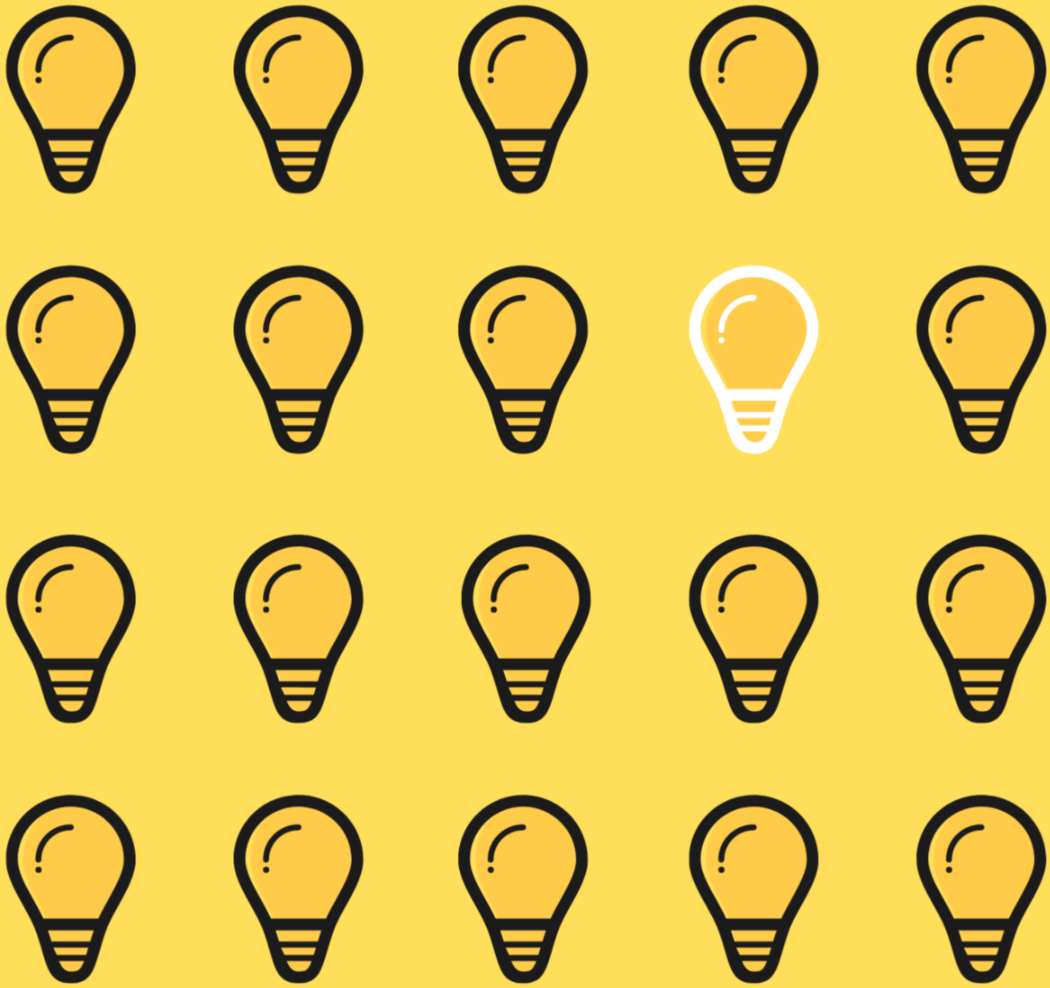


HAWAI`I STATE ENERGY OFFICE

# RENEWABLE ENERGY LABS

GRADES: 6-8 #2

State of Hawai‘i

Department of Business, Economic Development, and Tourism

**Hawai‘i State Energy Office**

**CLEAN ENERGY EDUCATION CURRICULA and TOOLKITS**

The purpose of the Hawai‘i 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 Hawai‘i 's transition to a decarbonized economy; and to encourage Hawai‘i 's K-12 students to become the next generation of clean energy leaders.

This project and material is based upon work supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE) under the State Energy Program Award Number DE-EE0008286.

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

| Curriculum at a Glance | |
|---|---|
| Grade Levels | 6 - 8 |
| Time Required | 5 - 10 Class Periods |
| Activity Group Sizes | 3 - 7 |
| NGSS Performance Expectations | MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4, MS-ESS3-3, MS-PS1-3, MS-PS3-2, MS Engineering Design NGSS PDF |
| **Activity Title** | **Guiding Questions** |
| **Phenomena Exploration:** Electricity | What things need electricity to work?<br>Where does electricity come from? |
| **Kit Discovery:** Snap Circuit My Home Plus | What is included in my kit?<br>What can I create with the modular snap circuit pieces? |
| **Lab 1:** Circuit Basics | How is electricity transported?<br>How does a battery work?<br>What happens when I flip a light switch? |
| **Lab 2:** Electricity Generation | How is electricity generated?<br>What are the pros and cons of different energy sources?<br>What happens to an LED powered by wind or solar if I change a variable such as wind speed or light intensity? |
| **Lab 3:** Home Wiring | What types of circuits work best in a home's electrical system?<br>Can various energy resources be used together to power a home? |
| **Lab 4:** Engineering Design Challenge - 3D Home | What processes and tools do engineers use?<br>How can I create an optimal design with constraints? |
| **Online Extension:** | Practice innovation and more complex circuits. |
| **At Home Extension Lessons:** Energy Consumption Monitoring | What items in my home need electricity to work?<br>How do I read an electric bill?<br>How can I reduce energy consumption? Test this for one month! |

## 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 learners in grades 6-8 with the opportunity to begin building **energy literacy** through exploration, experimentation, engineering, and hands-on fun. In the pages that follow, *your students* will explore different types of energy sources including renewable and non-renewable sources; experiment with creating circuits by testing series and parallel circuit designs; and discover how electricity is delivered through circuits to power different objects in a home. Students will also use common electrical symbols to create their own blueprints, and practice the engineering design process using constraints to develop their very own home wiring system. They will then test their design by building it using the snap circuit modular pieces, and modifying their "wiring" until an optimal solution is reached.  Throughout, they will be exposed to fun facts, key renewable energy concepts, careers, and more.

The classroom toolkit for this curriculum includes a book on solar powered homes for design inspiration and building literacy and critical thinking skills. The toolkit also includes Snap Circuit My Home Plus kits and rechargeable batteries so that you can continue to teach this curriculum year after year. In each of the activities and four hands-on labs, students will make hypotheses, develop models, collect data, analyze their results, revise their designs, and present their solutions - just like real scientists and engineers. 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 home electricity usage to engage other members of the household. *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 that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. *In Lab 1, students will attempt to build a circuit using the snap circuit pieces without any constraints or assistance from the Snap Circuits project book. Some groups may fail to create a functioning circuit, and others may struggle through several designs. During the process of exploration and discovery, they should ask questions based on what they observed (why did a certain arrangement work or fail), note any surprising results, and seek additional information about how they can build more complex circuits using the pieces provided by the kit. This exploration activity should help reveal gaps in their knowledge and understanding of electricity and circuits.*

- Ask questions to clarify and/or refine a model, an explanation, or an engineering problem. *In each of the four labs, students are encouraged to ask questions about how circuits work to power technologies in their home. In Labs 2-4 they should ask questions about how they can modify their circuit model with other snap circuit pieces to perform a new action or working configuration, and how to expand upon the kit's 3D house models provided to create their own.*

**Developing and Using Models:** A practice of both science and engineering is to use and construct **models as helpful tools for representing ideas and explanations**. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

- Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. *In Labs 2 and 3, students will follow the project models to construct various circuits, and test the output from various configurations. For example, an LED light turns on (output) when electricity is generated by the sun (input) using the solar panel and a closed circuit configuration. In Lab 4, they will use the skills and concepts they learned in Labs 1-3 to develop and test their own 3D model, sketched in an engineering blueprint format, of a home that contains both parallel and series circuits powered by wind, solar, and batteries.*

**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.**

- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. *In all four labs, students will need to work together to investigate the phenomena in question for each experiment, and evaluate if they met the goals of the investigation. If a circuit does not perform as required, they have not met the goals of their investigation. In this case, they'll need to work together as a team to troubleshoot their design.*
- Collect data about the performance of a proposed object, tool, process, or system under a range of conditions. *In Lab 2, students will collect data to test how variable wind speed and light intensity affects the brightness of a wind and solar powered LED.*

**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.

- Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. *In all four labs, students will explore, test, and apply the basic principles of circuit design to construct and test powering different pieces of technology such as an LED light or motion sensor. Their circuits will include resistors, capacitors, inductors and source and require an understanding of voltage and current. These principles will be contextualized in terms of real-world settings and objects (i.e. the home).*
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting *In Lab 4, students will design their own home without assistance from the snap circuit manual. This is their opportunity to put what they have learned into practice. Their home design will be limited to the pieces provided in the kit. There will be tradeoffs between what items are powered by wind, solar, and batteries. Their design will likely require testing, revising, and retesting before they end up with a successful home model.*

---

## Career Connections

### Architect

Architecture is the art and science of designing buildings and other built spaces that serve both utilitarian and aesthetic purposes. There are six types of architects: 1) Residential Architects who design homes, 2) Commercial Architects who design commercial buildings, 3) Restoration architects who analyze older structures and design ways to restore them, 4) Landscape Architects who design landscapes for parks, commercials spaces, and homes, 5) Interior designers who design the insides of built structures, and 6) Green Design Architects who make sure a design for any built space is environmentally friendly from the materials used to the energy efficiency of the building.

Renewable energy and architecture come together in an aim to address the global climate crises by reducing greenhouse gas emissions through more sustainable building designs that incorporate renewable energy solutions such as solar panels and seawater cooling. Architects can play a role in helping to design energy efficient buildings - these are buildings that have a reduced need for energy consumption used for ventilation, lighting, cooling and heating. Strategies that architects can use to reduce energy demand include considering orientation to the sun, shading, window-to-wall ratio, roofing and construction materials used. Students will have a chance to think like architects and engineers in the laboratories included herein.

### Engineer

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, modeling, prototyping, and multiple iterations of modifying their designs 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 laboratory activities herein, students will have the opportunity to practice teamwork and their communication skills. The average salary for engineers in Hawaiʻi is $84,631/year.

## Electricians

Electricians are trades people who specialize in electrical wiring of buildings, machines, transmission lines, and related electrical equipment. Electricians may also specialize in wiring ships, airplanes and other mobile platforms. Typically electricians are employed in the installation of new electrical components or the maintenance and repair of existing infrastructure. The average salary of an electrician in Hawaiʻi, as of February 2022, is $33.89/hour.

## 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 **electricity generation, circuits,** and **grids**. Throughout these lessons and hands-on laboratory activities, you will discover the answer to questions like these*:

- **What is energy?**
- **What is electricity?**
- **Where does electricity come from and how does it power the electronics I use daily?**
- **How do we generate electricity to power our homes and communities?**
- **What sources of energy are nonrenewable?**
- **What sources of energy are renewable?**
- **What role do scientists and engineers play in designing buildings that work?**
- **How can I reduce my energy consumption?**

**Take a minute to pose these questions to your students and let them share some of their ideas. There are no right or wrong answers at this point.*

And **more importantly**, you'll **learn how to ask and investigate the answers to your own questions to develop solution**s and **to engineer models**.

So *what is energy*? Well, energy is all around us! It is the power that brings things to life. Energy describes the work that can be done from energy suppliers like fossil fuels such as oil and gas (non-renewable), biofuels, nuclear fuels, wind, and solar radiation (renewable). Electricity is **a carrier** of energy that is produced by one of these resources. We use electricity to carry energy to power our homes and everyday electronics.

In Hawaiʻi, our state established the Hawaiʻi Clean Energy Initiative in 2008 (HCEI) with an ambitious goal to produce **100%** of our energy needs from renewable energy sources like solar, wind, geothermal, hydroelectricity, biomass, and biofuels by the year 2045. As of 2020, 30% of electricity generated in our state has come from renewable sources.

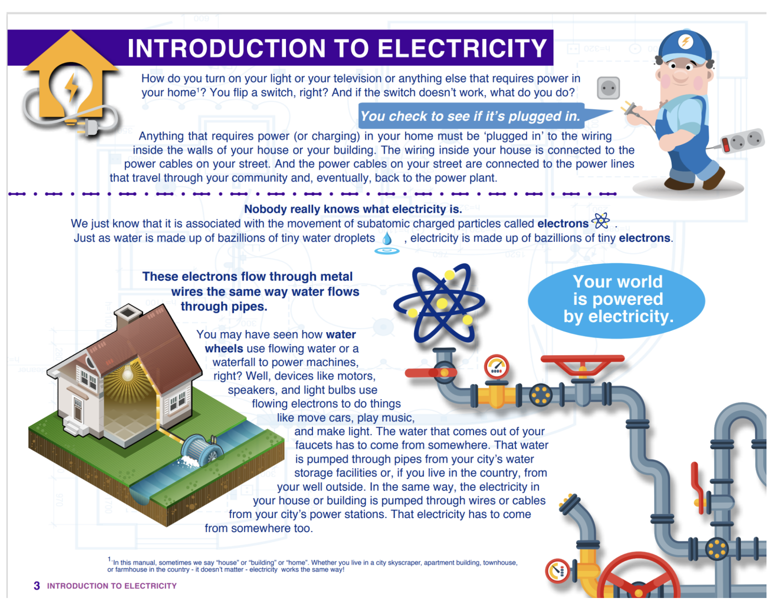
In the labs to follow, you will have an opportunity to test how electricity is produced, and how **circuits** are used to control the flow and transportation of electricity from a point of generation, to various targets that you could find in a home such as lights, motion sensor activated alarms, fans, and doorbells. Let's begin by cataloging items that need electricity to work.

## Phenomena Exploration: Electricity *(1 class period or less)*

It is 6am and your alarm clock beeps. It is hot and muggy outside, but you can hear the hum of the air conditioner or fan keeping the house cool. You jump out of bed, and switch on the lights. In just the first few seconds of being awake, you've already used electricity to wake you up, keep you cool, and to provide light so that you can see while it is still dark. Electricity is everywhere! Whether you live in a skyscraper in urban Honolulu or a home in the countryside of Molokai, our homes, schools, and communities are powered by **electricity**.

To understand electricity, you have to understand the smallest bit of any material called an **atom**. Atoms are made up of tiny particles called **protons** and **neutrons** bundled together at the center, and **electrons** whizzing around in a "cloud". Each electron (-) and proton (+) has an itty-bitty **electric charge**. If two particles have opposite charges they will attract, and if they have the same charge, they will repel each other away. Electrons are special in that they can break free from their original atom, and hop from one atom to another. These adventurous electrons are what make all electronics come to life.

*Want to learn more about how electricity works? You can do a deeper dive by reading pages 3 - 6 in the Snap Circuit My Home Plus Manual.*




*Graphic from the Snap Circuit Manual Page 3. Read more about electricity in the first few pages of this manual.*

**Part 1:** Take a minute to walk around your classroom and if you have time, your school campus. Identify items that need electricity, and where *you think* (your best guess) the electricity comes from:

| **Electricity Exploration and Hypotheses** | | | |
|---|---|---|---|
| | **Item** | **Where does the electricity come from?** | **What is the energy source?** |
| 1 | Lights | | |
| 2 | Air Conditioner | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |

How does electricity get from one place to another like from the wall to your computer? How did it get to the wall? *Answers will vary. There are no right or wrong answers at this point. The purpose of this is for students to self-identify gaps in their knowledge.*

**Part 2:** Now that you have your list, it is time to do some research on how the items you identified are powered. This may require you to do some research on the internet, or even interview folks on your school's maintenance and/or administration team.

| **Electricity Generation - Research** | | | |
|---|---|---|---|
| | **Item** | **Where does the electricity come from?** | **What is the energy source?** |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |

After your **research**, did you discover anything that surprised you?

*Answers will vary. If your school is partially powered by solar power, your students might be surprised to learn this.*

**Check out the HIDOE Dashboard. Mana - HDOE Dashboard - Ahuimanu Elementary (manamonitoring.com)**

**Key Concepts:** Some electrical items like computers, flashlights, and small electronics are powered by batteries, but most of the electricity we use in our world is generated by large generators driven by high pressure steam or water pressure (created by burning fossil fuels), or increasingly by wind or solar power. Wires (made of conductive materials) are used to transport this energy to lights, electrical outlets, air conditioners, and appliances like refrigerators, ovens, and washing machines. Electricity may be transported over very large distances such as a power station miles away, to very tiny distances, like through circuits in your computer. For more details, take a look at pages 3-11 in the snap circuit manual.

While we cannot see electricity, that does not mean it is magic -  it's science, and it's really easy to learn. Let's use the Snap Circuit My Home Plus Kit to discover more about how our buildings and electronics are powered.

## **Kit Discovery: Snap Circuit My Home Plus** *(1 - 2 class periods)*

### Before the Activity

- Have students select their teams. Make sure that each team member has a chance to participate in the hands-on portion of the lab

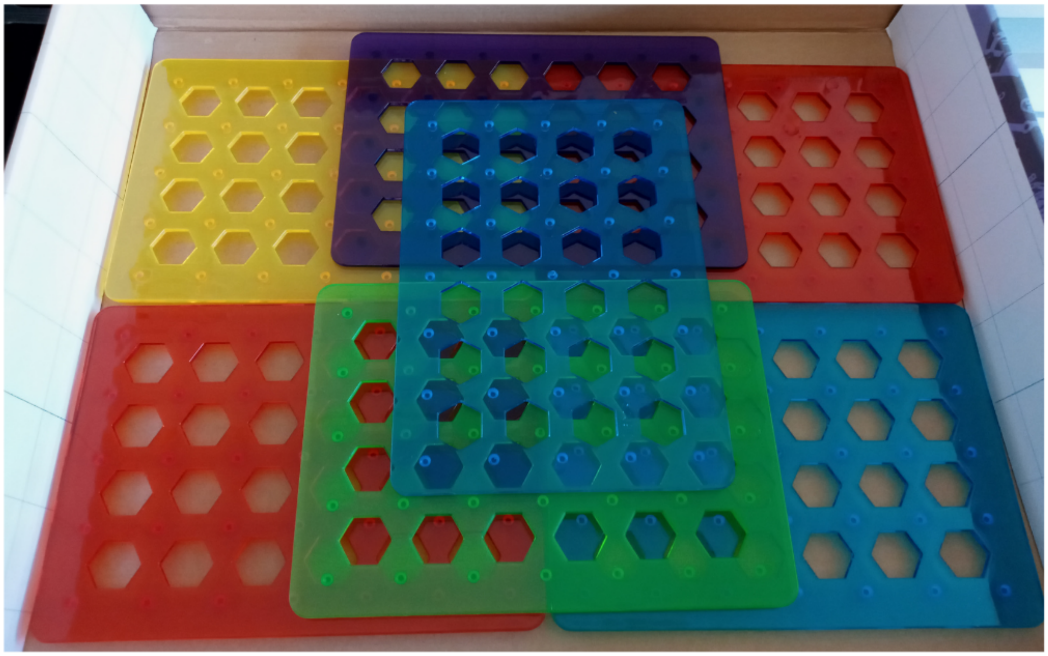
### Materials List - For this activity, each group will need:

- One Snap Circuit My Home Plus Kit per team
- 3 Charged Batteries per kit
- Scratch Paper (*not included*)
- Pencil (*not included*)

This kit provides a fun, tangible way for you to research how electricity works **by doing**.

**Each kit includes:**

- Seven colored base grids to construct 2D and 3D circuits



- Approximately 60 parts. A list of parts can be found on Page 76 of the manual.

- Illustrated, easy-to-use, full-color project manual with 53 different projects to learn about circuitry, electrical engineering, chemical energy, solar energy, wind energy, lights, dimmer switches, security systems, alarms, motion detectors, fan speeds, appliance motors, and much more!


*Break up into evenly divided teams*

**Part 1: Identify Parts**

Procedure:

1. Open up the snap circuit kit, and turn the manual to page 76.
2. Match the items from the Parts List with the parts in the kit.
3. Are there any parts that are unfamiliar to you (you don't know what they are, what they do, or how they work)? If so, check the box next to those parts in Column 1 of Table 1 below.

Table 1: Snap Circuit Parts

| Check if unfamiliar | **Part Name** | **Research** |
|---|---|---|
| ▢ | Snap wires | |
| ▢ | Solar Cell | |
| ▢ | Capacitor | |
| ▢ | LED | |
| ▢ | Fiber Optic Festive Tree | |
| ▢ | Jumper wire<br>(black, red, or blue) | |
| ▢ | 4.5V<br>(for the lamp) | |
| ▢ | Meter | |
| ▢ | Transistor | |
| ▢ | Phototransistor | |
| ▢ | Adjustable Transistor | |
| ▢ | 5.1kΩ Resistor | |
| ▢ | 10kΩ Adjustable Resistor | |
| ▢ | Slide Switch | |
| ▢ | Press Switch | |
| ▢ | Speaker | |

| | | |
|---|---|---|
| ▢ | Recording IC | |
| ▢ | Motion Detector | |
| ▢ | Melody IC | |
| ▢ | Microphone | |
| ▢ | Other: | |
| ▢ | Other: | |
| Notes: | | |

4. Read through pages 77 - 80 to learn more about each part. Pay special attention to the items that you checked in table 1. *You may want to print as a separate handout.*
5. In your own words, describe what each item is and what it does in Table 1
6. Which items were you most surprised to learn about and why?

7. After learning about the parts in this kit, how do you think you can use them to create and transport electricity?

**Part 2: Kit Discovery Challenge**

Now that you have had a chance to learn about the parts included in your kit, it is time to explore how they work. **Without looking at the manual**, try to assemble a working **circuit**. **Failure is OKAY!** Failure is a huge part of the engineering design process, and each trial is a learning opportunity. You may stop once you are successful or have completed three trials. *It is okay if they fail both challenges.*

**Snap circuits use electronic blocks that snap onto a clear plastic base grid to build different circuits. Use one grid and any combination of blocks to create a working circuit that:**

**Challenge #1: Activates the White LED**

| **Trial** | **Sketch** (sketch a model of your configuration) | **Did it work?** |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| Notes: | | |

| |
|---|
| |

**Challenge #2: Activates the Speaker**

| Trial | **Sketch** (sketch a model of your configuration) | **Did it work?** |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| Notes: | | |

### Kit Discovery Summary:

In this challenge, whether you recognized it or not, you were thinking like an **engineer**! Each trial you completed was part of what is called the **iterative design** process. With each trial, you worked together collaboratively to **troubleshoot**, in order to make improvements, and hopefully bring you one step closer to a functioning circuit.

The snap circuit kit is an example of **modular design**. There are many different components (parts and pieces) that you can assemble in different configurations. If your design did not work, you don't have to take the entire thing apart, but rather you could move or exchange one component. Designing modular products is better for budgets and the environment because they result in less waste.

These challenges also introduced you to **constraints**. You were only permitted three trials and needed to power an LED and a speaker. In reality. All engineers are limited by time and resources. Engineers have to work with what they have in the time they have available to them. Constraints often inspire innovation and creativity.

If you were not successful in completing one or more of the circuit challenges, that is okay! In Lab 1, we're going to learn more about basic circuit designs.

If you were successful in completing one or more of the circuit challenges, congratulations! You created a **closed circuit**. Can you explain how your circuit works to transport electricity? ________

______________________________________________________________________________

______________________________________________________________________________

What type of circuit did you create?

- ☐ Simple Circuit (*powers one item such as one LED)*
- ☐ Series (*individual charge passes through more than one electrical component)*
- ☐ Parallel (*individual charge only follows one branch, multiple branches)*
- ☐ I am not sure (*Most likely response. They likely will not know at this phase.)*

*Here are some examples of series and parallel circuits.*

In Lab 1, we're going to use diagrams and models to learn more about how electricity travels through circuits, basic circuit designs. You'll also build a series circuit model and a parallel circuit model and compare the differences, pros, and cons.

## Lab 1: Circuit Basics *(1-2 class periods*)

| NGSS Performance Expectations | | |
|---|---|---|
| **MS-ETS1-2** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.<br><br>*Students are asked to assemble a simple circuit. Success is measured by whether or not their circuit works to power the light(s). Students will need to use a systematic process to assemble the circuit correctly and to ensure that they have constructed a closed circuit. The constraints (pieces they may use) are provided by the activity.* | | |
| This exercise focuses on the following three dimensional learning aspects of NGSS | | |
| Science & Engineering Practices | Disciplinary Core Idea | Crosscutting Concepts |
| **Engaging in Argument from Evidence**<br>Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.<br>● Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. | **ETS1.B: Developing Possible Solutions**<br>● There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.<br>. | **Energy and Matter**<br>Energy can be transferred in various ways and between objects.<br>- - - - - - - - - - - - - - - -<br>***Connections to Nature of Science***<br><br>**Science is a Human Endeavor**<br>Most scientists and engineers work in teams. Science affects everyday life.<br><br>**Influence of Science, Engineering, and Technology on Society and the Natural World**<br>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. | | |

## Prerequisite Knowledge

*In these experiments students will explore various circuit configurations to power a light. 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 below. Students should know that electricity is the flow of charged particles - electrons flow through conductors. Note - the battery in this kit stores electrical energy as 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

- Have students select their teams. Make sure that each team member has a chance to participate in the hands-on portion of the lab

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

- One Snap Circuit My Home Plus Kit per team
- 3 Charged Batteries per kit
- Scratch Paper (*not included*)
- Pencil (*not included*)

## Potential Safety Issues

- None

## Potential Obstacles

- *Students must pay close attention to how circuits are configured by following the directions provided in the manual. Troubles will usually arise if they left out a piece, such as a single snap hidden under other snaps, or over/under arrangement of pieces. If their circuit design doesn't work, this is a great opportunity for students to practice* ***troubleshooting****.*

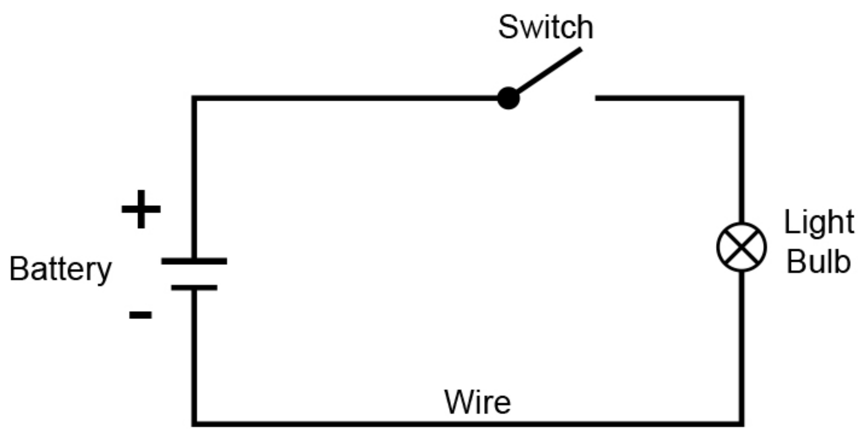
### Pre-Activity Assessment

**Question:** *If you have wires, a battery, and a lightbulb, how can you make the bulb light up?*

____________________________________________________________

____________________________________________________________

____________________________________________________________




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. The battery in this circuit pushes electrons through the loop. These moving electrons are called an **electric current**. 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 from a starting point, through the circuit loop, and back to the starting point again. LEDs contain materials that give off light  and heat when a current runs through it. **Take a look at the simple circuit diagram above and draw the pathway of electrons using arrows.**

**Would the circuit as it is drawn above work? Why or why not?** ___________________________

_______________________________________________________________________________

*Electricity flows from - to + and needs a complete circuit of conducting wire to power electrical components. This means that this diagram would not work, because the switch is not activated in the down position.*

## Procedure

Snap circuits use electronic blocks that snap onto a clear plastic base grid to build different circuits. These blocks have different colors and numbers so you can easily identify them. You may use any of the five base grids for the following activities. Pay careful attention to the diagrams for each configuration.

**Part 1: Build a circuit that turns a light on and off [Project 1, Page 13]**

1. Assemble the circuit
2. Test that your switch works (light turns off and on). If it doesn't, revise your circuit.
3. Turn the switch to "on" and measure the current _____________
4. What happens to the current when the switch is turned off? __________________

Congratulations on building a simple circuit! For deeper learning, complete Parts B - G.

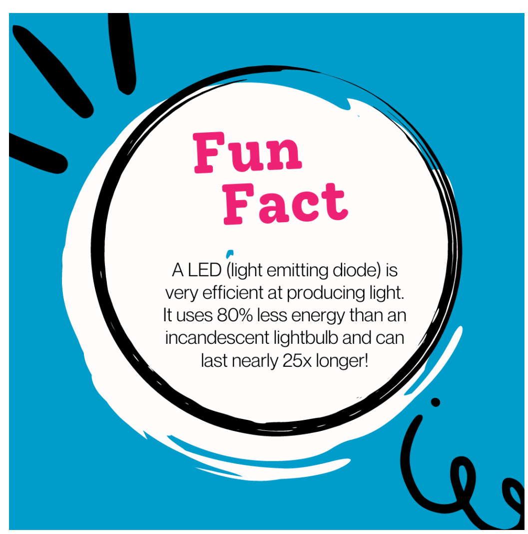
**Key Concepts:** As electricity moves through the wire in the bulb, the electricity is transformed into thermal energy that heats up the filament in the bulb, causing the heated filament to glow. Metal wires allow the electricity to flow, but the outside plastic covering around the bulb is an **insulator** that prevents electricity from transferring another **conductor** like your skin (thank goodness).

**Part 2: Build a series circuit that turns two lights [Project 2, Page 15]**

1. Assemble the circuit as shown on page 15.
2. Test that the color LED, Lamp, Motor, Melody IC, and White LED all work. If not, revise your circuit.
3. Try removing the lamp, motor, melody IC, and LEDs one at a time. What happens to the measured voltage and why? ______________________________________________
   ________________________________________________________________
   ________________________________________________________________
   *The lamp needs the most current to work, so it has the greatest effect on the battery voltage.*

4. What are some advantages/disadvantages of a series circuit? ____________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   *In a series circuit, you can use one switch to turn off all the lights at once, instead of using single switches to turn each one on and off. Another positive is that the wiring is very simple. However, if one light goes out, they all will.*
5. What could you do to increase the brightness of the LED or the speed of the motor? ______
   ________________________________________________________________
   *You could use a higher volt battery. The higher the volts, the more potential energy.*

Congratulations, in this circuit configuration, you tested how various electrical components can share the same circuit. This is called a **series circuit**. You may have noticed that the LEDs are dimmer than they were in your simple circuit configuration. This is because the same voltage from the batteries is now divided between the two LEDs. That is one of the drawbacks of series circuits. However, series circuits are very easy to wire. **You may want to use a string of Christmas lights as an example of a series circuit. If one of the lightbulbs falls off, it breaks the circuit and other lights in the series will not work.*



**Key Concepts:** The battery **voltage** (electrical pressure) may drop as the current increases, because the 4.5V batteries may not be able to supply all the current that is needed. Remember that **Voltage (V) = Current (I) x Resistance (R).** This effect is more noticeable when the batteries are weaker. Volts are a measure of potential energy. The higher the volts, the more potential energy is stored.

### How does a diode work?



Diodes only allow electricity to flow in one direction. Take a look at the symbols for "Diode" and "LED". The arrow points in the direction that electricity will travel. Diodes are extremely common in household devices, and they protect against reverse current. If you were to hook up a battery backwards in a circuit that you're building, it could potentially make electricity flow backwards through the circuit and fry or hurt other components. Diodes can prevent this from happening.

**Part 3: Build a parallel circuit [Project 4, Page 17]**

1. Assemble the circuit as shown on page 17.
2. Test that the circuit works, and the white and color LEDs are bright. If not, revise your circuit.
3. How does this circuit compare to the circuit you built in Part 2?________________________
   ____________________________________________________________________________
   ____________________________________________________________________________
   *LEDs are connected in parallel which makes them independent of each other. However the "wiring" is more complex.*
4. Are the LEDs brighter or dimmer than in the circuit you created for Part 2? _______________
   *They should appear brighter because each LED receives the full voltage from the battery.*

**Key Concepts:** In this **parallel circuit,** the batteries produce an electric current, which flows through the switch, splits between the 2 LEDs, then comes back together and flows back into the battery. The wiring is more complex, but the LEDs do not need to share the voltage. Most of the lights in your house are connected in parallel. This means that if one lightbulb burns out, you don't have to replace all the bulbs in your house.

In these three activities, you were thinking like electrical engineers! Electrical engineers design circuits for not only electrical components in your home, but also for robots, electric cars, computers, cell phones, prosthetics, space shuttles, drones, video game consoles, and more.

## Post Activity Assessment:

1. A closed path that allows electrical energy to flow is called ____________________ (*a circuit*).
2. How can you determine if a circuit is a series circuit or a parallel circuit? _________________

   ______________________________________________________________________________

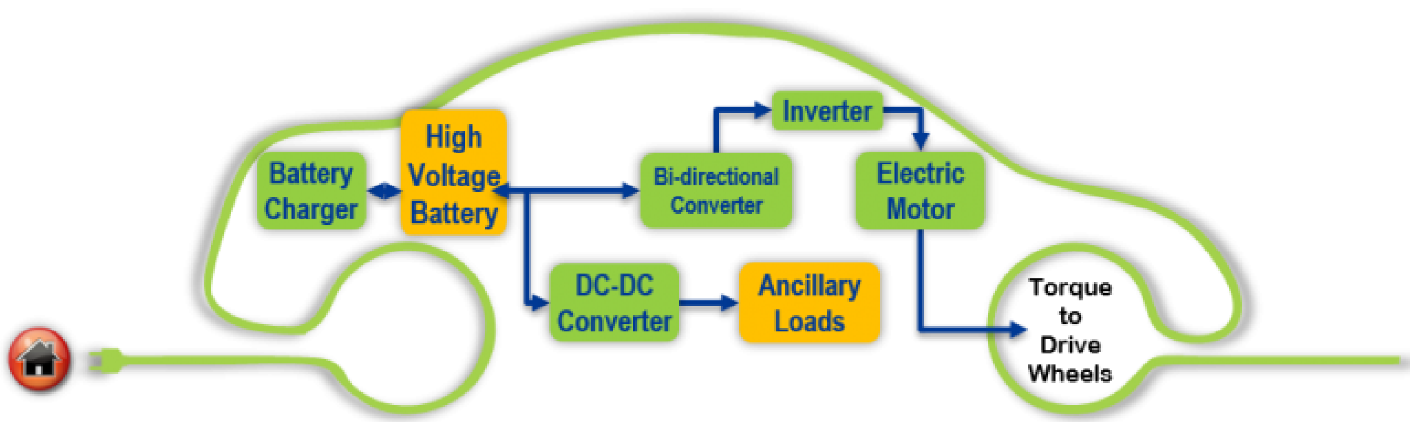
   ______________________________________________________________________________

   *(You could remove one component and see if the others still function)*

**Key Concepts:** Electricity is the flow of electrical energy from one place to another, and a closed circuit is needed for electricity to flow and power our electronics. 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 pushes electrons through the circuit. Moving electrons are called an **electric current**. The LEDs, light bulb, fan, and speaker in the kit give off light, spin, 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** as well as a more complex pathway with independent electrical components called **parallel circuits**. Way to go Electrical Engineers!

**Common Misconception:** You might think from your experiments that the battery is a source of charge (medium that moves the energy) in a circuit. This is a misconception. Batteries *supply* the energy needed to move a charge from low potential (-) to high potential (+). The charge actually originates in the wires, and that carries the electrons that belong to the atoms that make up the wires. This is why wires need to be made from conductive materials to move a charge. Conductors allow a current to flow easily.

**Renewable Energy Connection:** In this lab exercise, the electrical components were powered by batteries holding potential chemical energy waiting to be activated. Batteries are likely to play a big role in our renewable energy future. The Hawai‘i State Energy Office has taken a leadership role in advancing clean transportation including facilitating the deployment of zero emission, electric vehicles and charging infrastructure. Using electric vehicles, that are powered by rechargeable batteries, will help reduce fossil fuel consumption in the transportation sector.




Graphic Source

In terms of powering our homes, schools, and other infrastructure with renewable energy, 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 these renewable sources will be a key component of a 100% renewable energy future. Innovations in battery technologies are desperately needed. Will you be one of the engineers who design better batteries?

**Optional Deeper Dive:** What are batteries made of? (MS-PS1-3) Have students gather and make sense of information to describe that synthetic materials used to make batteries come from natural resources and impact society.

Just as there are many ways to create a complete circuit, there are also many ways we can generate electricity. In Lab 2, we will explore electricity generation from **Chemical Energy, Solar Energy,** and **Wind Energy.**

## Lab 2: Electricity Generation and Storage *(1-2 class periods)*

| NGSS Performance Expectations | | |
|---|---|---|
| **MS-PS3-2** Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.<br><br>*Students will construct a wind powered circuit model and a solar powered circuit model. They will test how applying wind or light at variable distances to the propellers and the solar cell affect the brightness of a LED.* | | |
| This exercise focuses on the following three dimensional learning aspects of NGSS | | |
| Science & Engineering Practices | Disciplinary Core Idea | Crosscutting Concepts |
| **Developing and Using Models**<br>Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.<br><br>Develop a model to describe unobservable mechanisms. | **PS3.A: Definitions of Energy**<br><br>A system of objects may also contain stored (potential) energy, depending on their relative positions.<br>**PS3.C: Relationship Between Energy and Forces**<br><br>When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. | **Energy and Matter**<br>Energy can be transferred in various ways and between objects.<br><br>- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -<br>**Systems and System Models**<br><br>Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. |
| **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. | | |

### Prerequisite Knowledge

- *Students should know how a generator works. When wind turns the shaft in a motor, a coil of wire on the shaft spins past a magnet and an electric current is created in the wire.*

- *Similar to a battery, a solar cell contains a positively charged side and a negatively charged side of silicon crystals arranged in layers that balance each other out (neutral). However, when the sun shines on a solar cell, charged particles in the light offsets the balance in the silicon layers and produces an electric voltage (the solar cell in this kit can produce up to 7V).*

### Before the Activity

- Break up into teams

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

- Snap Circuit Kit and Manual (*included*)
- Scrap paper (*not included*)
- Pencil (*not included*)
- Strong flashlight or lamp (*not included*)

### Potential Safety Issues

- None

### Potential Obstacles

- Just like in real life, the solar panel may not work well on a very cloudy day or in dim lighting.
- Due to the ongoing COVID-19 pandemic, you may want to use a fan and/or hair dryer in place of a student blowing on the windmill.

## Procedure

**Pre-activity assessment**: In this activity you will construct a model of a windmill that uses a base grid support and a model that does not use a base grid. Which of the two models do you **hypothesize** will be easier to light up a LED? Explain your reasoning. Hypothesis: _______________

_______________________________________________________________________________

_______________________________________________________________________________

**Just making their best guess. They'll have a chance to test the model to see what the data supports.*

**Part 1: Build a circuit powered by the wind (rotor blade) [Projects 5 & 6, Page 17-18]**

1. Assemble the windmill model (Project 5, page 17). Note: this circuit is a 3D model.
2. Test your windmill using your breath, a fan set on low then high, or a hair dryer set on low then high. Measure the voltage produced:

   Low speed: _________V

   High speed: ________ V
3. Replace the meter with the LED. Does the LED light up? Do you notice a difference if you supply a light wind versus a hard wind? __________________________________________

Now let's test your hypothesis to see if the windmill will work better without the supporting base grid.

4. Assemble the windmill model (Project 6, page 18).
5. Was it easier to light the LED up? _____________________ (*answer should be yes)*

**Key Concepts:** The wind blows because the sun heats up our earth's atmosphere unevenly. Warm air (lower pressure) rises, and cool air moves in to replace the warm rising air. Humans have been harnessing this movement of air for thousands of years to power ships using sails and to pump water or grind wheat using windmills. Today, we use windmills to generate electricity, just like you did here in your two windmill models. The wind pushes on blades (rotors) which spin a generator which induces an electric current. In your model, the motor has a coil of wire with many loops inside and as the shaft spins, the coil of wire moves past a permanent magnet and an electric current is created in the wire.

**Post-activity assessment**: What other renewable energy resource could you use to spin blades/rotors? _______________________________________________________(*water*)

**Fun Fact!** Did you know that a single large windmill can supply enough electricity to power hundreds of homes.

**Part 2 - Pre-activity assessment**: In this activity you will construct a model of a solar powered circuit and test what components you can power with up to 7V. What do you **hypothesize** will happen to your meter reading the further or closer you are to a light source?_____________________________________

________________________________________________________________________________

**At this phase they are just making their best guess. They'll have a chance to test the model to see what the data supports.*

**Part 2: Build a circuit powered by the sun with battery backup (solar panel) [Project 35 & 36, Page 51]**

1. Assemble the solar powered circuit (Project 35, page 51). Be sure to set the meter to the 5V scale by moving the switch on the bottom of the meter.
2. Test your hypothesis by holding the solar cell up to a light vs. far away from a light source. How do the meter readings compare? _______________________________________________

   Your solar cell can produce as much as 7V in very bright sunlight, so the meter reading may be off the scale.
3. Test one of the LEDs. Does the solar cell power it well? ___________________________
   a. What happens if you cover the solar cell with your hand? _____________________

4. Test the melody IC. Does the solar cell power it well? ______________________________
5. Test the fan. Does the solar cell power it well (may need to give it an initial spin)?
   ____________________________
6. Test the lamp. Does the solar cell power it well? ________________________(*it won't*)
   a. What happened to the meter reading __________________(*voltage should drop to 0V*)

**Key Concepts:** All Electrical Components require a certain amount of voltage to work properly. In this test, you saw that a single solar cell did not provide enough voltage to power the lamp. How could you fix this problem? ______________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

*They could link up more than one solar cell like we do on rooftops or have additional energy supplied by a battery, wind, or other energy sources via a grid.*

In question three, part a, you should have **observed** that the LED did not light up if you covered up the solar cell. We have this same problem in the real world. When it is nighttime, or a dark cloudy day, solar panels will not produce enough electricity to power a home. How can we solve this problem?

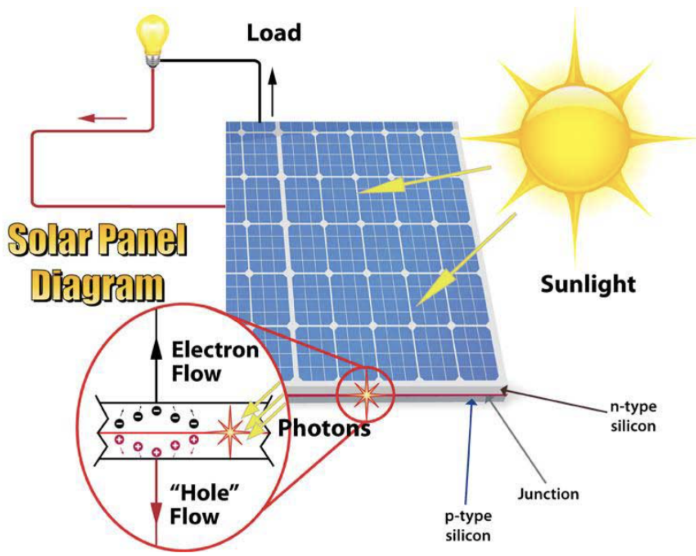
7. Assemble the solar powered circuit (Project 36, page 51). Be sure to hold your solar cell up to a bright light.
8. What happens to the red/yellow LED? _________________________ (*should light up*)
9. Cover the solar panel with your hand. What happens to the white and red/yellow LED? ________________________________________________________(*white light should light up indicating the batteries are powering the red/yellow LED*).

In this case, you build a model demonstrating how we can use a battery to supplement solar powered circuits. **Way to go electrical engineers.**

**Bonus Activity:** Want to learn other ways electrical engineers store energy? Try Project 13, page 29 to learn about **capacitors**. Capacitors cannot store as much electricity as batteries, but they can release electricity much faster, and store it for long periods of time. Capacitors are used in many devices in your home.

**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.

**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 can 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:** Solar power and wind power are both free, clean, and renewable. In just one hour, the sun sends more energy to our planet than we, all humans, consume in an entire year. The sun is also responsible for generating the winds. Scientists and engineers around the world are researching ways we can improve our technologies to harness enough solar and wind energy to supply our electricity needs. These renewable energy resources have enormous potential as a clean source of renewable energy to replace fossil fuels. According to the Hawaiian Electric Company, in 2021 renewable energy increased across the islands they serve as follows:

| Fuel | Oahu | Maui County | Hawaii Island |
|---|---|---|---|
| Solar | 5.1% | 1.1% | 0.3% |
| Wind | 2.65 | 20.4% | 12.4% |

Solar and wind power generated energy resources are going to continue to expand across Hawai'i. Now and in the future, our state will need engineers who understand how to install and repair solar panels, as well as scientists and engineers to invent more efficient solar panels and better batteries for storing solar energy. 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 **wind power** on their own.*

Wind Power Pros:

-
-
-

Wind Power Cons:

-
-
-

**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.

**Bonus Video Resources:**

- Renewable Energy 101: How Does Solar Energy Work? - YouTube
- Renewable Energy 101: How Does Wind Energy Work? - YouTube
- How batteries work - Adam Jacobson - YouTube

## **Lab 3: Home Wiring** *(1-2 class periods)*

| NGSS Performance Expectations | | |
|---|---|---|
| **MS-ETS1-4** Develop a model to generate data for interactive testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.<br><br>*Students will construct a model of a house by selecting one of several possible designs. This model should be used to inform their own house design which they will build and test in Lab 4*<br><br>**MS-ETS1-3** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristic of each that can be combined into a new solution to better meet the criteria for success.<br><br>*Students will present their models to their peers and compare how the two home models are different, identify the best about both designs, and use this information to inform their own, improved design in Lab 4.* | | |
| This exercise focuses on the following three dimensional learning aspects of NGSS | | |
| Science & Engineering Practices | Disciplinary Core Idea | Crosscutting Concepts |
| **Developing and Using Models**<br>Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.<br><br>Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.<br><br>**Analyzing and Interpreting Data**<br>Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.<br><br>Analyze and interpret data to determine similarities and differences in findings. | **ETS1.B: Developing Possible Solutions**<br>A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.<br>Models of all kinds are important for testing solutions.<br><br>**ETS1.C: Optimizing the Design Solution**<br>The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. One design may not perform best across all tests. Identify the characteristics of the design that performed best in each test case. This information can be useful for the redesign process. | **Systems and System Models**<br><br>Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. |
| **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. | | |

## Prerequisite Knowledge

- *Students should be comfortable reading the snap circuit blueprints.*

## Before the Activity

- Break up into teams

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

- Snap Circuit Kit and Manual (*included*)
- Scrap paper (*not included*)

- Pencil (*not included*)

## Potential Safety Issues

- None

## Potential Obstacles

- The circuits in this lab are more complex, and will require you to **pay close attention to the directions**. You may need to do multiple iterations of your build to get it right.

# Procedure

**Half of the class should build Project 31: 3-Wall House on page 43 and the other half should build Project 53, page 71.**

1. Select which home model your team would like to build. The circuit in these home designs represent different ways that a home's electrical wiring may be configured to power various electrical components: light lights, doorbells, fans, home security systems, a christmas tree, and more.
2. Follow the assembly directions, and practice **iterative designs** until you are able to successfully power all components in the model.

### Post-Activity Assessment:

1. How many attempts did it take you to build your home model?___________________________

2. What lessons did you learn along the way? __________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

**Share**: Take a look at your peers' models. How does it compare to yours? What does it do better?

__________________________________________________________________________

__________________________________________________________________________

3. How would you improve upon this home model or what would you do differently? __________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

**Key Concepts:** Engineers use science, math, technology and creativity to solve problems. When it comes to developing complex electrical systems, it may take many iterations to be successful. In this activity, you had a guide to help you. In Lab 4, you'll get to combine all of the knowledge you have gained in the previous activities to practice the **engineering design process**. You'll design your own home model (with constraints), build it, test it, and revise it until you are satisfied with your final product.

**Renewable Energy/Career Connection:** Architects must work closely with folks in the construction and electrical industry to make sure that the homes they design are able to be wired up and work the way that they envision. In these snap circuit home models, you saw for yourself how batteries, wind power, and solar power can be used together to supply electricity to various components of a home.

Alright Electrical Engineers. Are you ready for the **grand**, **final**, **Engineering Design Challenge**? Let's go!

## Lab 4: Electrical Engineering Design Challenge *(2-4 class periods)*

| NGSS Performance Expectations | | |
|---|---|---|
| **MS-ETS1-1** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.<br><br>*Students will need to sketch a blueprint for a home wiring system that optimizes the use of renewable energy and is constrained by the components that they have in their kit. A successful solution is one that uses solar, wind, and battery power together, and all electrical components function properly.*<br><br>**MS-ETS1-4** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.<br><br>*Students will use their blueprint to build, test, and revise their home's wiring system until a successful design is achieved. A successful solution is one that uses solar, wind, and battery power together, and all electrical components function properly. Note that the most complex design is not always the best.* | | |
| This exercise focuses on the following three dimensional learning aspects of NGSS | | |
| Science & Engineering Practices | Disciplinary Core Idea | Crosscutting Concepts |
| **Asking Questions and Defining Problems**<br>Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.<br><br>Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.<br><br>**Developing and Using Models** | **ETS1.A: Defining and Delimiting Engineering Problems**<br>The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.<br><br>**ETS1.B: Developing Possible Solutions**<br>A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. | **Influence of Science, Engineering, and Technology on Society and the Natural World**<br>All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.<br><br>The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, |

| | | |
|---|---|---|
| Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.<br><br>Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. | Models of all kinds are important for testing solutions.<br><br>**ETS1.C: Optimizing the Design Solution**<br>The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. | and economic conditions. |
| **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. | | |

## Prerequisite Knowledge

- *Students should be comfortable with all of the snap circuit components, how they work, and various circuit designs.*

## Before the Activity

- Break up into teams. You may work on the same teams as in previous labs or select new ones.
- For extra fun: come up with a team company name, slogan, and logo.

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

- Snap Circuit Kit and Manual (*included*)
- Grid Paper or Ruler and Paper (*not included*)
- Pencil (*not included*)
- List of common electrical symbols

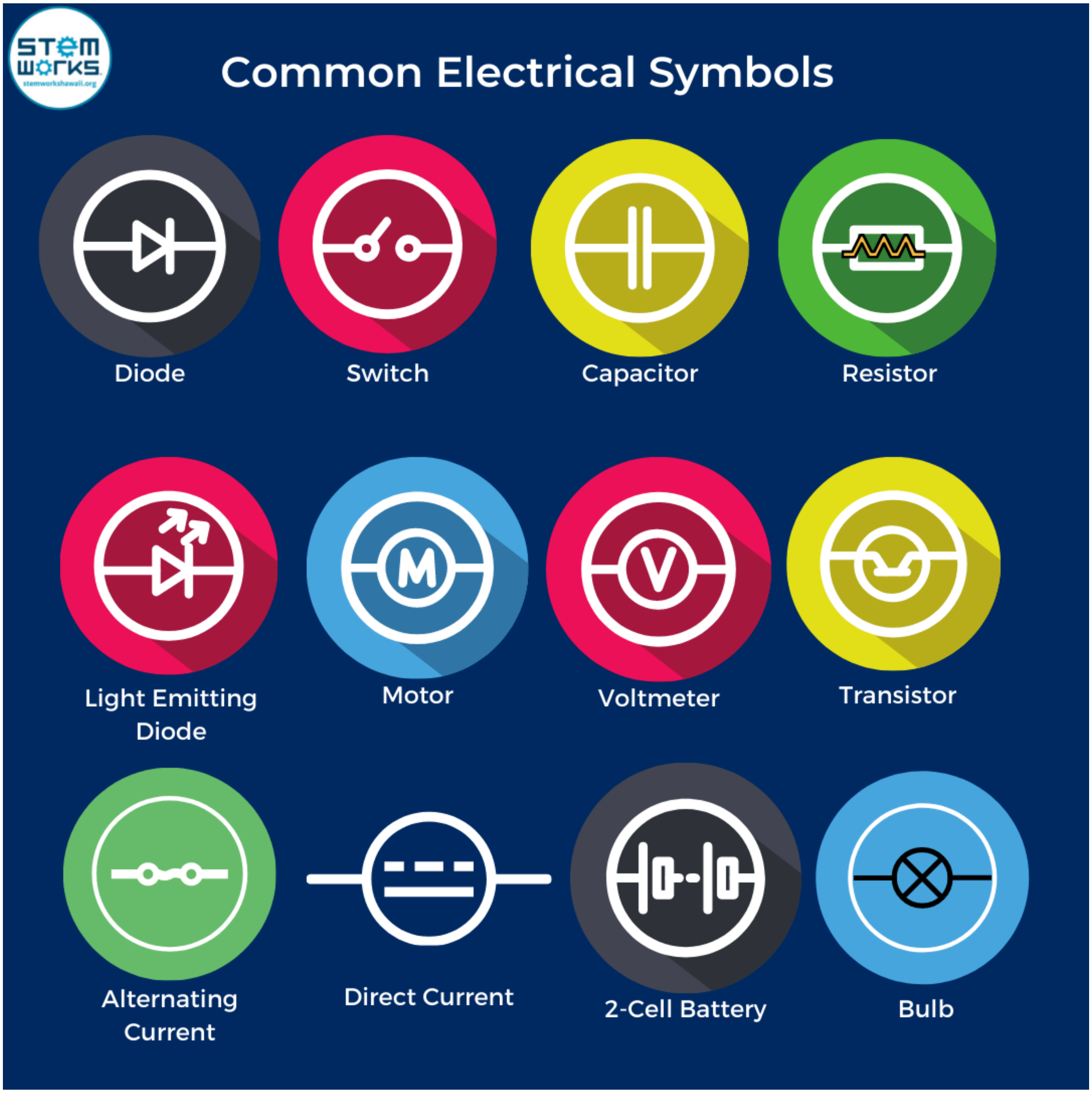
## Potential Safety Issues

- None

## Potential Obstacles

- This challenge is challenging! That's why it is called a challenge. Take your time, be creative.

**Engineering Design Challenge.** You have been hired by Green Home Designs to help with developing the electrical wiring of a client's new ʻohana unit. This client would like the home to be powered by renewable energy sources including wind and solar, and supported by batteries. The home may be one or two stories. It must include working overhead lights, a doorbell, and a motion detecting home security system. You'll need to provide a blueprint **drawn to scale**, and once approved (by teacher), move on to constructing the home. Below are examples of common electrical symbols for you to use in your blueprints. You may use the snap circuit manual as a *guide,* but try to come up with a **unique, original design**.




## Procedure

**Part 1: Draft a 2D (top down view) blueprint for your circuit(s) using the common electrical symbols above. You can think of each grid of the blueprint as a scaled layout to be used on each snap circuit base grid. Wires can be represented by a line. Be sure to indicate your scale.** **1 square on the grid represents _____ in real life.** *You may want to provide grid paper or have students draw gridlines.*

**Notes:**

*Check if they are using series, parallel, or both types of circuits.*

Rather do this online? Try this tool: [CircuitLab | Editing "Welcome to CircuitLab"]

**Design Approved ___________**

**Part 2: Build, test, and redesign your model.**

1. Using your blueprint as a guide, try to construct your home.
2. Does every component work? Have you met all of the client's constraints? If not, revise your blueprint and try again.
3. Once you have a successful design, share it with your teacher and present it to your classmates.
4. If you were successful, and any of your classmates are struggling, help them out. We're all stronger when we work together and support each other.

**Post-activity assessment**:

1. How did you go about developing a possible solution? ______________________________

   ______________________________________________________________________________

   ______________________________________________________________________________

   ______________________________________________________________________________

2. How many design iterations did it take for you to create an optimal design with the constraints provided? ____________________________________________________________
3. How would your design be different if you weren't limited by the components in your kit?

   ______________________________________________________________________________

   ______________________________________________________________________________

   ______________________________________________________________________________

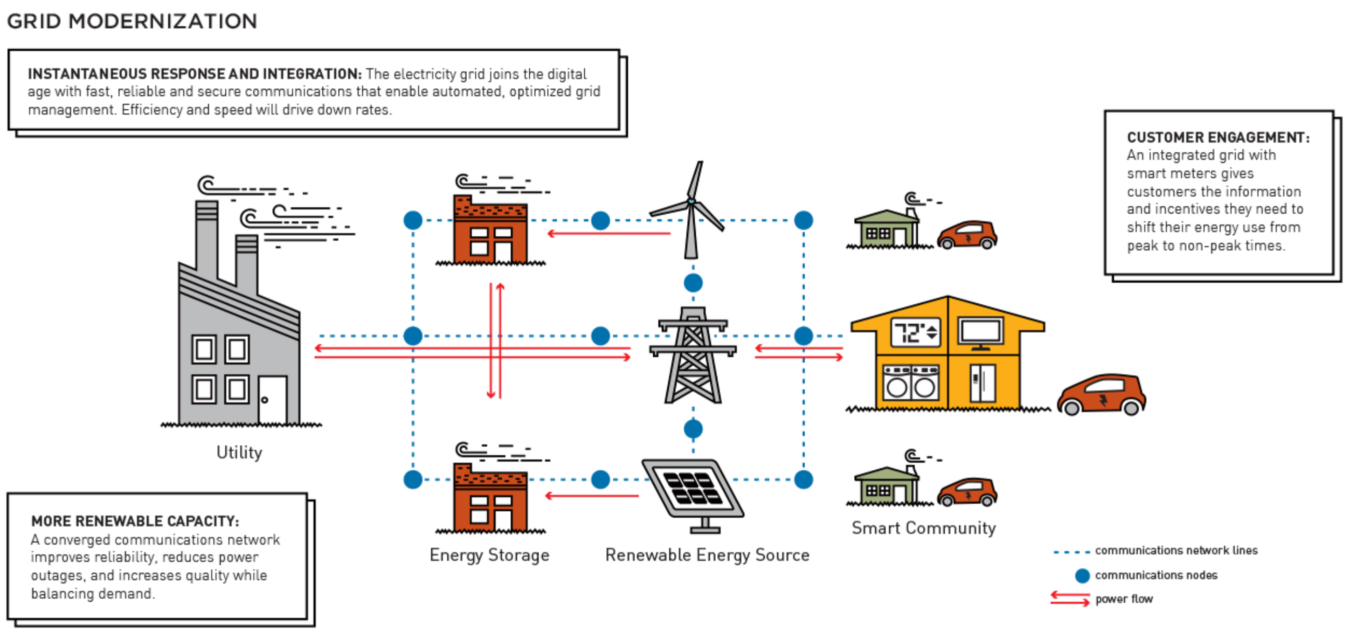
   ______________________________________________________________________________

   ______________________________________________________________________________

**Key Concepts:** Engineers use science, math, technology and creativity to solve problems. When it comes to developing complex electrical systems, it may take many iterations to be successful. In this activity, you independently practiced the Engineering Design Process - which is a series of steps used by engineers to guide the creative problem solving process and optimize a design solution. Engineers in all sectors must deal with constraints which may include time, budget, and/or materials. Usually a combination of all three. Your ideal solution may be very different from the solution you created with constraints, however, constraints are a fact of life. Way to make the best of the pieces you had to work with!

**Common Misconceptions:** Many students are afraid to become engineers because they do not like math. In this exercise, you were able to practice engineering with very little mathematics. Math is an important part of engineering, but you do not have to be a mathematician to pass the required math classes. You just have to get through them, and then you can still be a successful engineer. The key is grit and perseverance.

**Renewable Energy Connection:** In your model home design, you created an electrical grid that powers components using wind, solar, and chemical energy, and made sure that you had enough voltage for each component. If you didn't have enough sunlight, an overhead light in your model may not have worked if you did not have battery backup incorporated in your design. These are the same kinds of issues we face on a larger scale with communities and cities. For example, some homes in Hawaiʻi, equipped with solar panels, actually produce more electricity than they use and need. When this happens, they will ideally be able to sell some of that electricity back to their utility company who can then use it to power other parts of the city. Many scientists and engineers are working on ways to develop and deploy a "smart grid" that can optimize energy production and delivery to meet the needs of individual consumers, communities, and urban centers. Modernization of our energy grid in Hawaiʻi will be key to reaching our 2045 goals!




*For more information on Hawaiʻi 's energy sector and progress in the areas of energy efficiency, renewable energy, and clean transportation, download the 2020 Hawaiʻi 's Energy Facts & Figures (PDF).*

## Conclusion

Renewable energy resources are ultimately our best option to continue to power our home's, school's, and community's energy needs. Using renewable energy will help us to reduce our environmental impact so that we can enjoy the natural gifts and beauty of our planet for generations to come.

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 habits and create an action plan for conserving energy. No single person or technology is going to solve our energy needs or environmental problems. 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.

Note that while renewable energy such as sun and wind power are often referred to as clean energy, solar panels, batteries, and windmill hardware need nonrenewable resources to create wind turbine blades, lithium for batteries, metals for solar cells and wires. This means that even if we successfully transition to 100% renewable energy for electricity production in our state, it is still important to conserve energy where we can.

Mahalo nui loa for joining us on this energy exploration into the world of circuits, electricity, electrical engineering, and renewable 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.
- Hawaiʻi 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)
  - Hawaiʻi Island - 43%
  - Kauai - 56%
  - Maui County (including Molokai and Lanai) - 41%
  - Oahu - 25%
- Last Updated: January 21, 2021 SOURCE: EIA.GOV

## Words to know:

- Amp: a unit of electrical current. Short for “ampere”
- Blueprint: shows a plan that other engineers can use to build, test, and modify. These usually include technical symbols that all engineers can recognize, and labels such as the scale.
- Conserve: to use less of something like electricity or water.
- Consumption: the use of resources like energy, water, food, minerals, and more.
- Data: facts about something that have been measured, observed and can be analyzed.
- Design Constraints: The limitations placed on a possible engineering solution.
- Iterative Design: As you create something, continue to think about new ideas and ways you can make improvements.
- 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.
- Engineering: the use of science and math in the design and construction of things.
- Electrical Engineer: Engineers who use their knowledge of electrical currents and electricity to develop solutions and designs for electrical systems like buildings, computers, robots, and even electric cars.
- Electricity: flow of electrical power or charge.
- Fossil Fuels: coal, oil, natural gas. These energy resources come from the fossils of plants and tiny animals that lived millions of years ago.
- Generator: a device that converts mechanical energy to electrical energy.
- Innovation: a new invention or way of doing something
- Modular: products that have components that can be fixed, removed, and replaced without having to throw away the entire product and starting from scratch. Modular designs are better for the environment.
- 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.
- Research: The process of gathering reliable, relevant information and ideas related to a scientific or technological issue.
- Smart Grid: a computer-based remote control and automated system for electricity delivery. It includes two-way interaction between the generation facilities, utilities, and consumers.
- Solar Power: energy from the sun that is converted into electricity.
- Technology: tools, methods, and systems used to solve a problem or do work.
- Trade-off: a compromise.
- Troubleshoot: as you design a blueprint or build a model, something may not work. In this case you will need to think about what went wrong and how you can fix it. Sometimes this will be a process of trial, error, and discovery.
- Turbine: a device that uses pressure on blades by water, air, or steam to spin generators that create electricity.
- Volts: a unit of electrical potential also known as electromotive force.
- Windmill: a machine with blades or rotors that are rotated by the wind to do work.

## Online Extension Activities *(Optional)*

1. **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 our favorite).*


## 2. 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.

## At Home Extension Lesson: Electricity Reduction Experiment (*Homework*)

This week, your child learned all about electricity, circuits, grids, and renewable energy generation. They had the opportunity to explore what components in their school use electricity; different sources of energy including renewable and nonrenewable resources; how electricity is produced; how circuits work through hands-on activities; and they even engineered (designed, built, and tested) their very own home wiring system powered by wind, solar and batteries.

They also learned that Hawaiʻi 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, everyone must get onboard. Take a minute to discuss the following questions with your child:

1. How do you and your household use electricity in your daily life? ______________________

   ______________________________________________________________

   ______________________________________________________________

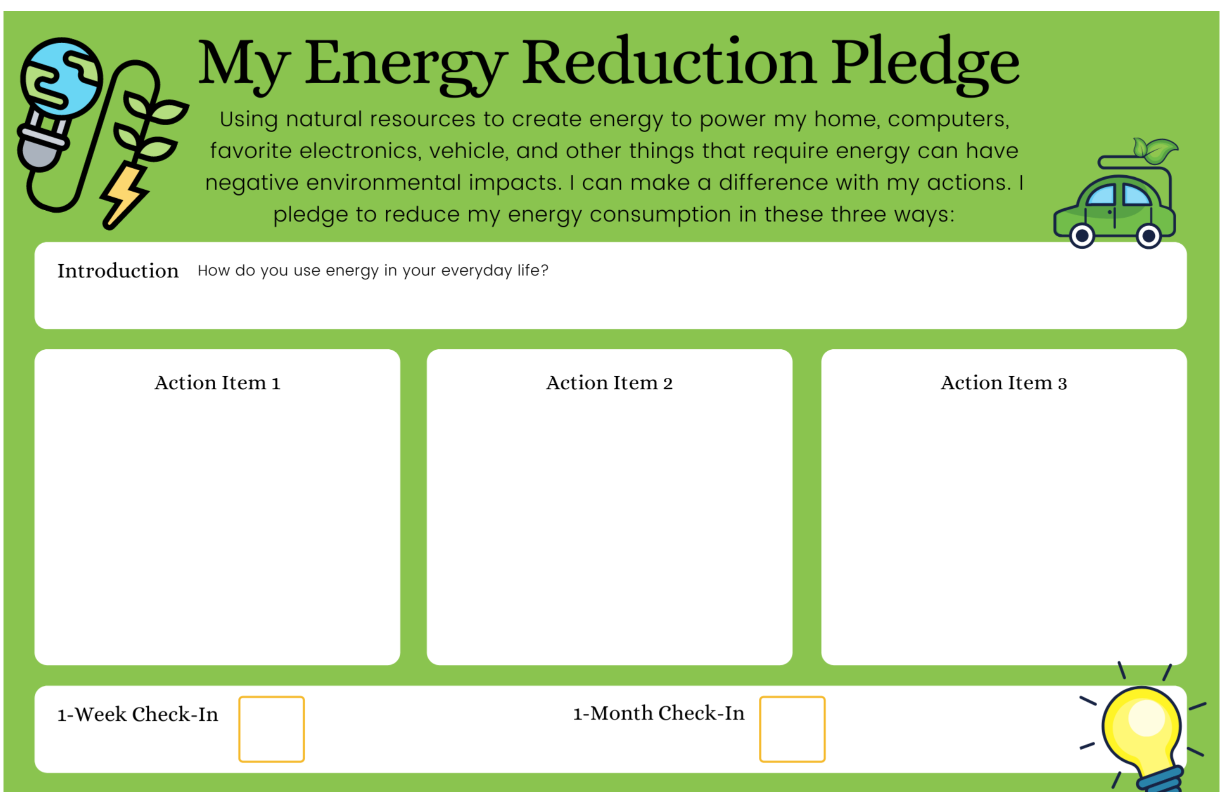
   ______________________________________________________________

   ______________________________________________________________

   ______________________________________________________________

   (You may want to make a list of items in your home that use electricity. Some big consumers are hot water heaters, refrigerators, washing and drying machines, and other large appliances.)

2. What are some ways that you can reduce your energy consumption? Come up with at least three action items.



# 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 ☐

3. How will reducing your energy consumption affect our natural resources? _______________

_______________________________________________________________________________

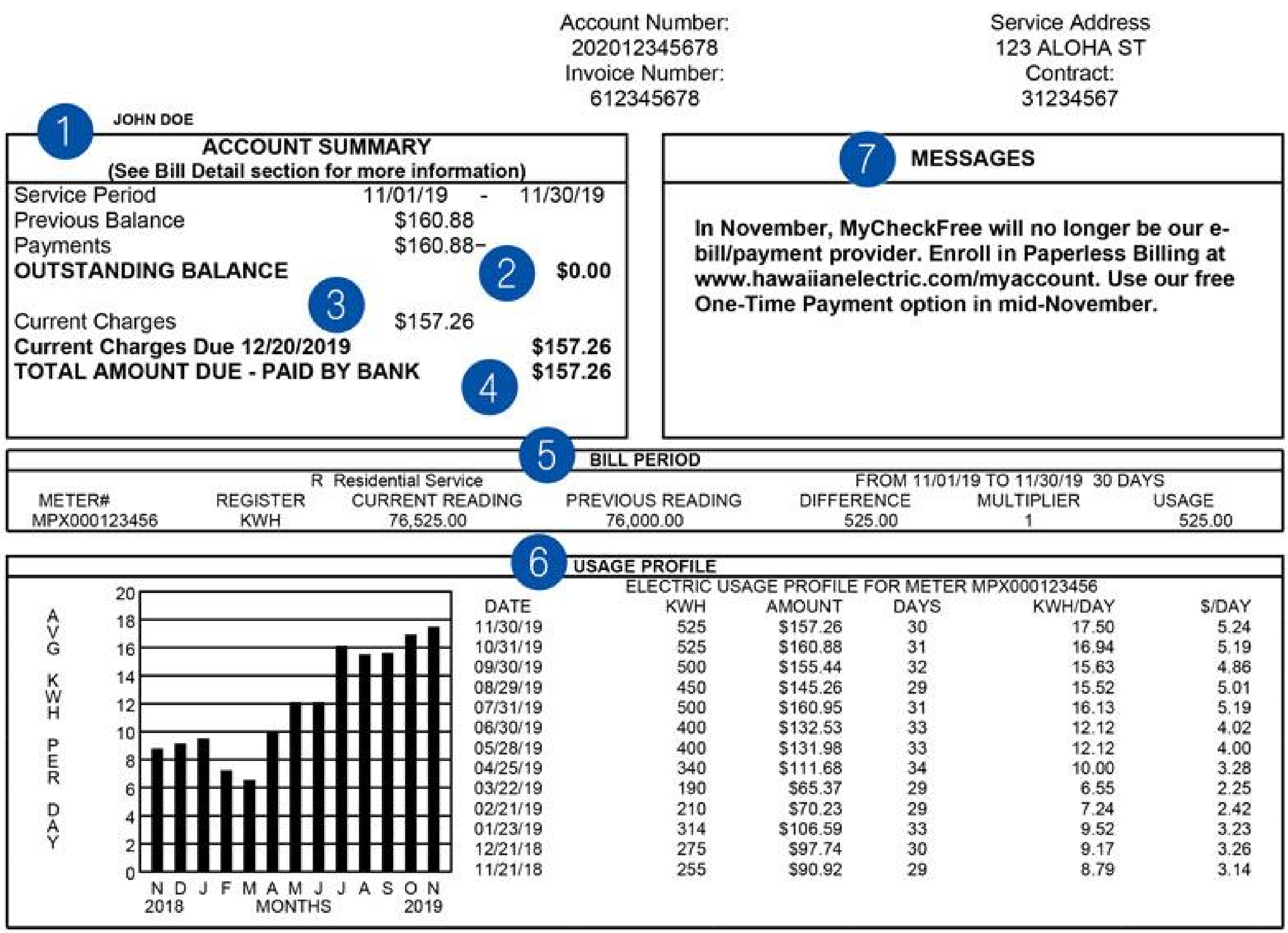
_______________________________________________________________________________

4. How will reducing your energy affect your family's finances? To test this, take a look at your electric bill for this month and then compare 1-month later after practicing your energy pledge action items.

Original Bill KWH/Day_______________ Conservation Month Bill KWH/Day _______________

Amount Saved? $_______________

To get a better understanding of your energy consumption, you can check your electrical bill. Sit down as an ‘ohana, and look over your electric bill together. It should look something like this:



Account Number: 202012345678
Invoice Number: 612345678

Service Address 123 ALOHA ST
Contract: 31234567

JOHN DOE

1 **ACCOUNT SUMMARY**
(See Bill Detail section for more information)

| | | |
|---|---|---|
| Service Period | 11/01/19 - 11/30/19 | |
| Previous Balance | $160.88 | |
| Payments | $160.88- | |
| **OUTSTANDING BALANCE** | | **$0.00** |
| Current Charges | $157.26 | |
| **Current Charges Due 12/20/2019** | | **$157.26** |
| **TOTAL AMOUNT DUE - PAID BY BANK** | | **$157.26** |

7 **MESSAGES**

**In November, MyCheckFree will no longer be our e-bill/payment provider. Enroll in Paperless Billing at www.hawaiianelectric.com/myaccount. Use our free One-Time Payment option in mid-November.**

5 **BILL PERIOD**

R Residential Service — FROM 11/01/19 TO 11/30/19 30 DAYS

| METER# | REGISTER | CURRENT READING | PREVIOUS READING | DIFFERENCE | MULTIPLIER | USAGE |
|---|---|---|---|---|---|---|
| MPX000123456 | KWH | 76,525.00 | 76,000.00 | 525.00 | 1 | 525.00 |

6 **USAGE PROFILE**



ELECTRIC USAGE PROFILE FOR METER MPX000123456

| DATE | KWH | AMOUNT | DAYS | KWH/DAY | $/DAY |
|---|---|---|---|---|---|
| 11/30/19 | 525 | $157.26 | 30 | 17.50 | 5.24 |
| 10/31/19 | 525 | $160.88 | 31 | 16.94 | 5.19 |
| 09/30/19 | 500 | $155.44 | 32 | 15.63 | 4.86 |
| 08/29/19 | 450 | $145.26 | 29 | 15.52 | 5.01 |
| 07/31/19 | 500 | $160.95 | 31 | 16.13 | 5.19 |
| 06/30/19 | 400 | $132.53 | 33 | 12.12 | 4.02 |
| 05/28/19 | 400 | $131.98 | 33 | 12.12 | 4.00 |
| 04/25/19 | 340 | $111.68 | 34 | 10.00 | 3.28 |
| 03/22/19 | 190 | $65.37 | 29 | 6.55 | 2.25 |
| 02/21/19 | 210 | $70.23 | 29 | 7.24 | 2.42 |
| 01/23/19 | 314 | $106.59 | 33 | 9.52 | 3.23 |
| 12/21/18 | 275 | $97.74 | 30 | 9.17 | 3.26 |
| 11/21/18 | 255 | $90.92 | 29 | 8.79 | 3.14 |

1. **Account Summary:** This section provides the electric service billing period for the current bill and summarizes what is owed on the current bill.

2. **Outstanding Balance**: The previous balance line item shows the total charges on your last electric bill. The payments you made toward the last bill are subtracted from the previous balance to determine how much, if anything, remains to be paid toward the previous bill, that amount is the outstanding balance.
3. **Due Date**: This is when your payment should be received to avoid a late payment charge.
4. **Total Amount Due**: This is how much you currently owe. The total amount due includes the current charges, any adjustments made to your bill, plus the outstanding balance. Adjustments may include items such as: fees for service establishment, reconnection, late payment, returned check, or Sun Power for Schools donation.
5. **Bill Period**: This box contains data that describes your electricity use during the billing period and the rate schedule (such as R Residential Service) used to compute your electricity charges. The beginning and ending dates of the electric service billing period and the number of days in the billing period are provided.

   **Meter #** is the identification number on the electric meter. Register provides the meter's unit of measure. KWH means kilowatt-hours. For accounts that have two electric meters, the second meter number and corresponding data will be shown below the data provided for the first meter.

   **Current Reading** is the cumulative number of kilowatt-hours shown on the meter when it was read for the current electric bill. Previous reading is the cumulative number of kilowatt-hours shown on the meter when it was read for the previous bill. The difference is computed by subtracting the previous reading from the current reading. For accounts that use large amounts of electricity, the meters may not register electricity use by single kilowatt-hours. They may register electricity use by tens or hundreds of kilowatt-hours. That is explained by the multiplier. **For most residences the multiplier is 1.** For large power users, like a university or hospital, the multiplier may be as high as 240. When the difference is multiplied by the multiplier, the electricity usage for the billing period is determined in kilowatt-hours. At times, your electric bill may have to be estimated. In those cases, (EST) will be printed on the bill next to the current reading.

   Residential and Schedule G commercial customers with **advanced meters** may see a KW line item underneath their KWH usage. Please disregard this at this time as it does not factor into your bill calculation. It may be used in the future when additional rate options and programs become available.
6. **Usage Profile:** This section provides you with a historical view of your electricity use. The handy bar graph on the left side tells you at a glance how much your average daily electricity use has fluctuated over the past year. The electric usage profile for your meter can help you monitor your electricity use. It provides a record of the electricity use for your account for the past year. The date is the ending date of a billing period. KWH is the number of kilowatt-hours used during that period. The amount and days are the total current charges on your electric bill and the number of days in that billing period, respectively. **KWH/day lists the average number of kilowatt-hours of electricity used per day during the period. $/day tells you, on average, how much your electricity costs per day.**
7. **Messages:** This area contains useful information and tips for managing your electricity use. It also may contain specific messages for individual customers about their electric account.

# 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.stemworksHawai'i .org

energy.Hawai'i .gov