, and here we're asking them to try to explain it. Students should recognize that they have gaps in their knowledge and be encouraged to ask questions. This process helps to engage students in the science, engineering, and discovery process. We want to avoid short circuiting their learning - pun intended. This is part of the major shift from Common Core to NGSS.*

7. Make a list of *at least* three questions you would like to ask about circuits:

   1.

   2.

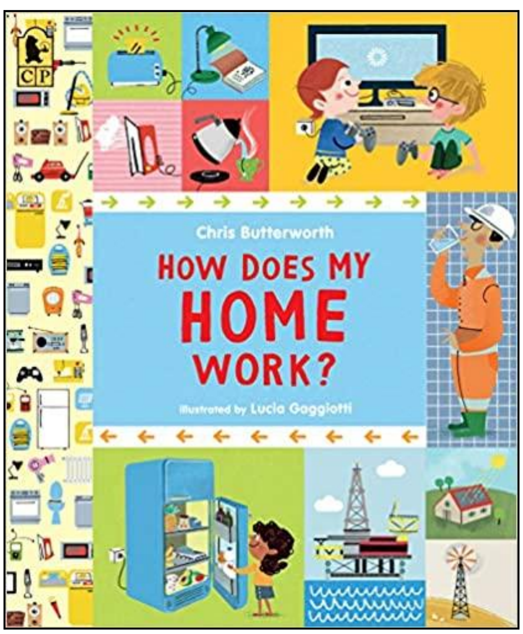
   3.

Key Concepts

In this Crazy Circuit exploration activity, you observed that your body (actually your skin) can be used to **conduct electricity**. Electricity is a **carrier** of energy. When you held both ends of the stick by yourself, or created a complete circle with multiple people, you created a pathway for **electrons** to travel. That pathway is called an electrical **circuit**. Let's explore how circuits are used to power other electrical items, like things you can find in your home.

Extra resource for teachers *- Fun video on energy transfer:* *Energy Transfer Video For Kids | 3rd, 4th & 5th Grade (generationgenius.com)*

Reading Exercise 1: How Does My Home Work (*1-class period or less*)



Read this book out loud in your classroom. It will serve as a jumping off point for Lab 2. For older students, you may want them to read this on their own or with a partner. One copy has been provided for you in your classroom kit. If you need more copies, you may want to reach out to your school librarian. This book will help young learners discover the secrets behind how many items in a home work. They may have never thought to ask why a light comes on when they flip a switch, or how their video games or computers get energy from the socket in the wall. While reading, let your students know that they will have the opportunity to investigate materials that allow electricity to travel from one point to another in Lab 2: Crazy Circuit Science.

Discussion Questions: *The second and third page of this book has pictures of many different items that may be found in the home. Ask students,* "Select three items that you use regularly. How do these items work? Where do they get their energy from?” *Answers will vary and may be vague such as “the toaster gets energy from the socket in the wall”. Young learners will often know that items need electricity and that electricity is delivered through wires, but they may not know the source of the electricity (carrier of energy), how it is generated, or how it is transported.*

Item #1 _________________

____

____

____

Item #2 _________________

____

____

____

Item #3 _________________

____

____

____

**Affirm their ideas and understanding wherever they are at, and explain that the facts presented in the book will help to explain how the objects they selected are powered in more detail.*

Suggested Embedded Reading Commentary

Note the text in this book is very simple and well below a 5th grade reading level. However the illustrations are fabulously detailed, and the information presented may not be known or understood by many students in the 3-5 grade bracket. Be sure to take time to let students really examine the illustrations and annotations. Have them identify how their home(s) might look a little different. If the home environment is an uncomfortable topic for any of your students (for example, if you have a houseless student), feel free to use your classroom as an extended example instead.

- **Page 8 -** *introduces students to “**natural gas**” delivered by pipes and “**electricity**” delivered by wires. This is a good opportunity to see if any of your students have power supplied by natural gas. You can ask if anyone has a cooktop that produces blue flames.*
- **Page 12 -** *reinforce that the air pollution created from burning fossil fuels like coal, oil, and gas are one of the major reasons Hawai‘i wants to move to 100% renewable energy. Air pollution contributes to climate change, and climate change results in rising sea levels among other natural hazards.*

- **Page 13 -** *take time to explain how a generator works. This is likely new information for them and helps them make the connection between energy resources and how energy is created. Allow them to ask their own questions as well.*
- **Page 14** - *note that some cities have underground cables, and some communities are "off the grid" this means that there are no cables available to deliver electricity into the home. Are any of your students off the grid?* **Career Connection:** *Has your electricity ever turned off during a storm? Who helps to get you reconnected? (Electrical Engineer)*
- **Page 15** - *a light switch acts as a gateway to stop the flow of electricity from one wire to the next, or to open the flow of electricity. The piece of metal that creates a connection between two wires when you turn the switch on is a* ***conductor****.*
- **Pages 16-21** - *are about water resources. These are not directly connected to this curriculum, but are still valuable information for students to learn about. Note on* **Page 20***, water treatment plants often require a lot of energy, and can also be a source of air pollution if the energy is not generated by renewable sources.*
- **Page 22 - Career Connection:** *Who knows where to find natural gas? (Earth Scientists) Who gets it out of the ground? (Petroleum Engineers).*
- **Page 23 -** *Note that we do not have any natural gas resources in Hawaiʻi. The gas that we use is synthetic natural gas. Want to learn more? Check out this video. Not all homes in Hawaiʻi have natural gas. One way to know is to have students ask their parents if they have a gas bill. You can also ask if their stovetop has heated coils (electricity) or flames (natural gas).*
- **Pages 26 & 27 - *Challenge:*** *Have students identify which of the actions they could take to reduce their energy consumption. Ask them what other actions they could take that were not listed (think about all the items on page 2 and 3 - how could they use these items less or more efficiently. You may want to make this a trackable challenge by setting up a tracking sheet for a week or a month for students to take home.*

Post-reading assessment: Let's revisit the three items you selected at the beginning of this lesson. After reading this book, can you provide a more detailed description of how the items you selected get their energy?

8. Item #1 ________________

    ____

    ____

9. Item #2 ________________

    ____

    ____

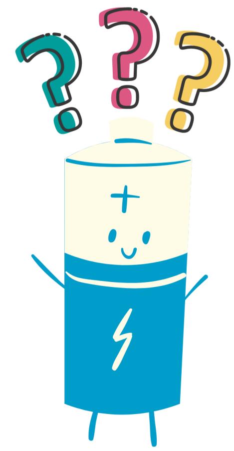
10. Item #3 ________________

    ____

    ____

**Check if their explanations improved. Note that each student likely started at a different starting point with varying degrees of understanding about how items in their home are powered. After reading this book together, they should all be at about the same level of understanding.*

This energy and electricity stuff is really interesting. In our first lab activity, we learned that our skin can be used to create or break a **circuit.** I wonder what else we can use to create a circuit? Do you have any ideas?



Let's go do some experiments.

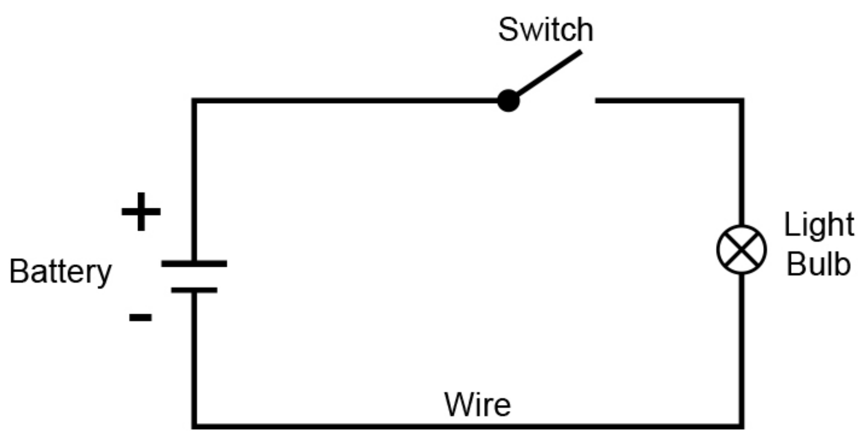
Lab 2: Crazy Circuit Science (1-class period)

NGSS Performance Expectations
4-PS3-4 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. *Students will use the energy stick to apply scientific ideas to formulate a hypothesis, test, and refine a device that converts energy from one form to another - in this case an electric circuit is used to generate light and sound. They will create closed circuits and test various materials to determine if they are conductors or insulators.* **3-5-ETS1-2** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. *In this lab, the problem is that they need to create a complete circuit in order to activate the energy sticks' sound and light functions. Students will test materials to determine if they are conductors that can complete the circuit or insulators that will prevent the flow of electrical energy. Students will then make predictions about whether other materials (not yet tested) will work or not. They will also have the opportunity to create their own invention using what they've learned about circuits in this lab. You may choose to give them constraints.*
This exercise focuses on the following three dimensional learning aspects of NGSS

Science & Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
Planning and Carrying Out Investigations Make observations to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.	**PS3.A: Definitions of Energy** Energy can be moved from place to place by moving objects or through sound, light, or electric currents. **ETS1.B: Developing Possible Solutions** Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. At whatever stage, communicating with peers about proposed solutions is an	**Energy and Matter** Energy can be transferred in various ways and between objects. - ***Connections to Nature of Science*** **Science is a Human Endeavor** Most scientists and engineers work in teams. Science affects everyday life. **Influence of Science, Engineering, and Technology on Society and the Natural World**

Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem.	important part of the design process, and shared ideas can lead to improved designs.	Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands.
HĀ outcomes practiced: 1. Belonging - students will work in teams, actively participate, and practice communicating with clarity and confidence. 2. Responsibility - students will be active learners, encouraged to ask for help, will need to set goals and complete tasks with their team. 4. Aloha - students should learn to appreciate the gifts and talents of their team members, make everyone feel welcomed and heard, be respectful of all ideas, and share responsibilities.		

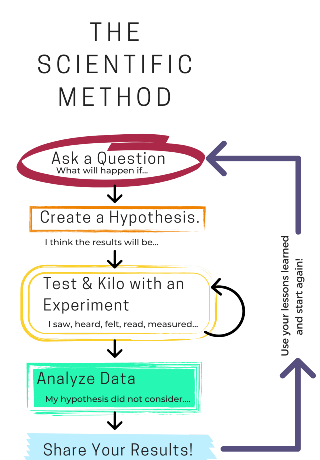
In this lab, we are going to learn about **conductors**, **insulators,** and **circuits**. Materials that are *conductors of electricity* allow **excited electrons** to flow from one place to another. Insulators are *materials that block or slow the flow of energy*. A *circuit* is like a racetrack that allows electrons to travel in one direction at a time from a starting point, through the circuit loop, and back to the starting point again. Take a look at the simple circuit diagram below:



Simple Circuit Diagram

We cannot see electricity, *but we can* observe how electricity works by using a simple circuit. Electricity from a battery flows out the negative (-) end, travels around the circuit, and if the circuit is **closed**, the energy lights up the light bulb, and returns to the positive (+) end of the battery. **You may want to have them draw over the circuit diagram with arrows showing the pathway electrons flow.*

Let's go test this concept out by creating our own crazy circuits! In this activity, you will discover what materials allow you to create a **functioning closed circuit**.



Prerequisite Knowledge

In this experiment students will explore what materials are conductors (their crazy circuit is activated) and what materials are insulators (their crazy circuits will not work).

- *Review the Scientific Method (it is actually much more complicated. [See here](#)).*
- *You may want to teach your students about, or review, what an atom is made up of (protons, neutrons, electrons). If you can*

break an electron free from an atom and force it to move, you can create electricity. Elements that are conductors such as copper, silver, and gold, have very mobile electrons. We use these materials to create wires to help electrons flow. Electrons in elements with low conductivity (insulators) do not break free very easily, preventing the flow of electrons. These are materials like glass, rubber, plastic, and air.

- *Review the simple circuit diagram. Students should know that electricity is the flow of charged particles - electrons flow through conductors. Note - the battery in the energy stick stores electrical energy (chemical energy). Batteries all have a - side where there is an excess of negative charges, and a + side where the positive charges gather. Batteries are stored electrical potential just waiting to be activated by a closed circuit.*
- *Want more details? Here is an excellent tutorial with simple animations: [What is Electricity? - learn.sparkfun.com]*

Before the Activity

- Select groups of 2-3 students
- Gather materials (list below)

Materials List - For this activity, each group will need:

- One Energy Stick (*included)*
- 10 random classroom materials to test (*not included*)
- Datasheet (*included; you may want to print*)
- Pencil (*not included*)

Potential Safety Issues

- Have students wash their hands with soap or hand sanitizer before engaging in this activity.
- Be careful with handling any sharp objects like scissors.

Potential Obstacles

- *Students must have their hand(s) and selected item in contact with the silver tape (electrodes) on the energy rod.*

Pre-Activity Assessment

Step 1: Ask a Question: *Ask the students to write down or verbalize. "*Which of your ten items do you think are **conductors**? Which ones do you think are **insulators**?" Make a **Hypothesis** for each item and record your predictions in the table below (Table 1).

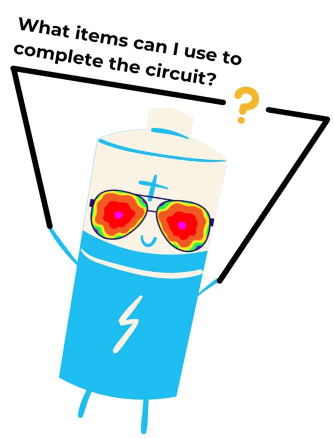


Table 1: Hypothesis "I think…"		
Item Name	**Conductor**	**Insulator**
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
Notes:		

Now it is time to test these predictions. When you see flashing lights and hear the crazy sounds, you'll know that you have created a complete circuit using **conductive** materials.

Hint: *Remember, for a circuit to work, it must be* ***a closed, never-ending loop of conductive materials****. There cannot be any insulating gaps in the loop, including air.*

Procedure

Step 2: Data Collection - Conductor or Insulator Test

Your mission is to find the coolest conductors of electricity. Hold onto one end of the energy stick and have a teammate hold onto the other end. With your free hands, hold onto one of the ten random objects in your classroom. If the energy stick is activated, you have identified a conductor. If it is not activated, you are holding an insulator. Record your data and observations in Table 2. You should test your items in the same order as Table 1.

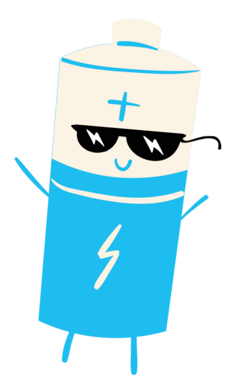
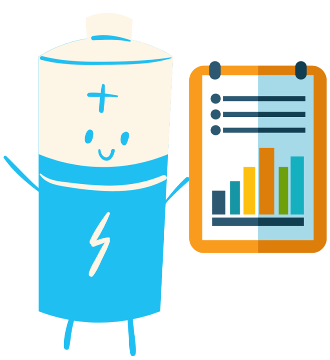


Table 2: Tests & Observations "I saw…"		
Item Name	**Conductor**	**Insulator**
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
Notes:		

Step 3: Analyze Data

1. Take a look at your hypotheses (Table 1) and test data (Table 2). How do they **compare**? Did you predict correctly which items would be insulators or conductors? How many did you predict correctly? Which hypotheses did you prove wrong through experimentation? *(answers will vary)*



Step 4: Future Predictions

Career Connection: Scientists often make hypotheses that prove to be wrong once they conduct experiments and collect data. However, with **empirical data**, scientists can improve their hypotheses to make better predictions in the future.

Let's try this out. **Select five items in your classroom that you have not tested yet**. Identify which materials your new items are most like from the ten items you previously tested. Make a prediction if your new items are conductors or insulators (Table 3). Then test to see if your predictions are correct.

Table 3: Informed Hypothesis				
	Prediction		**Reality/Test**	
Item Name	**Conductor**	**Insulator**	**Conductor**	**Insulator**
1.				
2.				
3.				
4.				
5.				
Notes:				

Post-Activity Assessment

Gather, and summarize student responses. (Answer will vary. Ideally students will have identified a pattern that plastic and rubber items are insulators and most metals are conductors.)

1. What types of materials did you discover to be good conductors?

   ____

   ____

2. What types of materials did you discover to be poor conductors (insulators)?

   ____

____

3. After testing 10 items, were you able to make more informed predictions in Table 3?

____

____

4. Look at the simple circuit diagram below. If the switch is made from a conductor, will the lightbulb turn on?

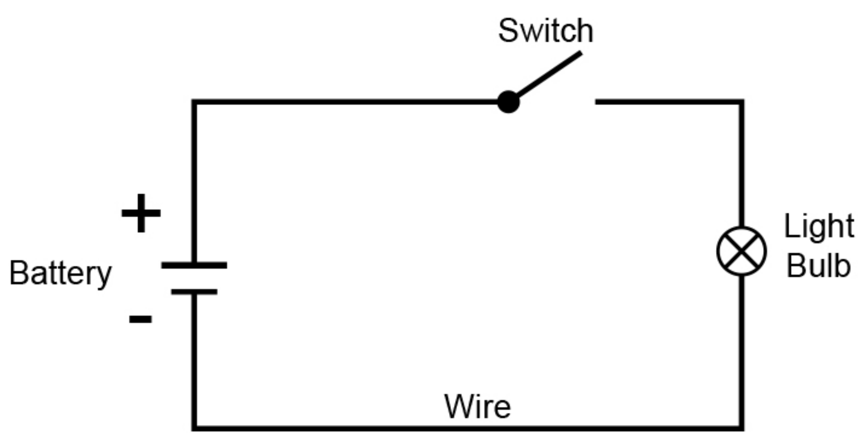
____

(yes)

5. If your switch is made from an insulator, will the lightbulb turn on?

____

(no)



Simple Circuit Diagram

Key Concepts: The crazy circuit energy stick has electrodes on each end, and when they are touched simultaneously using conductive materials (including skin), a complete circuit is created resulting in energy transfer that makes the LED lights begin flashing and sound to be generated. When the circuit pathway is broken by either letting go of one end (air is an insulator), or touching an insulator to one end, the LEDs and soundbox will not be active because there is a gap in the flow of electrons. **Moving electrons are what power everything from this crazy circuit to the lights in your classroom to computers, to everything that uses electricity.** All the wires in your classroom, home, and life are buzzing with jumping electrons.

Remember, atoms are made up of protons and neutrons at the center, and the electron cloud buzzes around the nucleus. These electrons can escape and transition from one atom to another. In this exercise, the battery in the energy stick pushes electrons through the circuit. Moving electrons are called an **electric current**. The LEDs and speaker in the energy stick contain materials that give off light and produce sound when an electric current runs through them. In this activity, you made a very simple circuit with one path for the electrons to take. This is called a **series circuit**. Way to go Electrical Engineers!

Common Misconception: You might think from your experiments that insulators do not conduct electricity. That would be a **misconception**. Any material can conduct an electric current. Materials that are labeled as conductors allow a current to flow **easily**. Materials that are labeled insulators do not allow a current to flow easily, and therefore the current might not be strong enough to power something like an LED. The difference between conductors and insulators is the degree to which they allow an electrical current to flow. Read more [here].

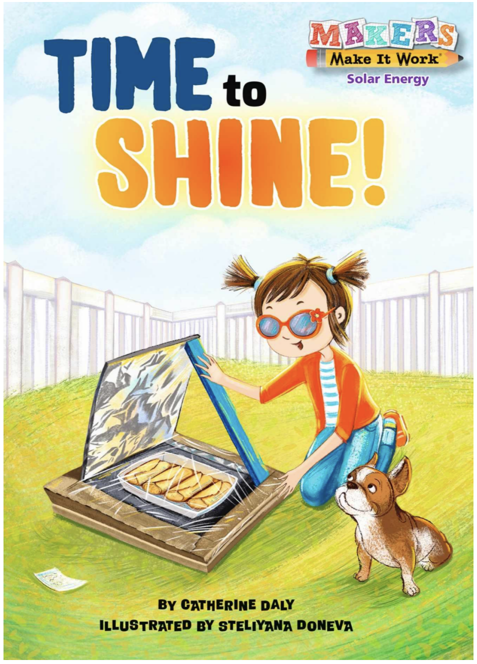
Renewable Energy Connection: In this lab exercise, the energy stick is powered by a battery holding potential chemical energy waiting to be activated. Batteries are likely to play a big role in our renewable energy future. The sun is not always shining to produce solar power, and the wind is not always blowing to produce wind power. Batteries that can store energy produced by renewable sources will be a key component of a 100% renewable energy future. Innovations in battery technologies are desperately needed.

Want to learn more about Circuits? Check out this **Circuit Builder** App. (*unfortunately, this app is $19.99. There are free simulators out there, but this was the best one we tested for this age range).*

(Optional) Online Extension Activity: Imagination Station

Using what you have learned today, brainstorm and sketch out a fun invention that needs a circuit to work. Once you have created a rough draft of your design here, move over to TinkerCad to create a 3D model of your invention. **Career Connection:** Architects, Electrical Engineers, Electronics Engineers, Roboticists, Interior Designers, City Planners, some Scientists, Mechanical Engineers, Artists, and Manufacturing Engineers all use CAD software in their professions.

Reading Exercise 2: Time to Shine *(1-class period or less)*



Read [this book] out loud in your classroom. It will serve as a jumping off point for Lab 3: Solar Rover Racing and Engineering. For older students, you may want them to read this on their own or with a partner. One copy has been provided for you in your classroom toolkit. If you need more copies, you may want to reach out to your school librarian. This book will help to inspire young learners to think like an engineer. Engineers recognize problems and use materials and tools to design, test and create solutions.

The reading level for this book is for K-3, so it may be too easy for 4-5. However, students of all ages can appreciate Sammi's creativity, empathy, and engineering skills. This story will also introduce your students to solar energy and how solar panels work to provide energy. This builds on what they learned about electricity generation in the first reading exercise. In this book, Sammi creates a solar oven to capture light energy, convert it to heat, and uses that heat to cook dinner. In Lab 3, your students will engineer a solar rover and discover how sunlight can be converted to electrical power that spins a motor and propels their rover forward.

Suggested Embedded Reading Commentary

There are numerous fact bubbles throughout the book that provide you and your students with detailed explanations about solar energy. Take time to explore and discuss these.

- **Page 6 -** *Oh no! The power went out. Ask your students,* "Thinking back to what you learned in the first reading exercise, what do you think caused the power to shut off?" *Sample answer: Lightning generally hits the tallest objects to serve as conductors - the fastest pathway to the ground. Utility poles, wires, and transformers are easy targets for lightning and will be damaged if struck. Lightning and wind can also cause trees to fall on wires which can also break the circuit loop. Car accidents into poles holding power lines can cut energy as well.*
- **Page 8 -** *After a power outage, it is important to avoid opening the refrigerator door as much as possible. Each time you open the door, you let cold air out, and warm air in.*
- **Page 10 -** *Ask students about Sammi's behavior. Sammi recognized a problem and she is working on a solution. All solutions begin with an "idea".*
- **Page 11** - For teachers: "*Solar Installations" here means solar panels. Solar panels are more technically referred to as "Photovoltaics" or PVs for short. Photovoltaic systems do not have moving parts or steam production to power generators like we learned about in the first reading exercise. Instead, sunlight shines on the solar panels and causes an electric current to be generated directly in the form of direct current (DC) electricity. Thousands of photovoltaic systems are used in Hawaiʻi. Some generate power for the building they are on such as a home, a school, a commercial building rooftop. Other much larger systems generate power that is provided directly to the electric utilities like HECO, so they can provide energy to their customers. As of 2019, 33% of single-family homes on Oahu, 27% in Maui County, and 20%*

on Hawaiʻi Island have rooftop solar (Source: [HECO](#)). Here are some more state solar facts: [| Solar (hawaii.gov)](#)

- **Page 12-13 -** *Walk through the 6 steps for generating electricity from photovoltaic systems. #2 mentions DC and AC currents. Here is a great video that helps explain the difference between the two. [Circuit Basics: What's the difference between AC and DC power? - YouTube](#) #3 mentions a breaker. Ask students if they have seen the breaker box in their home or their condo. If they haven't, assign them to ask their parents or gaurdien to show them. Breakers allow you to control the flow of electricity in your home. Sometimes you need to turn the power off to a part of your home to do repair work.*
- **Page 16 -** *Solar ovens are a super fun thing to build and a memorable activity for young people. You may want to build and test them with your students as an extension, engineering design activity using materials from home. STEMworks K-2 Renewable Energy Curriculum for HSEO has directions. There are also many designs you can find online.*
- **Page 21 -** *"insulation" here is referring to materials that trap heat. Just like the insulators your students tested in Lab 2 which stopped the flow of electrical energy. Insulating materials here stop the flow of heat energy and traps it inside the solar oven. Ask students, "*Remember what you learned in Lab 2, what materials do you think Sammi should use to insulate her solar oven. *Answers: plastic, rubber, glass, wood, ceramics, and air are all good insulators.*
- **Page 22 - 23 -** *Look at the illustrations on these two pages. Ask students,* "Why do you think the solar oven stopped working?" *Students should note that it is cloudy, there is not much direct sunlight.*
- **Page 24** - *It is revealed that the sun moved and the angle of the sun was no longer directly on the solar oven. We have the same problem with solar panels on cloudy days or panels that only receive direct sunlight for a portion of the day. These panels will not generate as much electrical current when the sun is not directly shining on them - you'll have a chance to explore this in Lab 3 with solar rovers. This is also why it is important for buildings to have batteries that can store solar energy.*

Discussion Question: *The last page of the book has several suggested discussion questions.*

1. What were you most surprised to learn about through this reading?

   ____

   ____

2. Sammi built a solar oven to cook food. What would you want to try to use the sun's energy for?

   ____

   ____

   ____

**Affirm their ideas and understanding wherever they are at. In Lab 3, they are going to have an opportunity to explore solar energy in a more tangible way.*

Lab 3: Solar Rover Racing and Engineering *(2-3 class periods)*

NGSS Performance Expectations
3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion. *Students will observe that in no light situations, the motor does not spin and the rover does not move. In low-light situations, the rover may move slowly or intermittently, in strong full-sunlight situations, the rover will move very quickly. Based on the sunlight energy that day, they should be able to predict how their solar rover will perform. You can also test the rover's performance on different surfaces to see which type of surface (smooth, rough, slick) it works best on.* -- **4-PS3-1** Use evidence to construct an explanation relating the speed of an object to the energy of that object. (Does not need to be a quantitative measure of changes in speed or direct quantity of energy) *Students will observe that in no light situations, the motor does not spin and the rover does not move. In low-light situations, the rover may move slowly or intermittently, in strong full-sunlight situations, the rover will move very quickly.* **4-PS3-2** Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. *Students will observe that sunlight energy is converted to electrical energy by the solar panel, which is transferred to the motor via wires. The motor then spins the gears and this propels the rover in a forward motion.* **4-PS3-4** Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. *Students will use a solar panel to convert sunlight into electrical energy that powers a motor. This circuit will convert electrical energy into motion energy of the vehicle.* -- **3-5-ETS1-2** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. *After testing their original solar rover design, students will be challenged to think of ways to improve the performance of the design given a set of constraints.*

This exercise focuses on the following three dimensional learning aspects of NGSS		
Science & Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems. Use evidence (e.g., measurements, observations, patterns) to construct an explanation. Apply scientific ideas to solve design problems. Make observations to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.	**PS2.A: Forces and Motion** The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level) **PS3.A: Definitions of Energy** The faster a given object is moving, the more energy it possesses. **PS3.B: Conservation of Energy and Energy Transfer** Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the	**<u>Patterns</u>** Patterns of change can be used to make predictions. **Energy and Matter** Energy can be transferred in various ways and between objects. - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Engineering, Technology, and Science on Society and the Natural World** Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. - ***Connections to Nature of Science***

Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem.	surrounding air; as a result, the air gets heated and sound is produced.Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. **ETS1.A: Defining Engineering Problems** Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. *(secondary)* **ETS1.B: Developing Possible Solutions** Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions.At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.	**Science is a Human Endeavor** Most scientists and engineers work in teams. Science affects everyday life.
HĀ outcomes practiced: 1. Belonging - students will actively participate, and practice communication skills. 2. Responsibility - students will be active learners, encouraged to ask for help, set goals and complete tasks with their team. 3. Excellence - students will utilize creativity and imagination to problem-solve and innovate their solar oven designs. 4. Aloha - students should learn to appreciate the gifts and talents of their team members, make others feel welcomed and heard, be respectful of all ideas, and share responsibility for the work.		

In the Crazy Circuit Labs, you created circuits that used **chemical energy stored in batteries**. You also tested various materials to **transport energy** (conductors). Just like there are many different materials that can be used to transport energy, there are also many different sources of energy that can be used to **generate electrical energy.**

In the first reading exercise, you learned that energy comes from many sources here on Earth, but *did you know* that **most of them originate from the sun**? *(surprised?)* The law of conservation of energy states that energy cannot be created or destroyed. It can only change form, and energy from the sun shows up in many forms here on our planet:

- Plants turn sunlight into food (chemical energy) through **photosynthesis** and these plants can be eaten to power our bodies.
- Plants, trees, and algae - also known as **biomass** - can be collected and burned to create fire and heat to cook food, and even be used to spin generators to create electricity.
- Animals (including humans) eat these plants and use that same **chemical energy** to live and move.
- **Fossil fuels** like coal, oil, and gas come from ancient decomposed plants and animals (ewww) that we burn to create electricity. Remember, these plants and animals once needed the sun to exist, reproduce, and survive.

- We can also change the form of living plants and algae to oil called **biofuel**, and use that oil similar to the way we use petroleum.
- Wind is created by heat energy from the sun. We can use **wind turbines** to use that mechanical energy and convert it into electricity.
- Water moves at the surface because of the wind (thanks to the sun), and deep in the water column because of heat differences (also from the sun) that create circulation cells. We can harness the motion from waves, tides, and currents to create **hydroelectricity** - electricity from the movement of water.
- We can also directly capture sunlight using **solar** panels to directly convert sunlight into electricity.

The other two forms of energy are not directly from the sun, but we can understand how they work by studying the sun.

- The sun is the ultimate nuclear fusion reactor. It is nuclear fusion that creates the heat and light that the sun produces. **Nuclear power** created here on Earth is not directly from the sun, but mimics the sun's behavior on a tiny scale.
- **Geothermal** energy is energy created from the heat (thermal energy) generated and stored inside the earth. The center of the Earth is thought to be the same temperature as the sun because of nuclear fusion.

The most amazing thing is that the amount of energy the sun sends to the earth in a single day is more than the amount of energy the *entire world* uses in a year! **Solar energy is renewable and abundant**. In this next lab, we are going to explore how energy produced by the sun can be transformed into electrical and mechanical energy using a **solar cell** to power a motor that makes a rover go.Just like Sammi, you're going to practice being an **engineer**!

Prerequisite Knowledge

- *Prior to this lab, students should know or learn about the Engineering Design Process. An infographic is included at the end of this activity.*
- *Remind students that a significant, and positive aspect of Engineering is **failure**. Failure is always an opportunity to learn, grow, and make improvements. Do not shy away from failure.*

Before the Activity

- Identify an appropriate area outside for your rover racetrack. It should be smooth, level, and exposed to direct sunlight.
- Mark a start and finish line with chalk or tape.
- Select groups of 2-4 students (*your kit includes enough supplies for 8 groups*)
- Gather materials (list below)

Materials List

For this activity, each group will need:

- 1 cardboard base (*included*)
- 1 DC Motor (*included*)
- Solar rover accessories - wheels, axels, and gears (*included*)
- 1 mini solar panel, 1-V, 400mA (*included*)
- Wire stripper (included)
- Rubber Mallet or Small Hammer *(not included)*
- Ruler *(not included)*
- Scissors *(not included)*
- Chalk or tape to mark the start and finish lines (*not included*)
- Meter stick or measuring tape *(not included)*
- Timer *(not included)*

Potential Safety Issues

- *Students may get sunburned if in direct sunlight for too long. You may want to have parents send in a hat, sunglasses, or full spectrum, reef safe sunscreen for this activity.*
- *Never touch bare wires that are part of a live circuit. (*current generated by this solar panel is small and will not be harmful).*

Potential Obstacles and Lab Tips

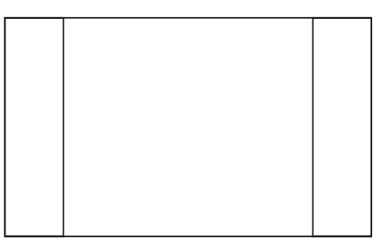
- The wheels and gears are meant to fit tightly onto the axles. If the fit is too tight, you might have to tap the axel with a rubber mallet or hammer.
- The gears need to be lined up well and secured.
- Ideally, test your solar rovers on a sunny day.

Procedure

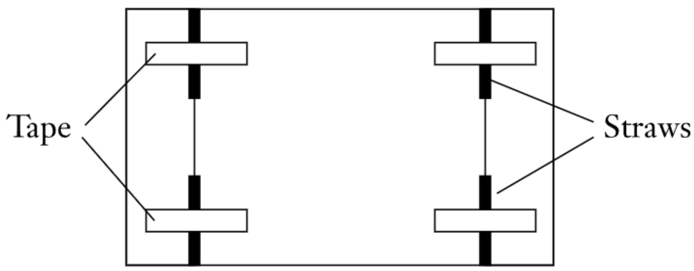
Present the students with this challenge: Today your **engineering design team** is challenged to design a solar rover that can traverse across the moon (*or Mars, or a volcano, etc)*. You will begin by using the kit materials provided to you *(constraints)*. Then, after several trials, you'll be challenged to try to improve your rover using your understanding of light energy, circuits, and engineering (weights, and forces if you've covered those topics previously)

Step 1: Build a Solar Rover Prototype (kit from Flinn Scientific)

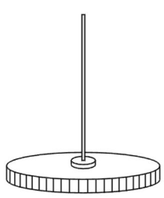
1. Use a pencil to draw a line across the cardboard base 2 cm from each end (rectangle).



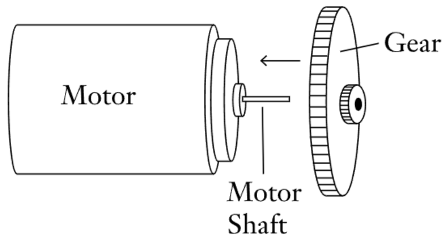
2. Use scissors to cut the straw into four pieces, each 4 cm long.
3. Tape one piece of straw along one pencil like on the base, with the end of the straw even with the edge of the cardboard.
4. Repeat step 3 with a second straw on the opposite end of the line.
5. Repeat steps 3 and 4 with the other line.



6. Dump out your accessory bag of wheels, axles, and gears. Be careful not to lose any pieces.
7. Insert the end of one axle into one wheel hole.
8. Insert the other end of the axle through the two straws on the base.
9. Press a second wheel onto a free end of the axle. Note that if it fits too tightly, set the axle down vertically with one wheel resting on your work surface. Press down on the top wheel and tap lightly with a hammer or rubber mallet. DO NOT BEND THE AXLE.
10. Select the largest gear from the accessory bag.
11. Place the flat side of the geer on the work surface
12. Insert a second axle into the gear.



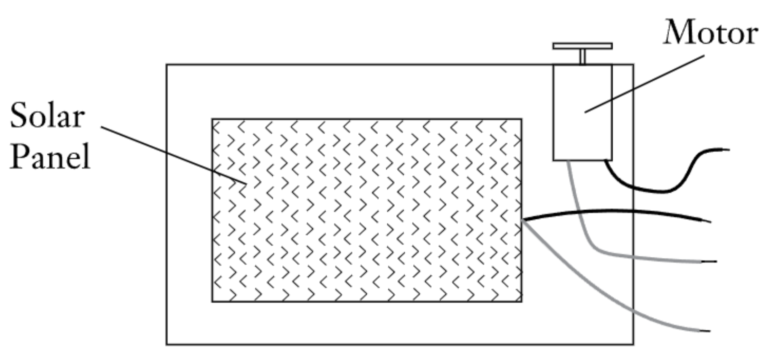
13. Lift the axle and gear and push the gear about 1 cm into the axle.
14. Insert the end of the axle with the gear into a hole on a wheel.
15. Repeat steps 8-9 with the other end of the base.
16. Attach the tires to the wheels.
17. Get the motor and the smallest gear.
18. Insert the motor shaft through the hole in the gear with the flat side of the gear facing towards the motor.



19. Mount the motor on top of the base with tape so the small outer gear attached to the motor meshes with the large gear on the axle. **Note:** It may be necessary to raise the motor up slightly by placing a small piece of folded paper under the motor. Test for proper alignment by setting the rover on a surface and moving it back and forth. When the motor is properly placed, the gear on the motor should mesh with the gear on the axle and turn easily without slipping.

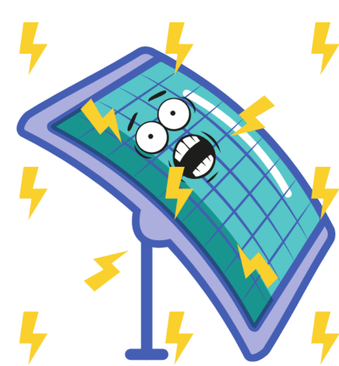
Attaching the Solar Panel

1. Get the solar panel.
2. Note the ends of the wires. If less than 1 cm of bare wire is visible, use wire strippers to remove more of the insulation.
3. Repeat step 2 for the motor wires if needed.
4. Make a loop of masking tape with the sticky side out and place it in the center of the upper side of the cardboard frame.
5. Gently press the solar panel on top of the tape to secure it near the center of the frame

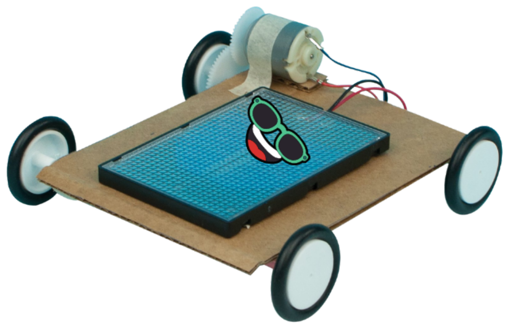


6. Bend the black & blue wires of the solar panel and the motor so they are under the cardboard frame.
7. Turn the rover over so that the solar panel is covered (no light).
8. Twist the bare ends together securely and tape the wires to the underside so they won't touch the work surface or the track surface when the rover is in motion.
9. Repeat steps 6–8 with the red wires of the solar panel and motor. Make sure the wires will not interfere with the motion of the rover.

Note: Connecting the wires should be done with the solar panel covered, otherwise **you will be working with live wires and could get shocked**.



Step 2: Test Your Rover



1. Take the rover outside to your track area. *Be sure to keep the solar panel covered.*
2. Set the rover on the ground and uncover the solar panel.
3. The rover should start moving across the ground. If it does not, check the following.
   a. If the motor does not turn, check the wire connections.
   b. If the motor spins, but the car does not move, check the gear alignment. Make any necessary adjustments.
   c. If the rover veers to the right or left, check the axle alignment and adjust as needed.
4. Note which direction the rover moves. If the motor is in front, it has "front-wheel drive." If the motor is in the back, it has "rear-wheel drive." *(**Note:** Swapping the wire connections will reverse the current, and the motor will spin in the opposite direction.)*
5. Once the rover is functioning well, go to the start of the race track.
6. Set the car down at the start, and **time how long it takes to travel 3 meters**. Record the time and any observations you make in the **Part A Data Table.**
7. Repeat step 6 for a total of 5 trials (*you may adapt this to 3 trials if needed)*.
8. Record the speed for each trial and calculate the average speed.
9. Record the values in the data table.

Step 3: Engineering Design Challenge (EDP Planning Sheet) *Review the engineering design process.*

Your mission is to modify your initial rover prototype to make it faster. The solar panel, motor, motor gear, wheels and axles must remain the same. The cardboard base must be used for the frame, but it may be modified. With your teammates, put on your hard hats, and let your imaginations run wild. Discuss the following questions:

1. How could you improve your solar rover design to make it travel in a straighter line, faster, and/or further? Make a list a variables that might affect your rover's performance (**Ask**)

Angle of solar panel, angle of sun's rays, intensity of light, weight of the rover, size of the gear, front-wheel drive vs rear-wheel drive, aerodynamics, stability of the rover, alignment of the wheels, amount of friction on the tires or other moving parts, the surface that the rover travels over.

2. Think about what materials you have available in your classroom. Using only those materials, sketch out a plan for an improved solar rover design. (**Plan**)

Modifications to the car may include changing the angle of the solar panel, the weight of the car, the frame, its aerodynamics, addition of a wind sail, size of gears, using front-wheel or rear-wheel drive. The intensity of the sunlight cannot be controlled, and if testing is limited to the same class period, then the angle of the sun cannot be controlled/tested either.

3. *Work with your team to build a better solar rover. Note, you should only change one variable at a time. If your team changes more than one variable at once, you won't know which variable made your rover perform better or worse. (**Build**)*

   NREL Solar Car Tips

4. Test the solar rover with your modification to see if it works better (**Test**). Follow the same procedure as you did during your first set of trials, and write your data in the second data table (Datasheet Part B)

   <Repeat Steps 3 & 4 for each variable/modification you want to make>

5. How might you re-engineer your design if you could use any materials without constraints (**Improve**)?

   They might realize that more solar cells would provide more power as would a more powerful motor.

PRINT Lab 3: Testing your original solar rover design (Part A)

Trial	Distance (m)	Time (s)	Speed (m/s)	Observations
1	*3.0*	*5.28*	*0.57*	*rover veered to the left. Made slight adjustment to the axel.*
2				
3				
4				
5				
Average	*3.0*	*5.28*	*0.57*	*On average, the car traveled fairly straight*

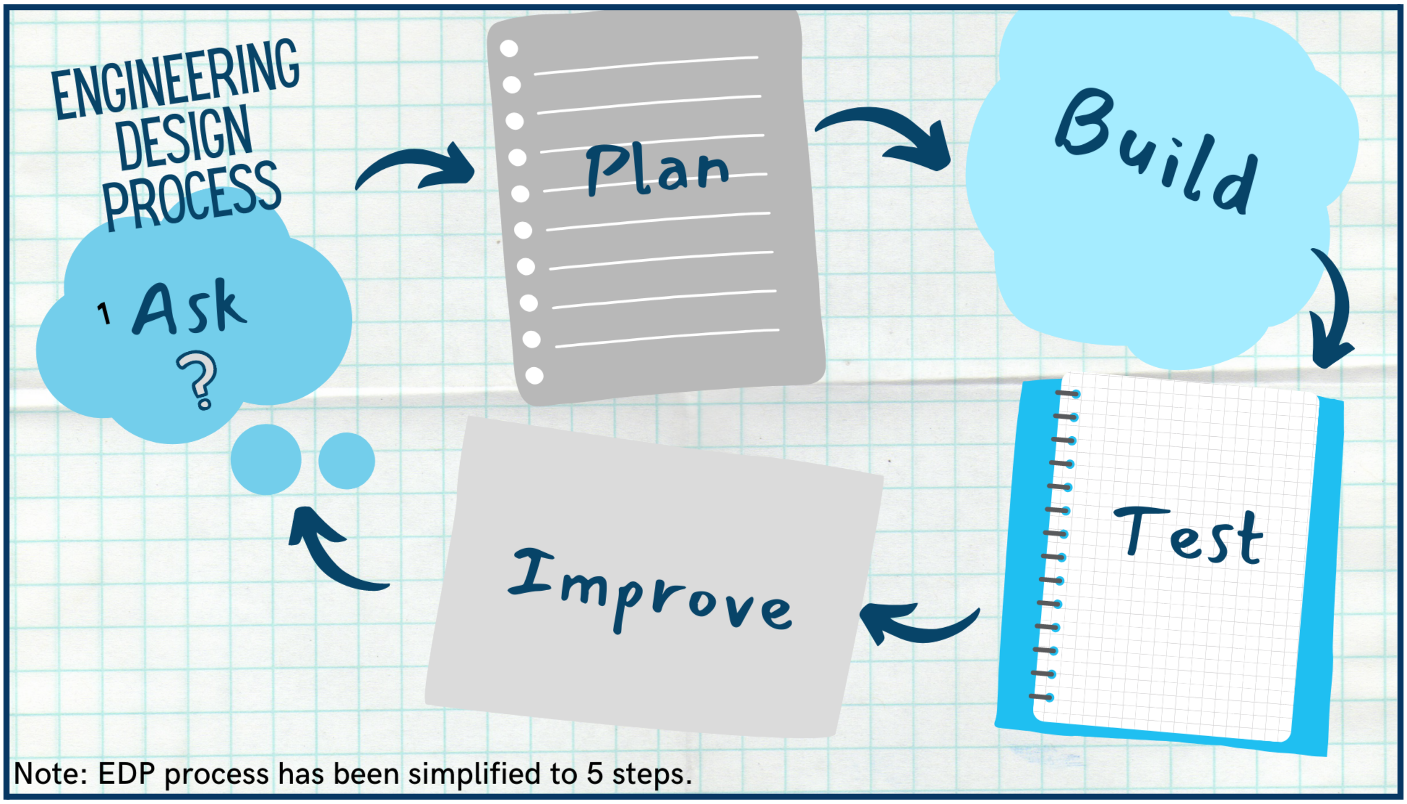
PRINT Lab 3: Testing your modified solar rover design (Part B)

**Print for each variable tested*

Variable Changed ________________________________

Trial	Distance (m)	Time (s)	Speed (m/s)	Observations
1	*3.0*	*4.72*	*0.64*	*Slight hesitation at the start. Checked gear alignment and tried again. Traveled quickly and straight*
2				
3				
4				
5				
Average	*3.0*	*4.72*	*0.64*	*My solar rover travels faster with this modification.*

PRINT Engineering Design Process Planning Sheet



Use this space below to sketch out your plan:

Notes:

Post-Activity Assessment

Discussion Questions: *Solicit and summarize student responses to the following questions:*

1. Describe your final design and give a reason for each of your **modification(s)**. (*Answers will vary.)*

2. Was your final design better than the original? If so, in what ways? (*Answers will vary. For example, their new design may travel faster or in a straighter line. If the average speed increased from 0.58 m/s to 0.64 m/s that means their new design is 10% faster.)*

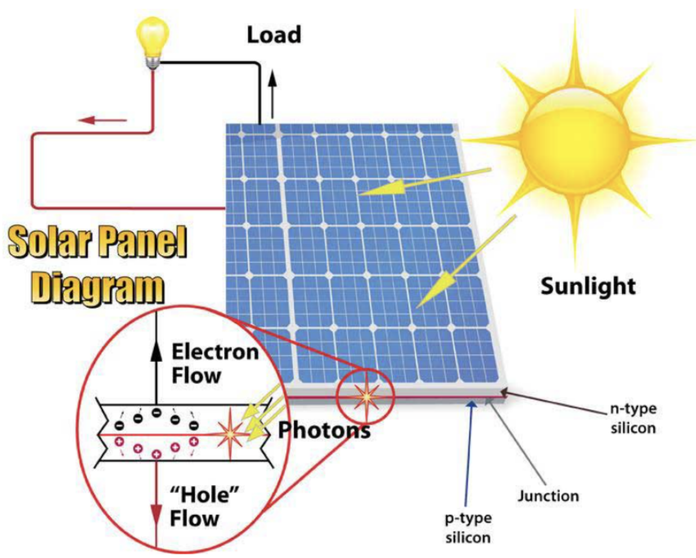
3. If you had any materials available to you and costs did not matter, what else might you do to improve your solar rover? (*Answers will vary. For example, they might add more solar cells in series or parallel, they could use a more powerful motor, or add more gears to create 4-wheel drive.)*

4. Describe how energy is transferred to make your solar rover run. *(Energy from the sun (electromagnetic energy) causes electrons to flow in the solar panel (DC electrical energy). The flow of electrons produces electricity, which causes the motor to turn (mechanical energy). The mechanical energy of the motor is transferred to the gears and from the gears to the wheels. The turning wheels propel the car forward, giving the car kinetic energy.)*

5. What are some advantages and drawbacks of using solar energy to generate electricity? (*Advantages of solar energy are that it is a renewable source, does not pollute, and there is an abundant supply. Drawbacks: using solar energy to generate electricity is currently expensive and not always efficient, only available during the day and dependent upon weather conditions)*

Key Concepts: A solar cell, also called a **photovoltaic** (literally means "light electricity") **cell** (PV cell), is a light-sensitive semiconductor device that uses the photoelectric effect to directly convert sunlight into electricity. PV cells use materials, such as silicon, to absorb energy from sunlight. One side of the cell has a tiny amount of different materials such as Boron or Phosphorus to give a positive electrical charge and the other side a negative electrical charge. The cell on its own has a neutral charge, however, when sunlight shines on the silicon crystals, charged particles in the light upset the charge balance in the cell and creates an electrical charge called a **voltage**. The sunlight energy causes some electrons to break free from the silicon atoms in the cell and these free electrons travel to one side of the cell to create a negative charge. This leaves a positive charge on the other side of the cell. When the PV cell is connected to a closed circuit with wires, the electrons will flow through the cell from the negative side to the positive side, just like what we learned about in the Crazy Circuit Lab.

The amount of current (flow of electrical charge) produced by a PV cell is proportional to the amount of light striking the cell. Panels of solar cells connected together generate enough electricity to power satellites, rovers, homes, and more. Unfortunately, current PV cells can only convert 15-20% of the sun's radiant energy into electricity. This means we need a lot of panels to create enough electricity to power a city, or we need to come up with more efficient PV cells.



*Picture Source: Flinn Scientific

Renewable Energy Connections: In just one day the sun sends more energy to our planet than we, all humans, consume in an entire year. Scientists and engineers around the world are researching ways we can improve our technologies to harness enough solar energy to supply our electricity needs. Solar energy, the conversion of sunlight to electricity, has enormous potential as a clean source of renewable energy to replace fossil fuels. Although solar energy has powered satellites and spacecrafts for more than 50 years, and PV panels are commonly seen on rooftops across Hawaiʻi, solar power accounts for less than 1% of electricity generated in the United States today at large. One drawback to solar generated energy is that, just like the solar rovers you built, solar panels do not work well on cloudy days. This is why we need batteries to store solar energy and/or supplemental energy resources for those cloudy days such as wind generated energy.

Solar power generated energy is one of the largest renewable energy resources we have in Hawai'i. In the future, we will continue to need engineers who understand how to install and repair solar panels, as well as scientists and engineers to invent more efficient panels and better batteries for storing solar energy. Scientists and engineers are continually researching ways to improve solar cell efficiency and also to bring down the cost. Finding ways to economically harness the Sun's energy is an important goal toward more clean energy alternatives.

Solar Power Pros:

- Solar energy is a renewable energy resource. We will never run out of sunlight in our lifetimes.
- Once a solar panel setup is paid for, solar energy is free for the life of that panel.
- PV cells can be used to create energy in rural areas, at sea, on top of mountains, and other locations that are far from an electricity generating power plant.
- Solar energy production from a PV panel does not create air pollutants

Solar Power Cons:

- Solar panels only last about 30 years. This means they must be disposed of (solid waste with toxic minerals).
- Solar panels can be expensive to make because they are fragile.
- Minerals used to manufacture PV cells require mining which may have negative effects on the environment.
- Solar panels only work when the sun is shining.
- Currently, panels take up a lot of space because they are not very efficient yet.

**If you have time, you may want your students to research the pros and cons of solar power on their own.*

Career Connection: Solar jobs are on the rise! Solar jobs require skills in science, technology, engineering, art, and mathematics. In Hawai'i, there is a growing need for solar panel installers and technicians. The installers are people who know how solar panels work, how to install them on rooftops or wherever the panels will be stationed, and connect them up to the proper wires. Solar technicians are people who can help check and repair solar systems once they are installed. There are several programs to learn how to become a solar installer and/or technician at the University of Hawai'i Community Colleges.

Video Resources:

- Solar for Schools
- Renewable Energy 101: How Does Solar Energy Work? - YouTube (Video is 1 minute, 54 seconds)

Online Extension Activity: Renewable vs. Nonrenewable Energy

NGSS Performance Expectations

4-ESS3-1 Earth and Human Activity Obtain and combine information to describe that energy and fuels are derived from natural resources and their use affects the environment. Examples of environmental effects could include loss of habitats, air pollution, water pollution, and climate change.

In this lab, students will explore the concept of renewable and nonrenewable energy through the "More chips?" hands-on activity. They will then watch a series of short videos showing the environmental impacts of different energy sources.

5-ESS3-1 Obtain and combine information about ways individual communities use science ideas to protect the Earth's resource and environment

In this lab, students will draw a sketch of their community, and using what they have learned about renewable energy, they will envision a community that is powered by renewable energy resources, and make an action plan for reducing their own energy consumption.

This exercise focuses on the following three dimensional learning aspects of NGSS

Science & Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluate the merit and accuracy of ideas and methods. Obtain and combine information from books and other reliable media to explain phenomena or solutions to a design problem.	**ESS3.A: Natural Resources** Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. **ESS3.C: Human Impacts on Earth Systems** Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.	**Cause and Effect** Cause and effect relationships are routinely identified and used to explain change. - - - - - - - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Science, Engineering, and Technology**- Knowledge of relevant scientific concepts and research findings is important in engineering. **Influence of Engineering, Technology, and Science on Society and the Natural World-** Over time, people's needs and wants change, as do their demands for new and improved technologies. ***Connections to Nature of Science*** **Science Addresses Questions About the Natural and Material World.** Science findings are limited to questions that can be answered with empirical evidence.

HĀ outcomes practiced: 1. Belonging - students will actively participate, and practice communication skills. 4. Aloha - students should learn to appreciate the gifts and talents of their team members, make others feel welcomed and heard, be respectful of all ideas, and share responsibility for the work.

Part of the scientific process is learning more about what other scientists already know. Scientists become experts in their field not only by doing experiments, but also by reading and researching existing scientific knowledge. Put on your research glasses and see if you can use the internet, books, or magazines to learn more about the different energy resources listed below. Then, after you have gathered reliable information, classify the energy sources in bold as renewable energy or nonrenewable energy. Be sure to cite your sources.

Suggested links to get you started:

- *HECO Renewable Energy Resources*
- Alliant Energy Kids: What is renewable energy
- Article by Solar Schools: Non-renewable energy
- Article by the Union of Concerned Scientists: Benefits of Renewable Energy Use
- TED-Ed Video: A Guide to the Energy of the Earth | Department of Energy Here is a good one to get you started:

Energy Sources: Some of these sources of energy listed below are what we call **renewable** energy resources. This means that they are not in limited supply. Renewable energy resources will be naturally replenished in a short amount of time. Everyday you can come back and there will be more available energy from this source. Some of these energy sources are limited in supply. We call limited resources **nonrenewable** energy resources. This means that there is a limited quantity of it. Once we use all of this resource, it will disappear. It may return in the future, but only after many, many lifetimes. Classify the energy sources in bold as renewable energy or nonrenewable energy. Be sure to cite your sources (what you learned and where you learned it from).

- Plants turn sunlight into food (chemical energy) through **photosynthesis**.

  What I learned:

  Where I learned it from:

  ☐ **Renewable** ☐ **Nonrenewable**

- Plants, trees, and algae - also known as **biomass** - can be collected and burned to create fire and heat to cook food, and even be used to spin generators to create electricity.

  What I learned:

  Where I learned it from:

  ☐ **Renewable** ☐ **Nonrenewable**

- Animals (including humans) eat these plants and use that same **chemical energy** to live and move.

  What I learned:

  Where I learned it from:

  ☐ **Renewable** ☐ **Nonrenewable**

- **Fossil fuels** like coal, oil, and gas come from ancient decomposed plants and animals (ewww) that we burn to create electricity. Remember, these plants and animals once needed the sun to exist, reproduce, and survive.

  What I learned:

  Where I learned it from:

  ☐ **Renewable** ☐ **Nonrenewable**

- We can also change the form of living plants and algae to oil called **biofuel**, and use that oil similar to the way we use petroleum.

  What I learned:

  Where I learned it from:

  ☐ **Renewable** ☐ **Nonrenewable**

- Wind is created by heat energy from the sun. We can use **wind turbines** to use that mechanical energy and convert it into electricity.

  What I learned:

  Where I learned it from:

  ☐ **Renewable** ☐ **Nonrenewable**

- Water moves at the surface because of the wind (thanks to the sun), and deep in the water column because of heat differences (also from the sun) that create circulation cells. We can harness the motion from waves, tides, and currents to create **hydroelectricity**.

  What I learned:

  Where I learned it from:

  ☐ **Renewable** ☐ **Nonrenewable**

- We can also directly capture sunlight using **solar** panels to make electricity.

  What I learned:

  Where I learned it from:

  ☐ **Renewable** ☐ **Nonrenewable**

- The sun is the ultimate nuclear fusion reactor. It is nuclear fusion that creates the heat and light that the sun produces. **Nuclear power** created here on Earth is not directly from the sun, but mimics the sun's behavior on a tiny scale.

  What I learned:

  Where I learned it from:

  ☐ **Renewable** ☐ **Nonrenewable**

- **Geothermal** energy is energy created from the heat (thermal energy) generated and stored inside the earth. The center of the Earth is thought to be the same temperature as the sun because of nuclear fusion.

  What I learned:

  Where I learned it from:

  ☐ **Renewable** ☐ **Nonrenewable**

- *You may also ask if they think* ***electricity*** *is renewable or nonrenewable? That is a trick question because it will depend on what resource was used to generate the electricity. Remember electricity is a carrier of energy, it is not a source of energy. Data for Hawai'i, Energy profile can be found here: Hawaii Energy Facts and Figures*

Identify the resource

Color the box with the correct classification - renewable or non-renewable energy resource

Solar

Renewable

Non-renewable

Coal

Renewable

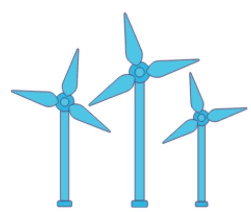
Non-renewable

Oil

Renewable

Non-renewable

Wind



Renewable

Non-renewable

Hydro

Renewable

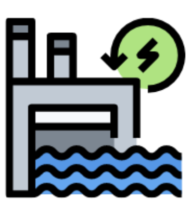
Non-renewable

Gas

Renewable

Non-renewable

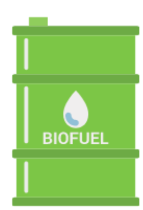
Tidal



Renewable

Non-renewable

Biofuel



Renewable

Non-renewable

Key Concepts: **Natural resources** are things, materials, substances and components found in the natural environment. There are two types of natural resources: renewable resources and nonrenewable resources. Renewable resources can be regenerated if they are alive such as biomass or can be replenished by physical means such as wind, solar energy, or wave energy. In theory, renewable resources will never run out. Nonrenewable resources cannot be regenerated or replenished by natural processes on human timescales. There is a limited amount of nonrenewable resources; once they are used up, they are gone. Fossil fuels, minerals and metals are examples of nonrenewable natural resources. Technically, fossil fuels are continually being made, however, the process is extremely slow, and we use fossil fuels at a much faster rate than they are created. Overtime, our population is growing and our nonrenewable resources are being depleted at a faster rate. This is just one reason why it is wise to make the transition to renewable energy resources.

Some children may not realize that electricity production requires the use of natural resources, or that natural resources can be limited. They may also not realize that man-made objects are created by using natural resources. For example, you cannot find a computer in the wild, but the metals and materials that make up a computer come from the natural environment and the transportation and manufacturing of computers requires fuels and electricity which also come from natural resources.

Renewable Energy Connection: In addition to their negative environmental impacts, fossil fuels are becoming increasingly harder to find, and it is urgent, for the sake of our climate and society, that we transition quickly to renewable energy resources for our energy needs. Engineers and scientists are racing to find solutions for more efficient and less expensive ways to capture and use renewable resources.

Action Challenge: Energy Reduction Pledge

Did you know that Hawai‘i was the first state to set a deadline for generating 100% of its electricity from renewable energy sources? Our state has a goal to achieve this milestone by 2045. To achieve this, all people and communities must get onboard. Now that you know more about renewable and nonrenewable energy resources, let’s take a look at how your school works.

Part 1: School Energy Survey and Action Plan

**Take your students on a mini-field trip around your school campus to see all the ways that energy is used at school. You may want to line up conversations with key personnel such as the principal, cafeteria staff, janitorial staff, and/or even ask for your school’s electricity bill.)*

Question	Who did you ask?	What did you learn?
What kind of energy cools our school on hot days?		
What kind of energy do we use to cook our food for lunch?		

What kind of energy heats up the water in the bathroom sink?		
What kind of energy fuels our school buses?		
What kind of energy do we use for our lights?		
What kind of energy do we use to charge our computers?		
How do we waste energy at our school?		
How do we save energy at our school?		
How can we save more energy at our school?		

Classroom Action Plan *What actions will your class take to save energy in your classroom? Is there anything your class could do to start an energy-saving campaign at your school?*

Part 2: Develop a Personal Action Plan

Brainstorm: *Solicit student responses on a whiteboard, blackboard, or jamboard. For older students, you may want them to write a paragraph or two on a sheet of paper or in a composition notebook.*

1. How do you use energy in your daily Life?
2. What are some ways that you can reduce your energy consumption?
3. How will reducing your energy consumption affect our natural resources?

Take the energy reduction pledge: *After discussing as a class, have each student fill out the energy pledge certificate below with actions that are most applicable and meaningful to them. Check in with them in one week to see if they have been successful in keeping their pledge. You may take their word for it, or ask parents to check the box if applicable. It is okay if they fail to keep the pledge. We all struggle with behavioral changes. Use that as a learning opportunity to discuss why they failed (triggers? unusual events?) and how they can get back on track to becoming an energy warrior.*

Some possible things they can do: Turning off the lights when you leave the room; Unplugging computers, phones, and other devices when not in use; Going outside to play instead of playing video games or watching TV Turning off the TV when nobody is watching it; Washing dishes with cold water (warming up the water requires electricity); Powering down the classroom computers on the weekend and during breaks; Using less resources like paper (saves energy in the production stage of products); reduce turning up the air conditioner in the summer by a few degrees to save electricity; Opening the windows and using natural light instead of electricity during daylight hours; Transportation: Walking or biking to school, carpooling with friends, or taking the bus, or rideshares to run errands.

NAME: CLASS: DATE:

My Energy Reduction Pledge

Using natural resources to create energy to power my home, computers, favorite electronics, vehicle, and other things that require energy can have negative environmental impacts. I can make a difference with my actions. I pledge to reduce my energy consumption in these three ways:

Introduction How do you use energy in your everyday life?

Action Item 1	Action Item 2	Action Item 3

1-Week Check-In ☐ 1-Month Check-In ☐

Key Concepts: Note that even renewable energy sources need nonrenewable resources to produce wind turbine blades, lithium for batteries, metals for solar cells and wires. If we cut down a forest to burn the biomass (lumber) for fuel faster than trees can grow, that resource may soon no longer exist. Any natural resource that we use, be it renewable or nonrenewable, will have some environmental impact. We must consider life technology life cycles and weigh the pros and cons. Even if we transition to 100% renewable energy for electricity production in our state, it is still important to conserve energy where we can. Young students often do not think about where their energy comes from. This activity aimed to build awareness about the energy sources that are used to power the everyday environment.

Renewable Energy Connection: Renewable energy resources are ultimately our best option to continue to power our energy needs as human populations continue to grow. The Hawaiʻi State Energy Office is working within its means to set clean energy goals for our state. However, each of us as individuals need to consider our energy consumption and create an action plan for conserving energy. Using renewable energy will also help us to reduce our environmental impact so that we can enjoy the natural gifts and beauty of our planet for generations to come.

Conclusion

No single person or technology is going to solve our energy needs or environmental problems. Solar power is fantastic, but solar derived energy alone will not provide all the energy resources we need. We must all work together to reduce our energy consumption, and to work toward powering our energy needs with a balanced portfolio of renewable energy resources. In the future, we will continue to need scientific and engineering breakthroughs in the energy sector, and maybe someone, possibly you, will help.

Mahalo nui loa for joining us on this energy exploration to learn more about circuits, electricity, and energy resources. With your help our future will be bright! ***Learn more about Hawai'i's Clean Energy Initiative by visiting:*** ***| Securing the Renewable Future (Hawaiʻi.gov)*** **energy.Hawaiʻi.gov**

Hawaiʻi - QUICK FACTS

- Hawaiʻi was the first state to set a deadline for generating 100% of its electricity from renewable energy sources, which is required to be achieved by 2045.
- Despite being among the five states with the lowest total energy consumption, Hawaiʻi uses about 11 times more energy than it produces. More than four-fifths of Hawaiʻi's energy consumption is petroleum, making it the most petroleum-dependent state.
- In 2019, solar power provided more than half of Hawaiʻi's total renewable electricity generation, primarily from small-scale, customer-sited solar panel systems, which have roughly tripled in capacity since 2015.
- The amount of Hawaiʻi's coal-fired generation in 2019 was the lowest since 1992, and coal fueled 12% of the state's electricity generation. The state's one coal-fired power plant is scheduled to be retired in 2022.

- Hawai‘i has the highest average electricity retail price of any state, in part because it relies on petroleum for more than 60% of its electricity generation.
- Current Renewable portfolio standards (RPS)
  - Hawai‘i Island - 43%
  - Kauai - 56%
  - Maui County (including Molokai and Lanai) - 41%
  - Oahu - 25%
- Last Updated: January 21, 2021 SOURCE: EIA.GOV

Words to know:

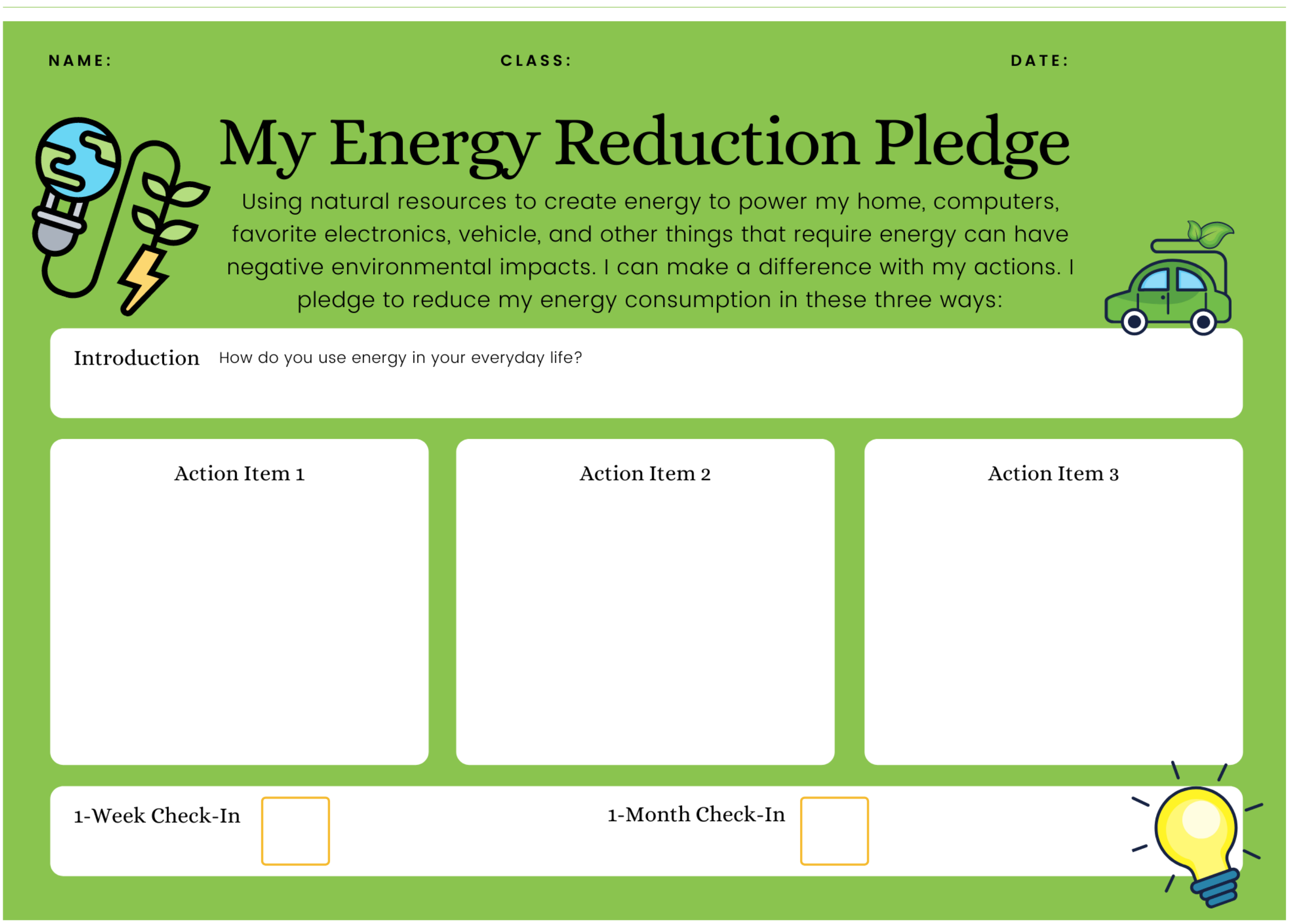
- Air pollution: chemicals like carbon and methane that are put into the air in such large doses that they are harmful for humans, animals, and the environment. Some forms of air pollution like smoke from burning coal can be seen, and some are invisible gases.
- Bioenergy: energy contained in living or recently living things.
- Biofuel: liquid fuel created from vegetation sources.
- Biogas: gas made from something that was alive.
- Biomass: plant materials and animal waste used as fuel.
- Climate Change: a change in the long-term average weather patterns of a place. Weather is day to day, climate is decade to decade.
- Conserve: to use less of something like electricity or water.
- Data: facts about something that have been measured and observed that can be analyzed.
- Efficient: wasting as little as possible; working as best as possible with fewer resources
- Emissions: something that is sent or given out, such as smoke, gas, heat, or light.
- Engineer: a person who uses science, math, and creativity to design and build things.
- Engineering: the use of science and math in the design and construction of things.
- Fossil Fuels: coal, oil, natural gas. These energy resources come from the fossils of plants and tiny animals that lived millions of years ago.
- Geothermal: heat energy from beneath the earth’s surface.
- Hydropower: energy produced by the movement of water.
- Innovation: a new invention or way of doing something.
- Photosynthesis: the process plants use to convert the sun’s energy into food.
- Photovoltaics: technology that converts sunlight into electricity.
- Renewable energy: a form of energy that doesn’t get used up, including the energy from the sun, wind, and tides.
- Scientific Method: the way scientists ask questions and do experiments to try to test or prove an idea.
- Solar Power: energy from the sun that is converted into electricity.
- Sustainable: a process or resource that can be used without being completely used up or destroyed.
- Technology: tools, methods, and systems used to solve a problem or do work.
- Trade-off: a compromise.

At Home Extension Activities (*Homework*)

1. **Energy Reduction Action Plan**

This week, your child learned all about energy - what it is, where we get it from, and why it is important. They had the opportunity to explore different sources of energy including renewable and nonrenewable resources; how electricity is produced; how circuits work; and they engineered (designed, built, and tested) their very own solar rover.

At school, they also learned what types of energy their school uses for electricity (lights, computers), cooking, heating hot water, fueling the school bus and more. As a class, they created an energy conservation plan. Each student also created an individual energy reduction action plan to reduce their energy consumption in their daily lives. Take a moment to talk with your child, and ask them what their personal action plan is. You may then want to build on their action plan as a household. For the next week, and month, work together to make your Energy Reduction Pledge a reality.



NAME: CLASS: DATE:

My Energy Reduction Pledge

Using natural resources to create energy to power my home, computers, favorite electronics, vehicle, and other things that require energy can have negative environmental impacts. I can make a difference with my actions. I pledge to reduce my energy consumption in these three ways:

Introduction — How do you use energy in your everyday life?

Action Item 1	Action Item 2	Action Item 3

1-Week Check-In ☐ 1-Month Check-In ☐

2. **Fun, Hands-on Activity: Cookie Mining**

Things that people use from the natural world around us, like plants, minerals, water, wind, and sunshine, are called **natural resources**. Natural resources help to sustain populations by providing humans with food, shelter, technologies, and energy.

In this activity, you and your child will explore how taking resources from nature through a process called **mining** can negatively affect the natural environment. A few things that we mine (or take) from the earth include:

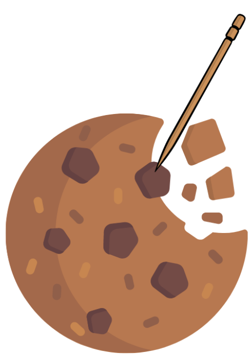
- Fossil Fuels like Coal and Petroleum (we burn for electricity generation)
- Copper (used for wires and electrical hardware)
- Rare-Earth Minerals (for electronics)
- Steel & Iron (used for wind turbines)
- Lithium (used in batteries)

Let's test for ourselves what impact mining can have on the ʻāina.

Materials:

For this activity, you will need:

- 1 chocolate chip cookie (or more if it is snack time)
- 1 toothpick or "mining tool" of some sort
- A mess mat or hard surface (place mat, wax paper, something that won't shred easily).
- Graph or regular paper
- Pencil or pen
- Timer (optional)



Procedure:

1. Gather your materials, and place your cookie on the graph paper.
2. Trace around the cookie with a pencil.
3. Using only the toothpick as a mining tool, extract the chocolate chip "coal" from the cookie. Do not use your fingers.
4. Place each piece of extracted "coal" outside of your mining area.
5. Set the timer for two minutes. When the time is up, count your coal.
6. Look back at your original cookie outline. Now you need to **reclaim** your mined area by putting the cookie back together.

Discussion:

1. Were you able to put the land (cookie) back together?
2. Knowing that you will want to reclaim the land, does it make sense to extract all the "coal"?

Reclamation is a process that mining companies use to try to return the land back to the way it was to prevent habitat loss, erosion, and to restore ecological balance. However, as you saw here in this experiment, reclamation can sometimes take a long time and can be difficult to do.

EXTERNAL RESOURCES ON PERFORMANCE EXPECTATIONS

How to Read the Next Generation Science Standards

NGSS Webpage that allows you to search for Performance Expectations based on grade, discipline, SEP, DCI, and/or CCC

Evidence Statements (describe a detailed look at the NGSS performance expectations)

NSTA Performance Expectation Finder

www.stemworkshawaii.org energy.hawaii.gov