HAWAI`I STATE ENERGY OFFICE

RENEWABLE ENERGY LABS

GRADES: 6-8 #1

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.

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

Curriculum at a Glance	
Grade Levels	6 - 8
Time Required	7 Class Periods
Activity Group Sizes	3 - 4
NGSS Performance Expectations	MS-PS1-2, MS-PS1-5, MS-PS1-6, Oxidation/Reduction (redox), MS-ETS1-1, MS-ESS3-3,
Activity Title	**Guiding Questions**
Activity: Electricity Exploration	What items need electricity to work? Where does electrical energy come from?
Scientific Research: Hydroelectricity	What is hydroelectricity? What forms of hydroelectricity do we have in Hawaii? How else could the ocean be used to generate electrical energy?
Kit Discovery: Electrochemistry, Metals, and the Impacts of Mining	What is included in my kit? Where do the metals and chemicals in this kit come from? What can they be used for? What impacts does mining raw materials have on the environment?
Lab 1: Aluminum Eater - Chemical Reactions	What is a chemical reaction? What observations tell me a chemical reaction has occurred?
Lab 2: Voltage Tests	How does a voltmeter work and what does it measure? What materials can I use to create a circuit? Which metals would I choose to power an electronic alarm clock? Where do metals come from? How does metal extraction and mining impact the environment?
Lab 3: Coin Cell Battery Flashlight	What is a battery and how does it work? How is chemical energy from a battery transformed into electricity?
Lab 4: Saltwater Powered Clock	How are chemistry and electricity related?

At Home Activities: 1. Energy Consumption Monitoring 2. Cookie Mining & Reclamation	What items in my home need electricity to work? How do I read an electric bill? How can I reduce energy consumption? Test this for one month! What impacts does mining have on the earth? What is reclamation and is it easy to do?

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, you and *your students* will explore the relationship between chemistry and electricity through experimentation. Students will begin with a laboratory activity to build their conceptual understanding of chemical reactions, learn how to use a voltmeter to test the voltage potential of different metals, build a simple coin cell battery to power an LED light, and discover the role that saltwater could play in our renewable energy future. Throughout these hands-on activities, students will also be presented with fun facts, key renewable energy concepts, career tips, and more.

The classroom toolkit for this curriculum includes a book on hydroelectricity to help build literacy and critical thinking skills. Hydroelectricity is a form of alternative energy that uses the motion of water via gravity, tides, and waves to create electricity. Here in Hawaii, the ocean is a tremendous, potential source of energy. The hands-on chemistry experiments will challenge students to think more creatively about how ocean water could be used to create electricity beyond waves, tide, and ocean thermal energy conversion. In each of the activities and four hands-on labs, students will make hypotheses, collect data through observations, analyze their experimental results, engineer a light and a clock and troubleshoot their constructions as needed - 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

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. *Students will develop models to generate data to test ideas about chemical reactions, the conservation of matter, voltages, the transfer of chemical energy to electrical energy and the flow of electricity.*

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 configurations.*
- 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 the various voltages of different metal combinations (electrical potential).*

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. *Students will use the scientific information they learned about chemical reactions, electricity, and circuits in Labs 1 and 2 to build functional, electrical products in Labs 3 and 4.*
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting *In Labs 3 - 4, students will build their own battery to power a LED and a saltwater powered clock. To be successful, they will need to follow the directions and models provided and will likely need to troubleshoot any errors in their assembly - possible through multiple phases of testing, revising and retesting.*

Career Connections

Electrochemist

Electrochemists develop batteries and electrochemical models to provide electrochemical, thermal, mechanical, designs and directions for industrial plants, power plants, and even electric vehicle programs. Electrochemists usually need a masters or bachelors degree and an understanding of various modeling tools.

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 *electrochemical engineers* are experts on designing and running industrial plants which include an electrolytic stage for the production of chemicals or for power generation. During the laboratory activities herein, students will have the opportunity to practice teamwork and their communication skills. The average salary for engineers in Hawai‘i 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 Hawai‘i, 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 hydro**electricity, chemistry, electrochemistry, batteries** and **circuits.** Throughout these lessons and hands-on laboratory activities, you will discover the answer to questions like these*:

- **What is energy?**
- **What is electricity?**
- **How can we use the motion of water to generate electricity?**

- **How can the ocean be used to generate electricity?**
- **What is the impact of mining on the environment?**
- **What role do scientists and engineers play in our renewable energy future?**
- **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 solutions**.

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), batteries and hydropower. **Electricity is a carrier of energy** that is generated by one of the aforementioned resources. We use electricity to carry energy to power our homes, cities, communities, and everyday electronics.

In Hawai‘i, we established the Hawai‘i 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 and this percentage is growing.

In the labs to follow, you will have an opportunity to test how electricity relates to chemistry, how **circuits** 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, and how the ocean around us can be used as a renewable energy resource.

Wait! The ocean? Did you know that the ocean can be used to power our homes, communities, and cities? How do *you* think the ocean could be used as a source to generate electrical energy and why do you think this?

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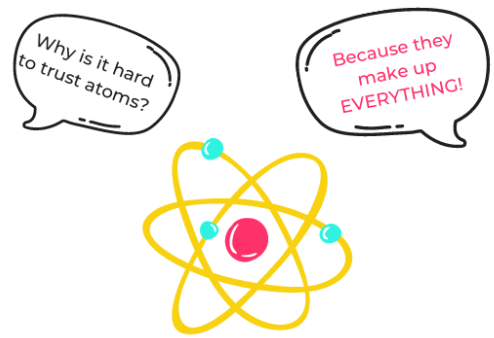
**Answers will vary. Some of your students may know about hydroelectricity through water wheel experiments they've done or encountered in the past. They may have seen videos, or read articles related to this topic. They are less likely to know much about Ocean Thermal Energy Conversion (OTEC), or electrochemical energy generation from seawater (the topic our the labs to follow)*

We'll come back to this topic of ocean-sourced electrical energy later. But first, let's think a little bit more about **electricity**.

Activity: Electricity Exploration *(1-class period)*

It is 6:00AM and your alarm clock beeps. It is hot and muggy outside, but you can hear the hum of the air conditioner or a fan keeping you 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.**



Take a minute to walk around your classroom and if you have time, your school campus. Identify items that need electricity to work, and where *you think* (your best guess) the electricity comes from. Then do some **research** to determine where the electrical energy actually comes from. Fill in the data table below:

Data Table 1: Electricity Exploration			
	Item	**Where does the electricity come from (guess)?**	**What is the energy source (research)?**
1	Lights		
2	Air Conditioner		
3			
4			
5			
6			
7			
8			
9			
10			

Tip: You may want to check out the **HIDOE Dashboard. [Mana - HDOE Dashboard - Ahuimanu Elementary (manamonitoring.com)]** to see if your school gets some or all of its energy from renewable energy sources

Post Activity Assessment:

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

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Answers will vary. If your school is powered by solar, your students may be surprised to learn this.

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, solar, and hydro 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. While we cannot see electricity, that does not mean it is magic - it's science, and it's really easy to learn.

In the labs that follow, we'll investigate how hydropower works, build our very own battery, and engineer a saltwater powered clock. Let's jump into **hydropower** next.

Scientific Research: Hydroelectricity (1-class period)

Scientists conduct **experiments** and make **observations** in order to discover the answers to questions that people generally do not know the answers to, or to broaden our understanding of a phenomena that we have a limited understanding of. **What is something that you always wanted to know more about?** ____

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Before jumping into experiments and/or field research, which can be very expensive, scientists must start by learning all they can about what is already known about their topic of interest. This process is called the **literature review**. In a literature review, scientists will learn everything they can about a topic by reading textbooks, watching videos, occasionally through news articles, and primarily by reading peer-reviewed publications (primary literature). After reading hundreds if not thousands of texts, scientists will have to **synthesize** and **summarize** their findings and use that information to present to others why there is a need for their proposed research or study.

In this activity, you will practice reviewing online, text, and video resources to learn about hydroelectricity.

Here are some guiding questions to help you begin your research:

1. What is hydroelectricity or hydroelectric power?
2. Why is hydropower considered a renewable resource?
3. Does Hawaii have any hydroelectric plants?
4. How can the ocean be used to generate electricity?
5. How is hydroelectric power similar to wind power? How is it different?

Hydroelectricity Research (Literature Review)				
	Information Source (Citation)	**Is your source credible? How do you know?**	**What did you learn?**	**Could this be a way to generate electricity in Hawaii? Why or why not? What would the challenges be?**
1				
2				
3				
4				
5				
Summary of findings				

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

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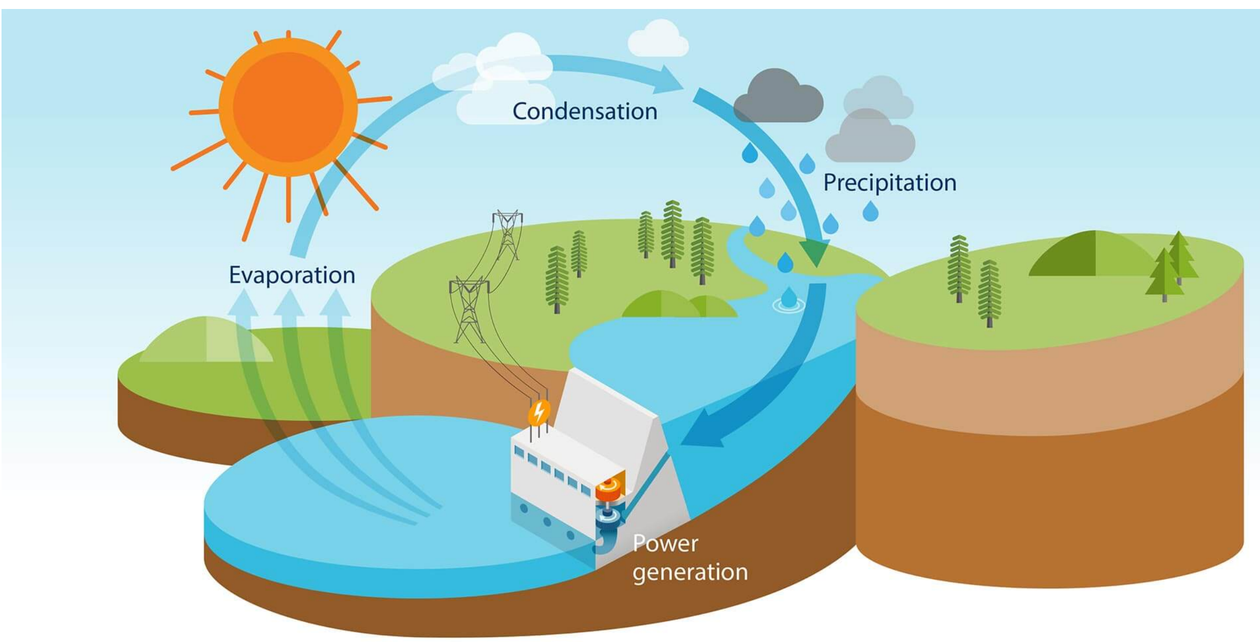
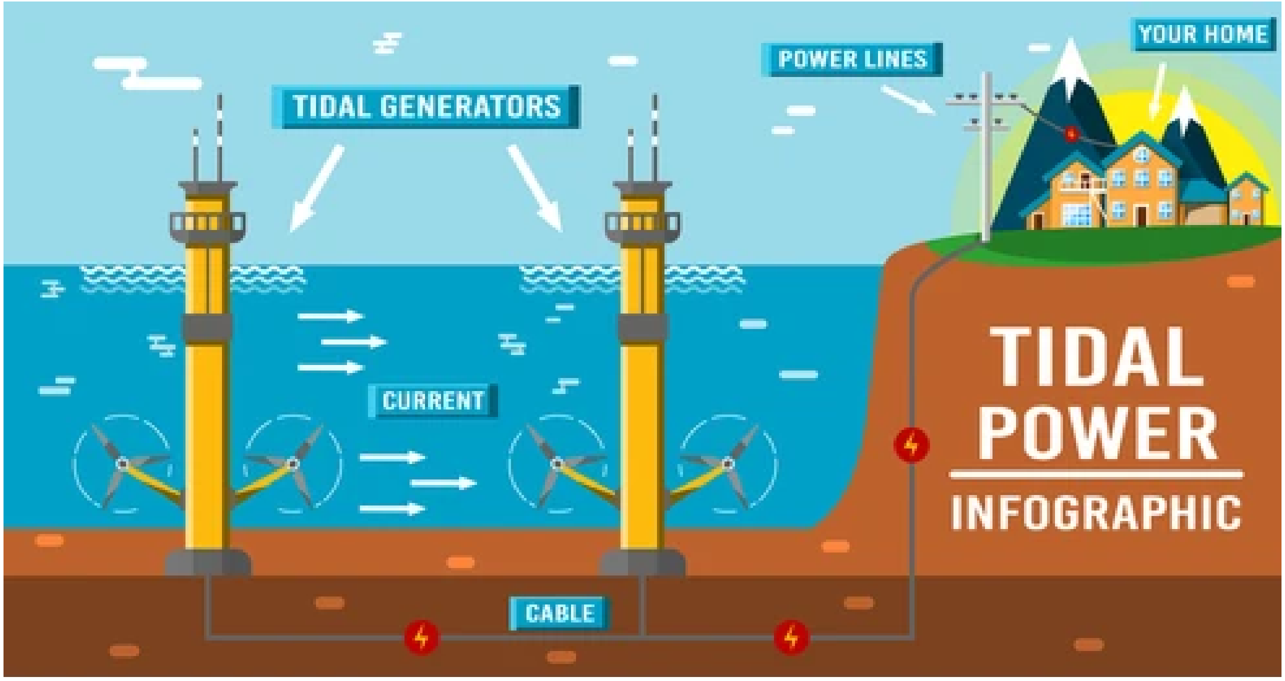
Answers will vary.

Key Concepts: Hydropower is the production of electrical energy through the use of gravitational force of falling or flowing water (kinetic energy). Water is about 800 times denser than air, so even a slow flowing stream, or moderate tides, can produce a considerable amount of energy by spinning a turbine (like a windmill). That mechanical energy is transferred to an electricity generator and the electrical energy is transported from the powerstation through power lines to power your home.



Hydrologic Cycle - [Hydropower | Advantages | Hydro-Québec (hydroquebec.com)]



Tidal Power Infographic (Free shutterstock graphic). Tides move a massive amount of water each day, but at low speeds which make energy conversion difficult. Tides are very predictable though which gives it a big advantage over other types of renewable energy sources like wind and solar.

Extra Resource: Check out this video: How Hydroelectricity Works.

Renewable Energy Connection: Moving water is a natural part of the hydroelectric cycle, and it is a renewable source of mechanical energy that can be harnessed and transformed into electrical energy. Hydroelectric power is a small, but growing source of renewable energy. It makes up about 1.4% of Hawaii's renewable energy portfolio as of 2022. Check out **Hydroelectricity | Hawaiian Electric** for more examples like this one below:

Hawaiian Electric Waiau & Puueo Hydropower

- **LOCATION:** Hilo, Hawaii (Wailuku River)
- **ENERGY SOURCE:** Run-of-river water flow
- **TECHNOLOGY:** Hydraulic turbine generators
- **SYSTEM SIZE:** 1.15 MW (Waiau), 2.25 MW (Puueo)
- **TYPE:** As-available
- **DESCRIPTION:** Hawaiian Electric owns and operates two hydroelectric facilities arranged in tandem along the lower reach of the Wailuku River near Hilo. The Waiau plant was constructed in 1920 and upgraded in 1947. The Puueo plant downstream was built in 1910 and upgraded in 1941. Penstocks (pipes that divert water to the plants) of both facilities were refurbished in 1998. Horizontal-axis, Pelton hydraulic turbines at each plant generate electricity

Our state has the potential to increase our percentage of hydroelectric energy generation if we can harness mechanical energy from the ocean's waves and tides. In Hawaii, we have highly consistent wave energy resources, and currently wave energy generation is in the experimental phase. Hawaiian Electric partnered with the Office of Naval Research to test wave energy generation off of Kaneohe Marine Corps Base of Oahu. This experimental setup employs the bobbing motion of buoys to drive an electrical generator. **Ocean Energy | Hawaiian Electric**

Another way the ocean can be used to generate electricity is through Ocean Thermal Energy Conversion (OTEC) which uses the temperature difference between cold deep seawater and warm coastal waters to produce electricity. Currently OTEC systems are extremely expensive and there are no commercial scale OTEC plants anywhere in the world. However, Hawaii has experimented with OTEC since the 1970s at the Natural Energy Laboratory of Hawaii (NELHA) on Hawaii Island. It was found to be technically feasible but prohibitively expensive in comparison to oil prices at that time. Maybe there will be a technological breakthrough in the future that can bring costs down. **Ocean Energy | Hawaiian Electric** *Want to learn more about harnessing the power of the oceans? Check out this book, The Next Wave.*

Now that you've learned about **hydropower**, did you know that there is ANOTHER way that we can use the ocean to produce electricity that doesn't involve mechanical or thermal energy? In the next four, hands-on laboratories, you're going to run several chemistry experiments to discover how we can use chemical energy to produce electricity. At the end of these activities, you will build your very own saltwater powered clock!

For these labs, we'll be using the Electrochemistry Lab Kit by KiwiCo. Let's take a look at what all is included in this kit. This kit provides a fun, tangible way for you to research how chemical energy and electricity are related **by doing your experiments**.

Electrochemistry Kit Discovery (1-class period)

<table>
<tr><th colspan="3">NGSS Performance Expectations</th></tr>
<tr><td colspan="3">MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Students are asked to research the metals and chemicals in this kit to determine where they come from, and are challenged to think about the environmental impact of mining these materials as well as potential solutions.</td></tr>
<tr><td colspan="3">This exercise focuses on the following three dimensional learning aspects of NGSS</td></tr>
<tr><th>Science & Engineering Practices</th><th>Disciplinary Core Idea</th><th>Crosscutting Concepts</th></tr>
<tr><td>Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
Apply scientific principles to design an object, tool, process or system.</td><td>ESS3.C: Human Impacts on Earth Systems
Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.</td><td>Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World
The uses of technologies and any 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, and economic conditions. Thus technology use varies from region to region and over time.</td></tr>
<tr><td colspan="3">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.</td></tr>
</table>

Before the Activity

- Have students select their teams of four
- 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 KiwiCo Electrochemistry Kit (included)

Procedure: Identify Parts

1. Open up the electrochemistry kit and remove all the pieces from the box
2. Match the items from the kit to the parts list on Page 2 and 3 of the manual

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 the table below.
4. For all the listed items, you may want to do some research to learn more about what they are, where they come from, and what they can be used for.

Electrochemistry Kit Exploration	
Part	**Research -** What is it? **Where does it come from**? What can it be used for? If it is a chemical, you may also want to look up the chemical formula
☐ Voltmeter	
☐ Alligator Clip	
☐ LED	
☐ Wires	
☐ Switch	
☐ LCD Clock	
☐ Cups, Vials, Beakers, Scoop	
☐ Steel Wool	
☐ Aluminum Foil	
☐ Magnesium	
☐ Copper	
☐ Zinc	
☐ Carbon	

▢ Copper Sulfate	
▢ Sodium Chloride	

In Labs 1-4 you will be doing **real chemistry experiments**. All of the items in your kit are safe to use, however:

- Be sure to keep chemicals out of your eyes and rinse immediately with water (remove contacts if you wear them). Place your entire face in water and flush your eyes. *(You may want to wear safety goggles if you have them)*
- Do not taste or try to eat any of the chemicals in this kit.
- Do not use any outside electrical components or chemicals for these experiments. Only use what is provided in this kit.

Kit Discovery Renewable Energy Connection: Most of the items in this kit came from materials that had to be mined or extracted from the earth. In reality, the technical components and industrial supplies for renewable energy systems also have to be mined from the earth whether it be the metals for turbines and generators, silicon and other materials for solar cells, lithium and other materials for batteries. Everything that we build will have some environmental impact. **Can you think of some ways that we could reduce our environmental impacts from mining raw materials?** __________

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This kit and following experiments also introduced you to **constraints**. You will only be permitted to use the supplies that have been provided to you. 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 and this includes chemical engineers. Constraints often inspire innovation and creativity. Alright, are you ready to do some chemistry? In Lab 1, you're going to use written instructions, diagrams, and models to learn more about chemical changes and reactions through experimentation and observations.

Lab 1: Aluminum Eater - Chemical Reactions *(1-class period)*

NGSS Performance Expectations
MS-PS1-5 Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. [Emphasis is on the law of conservation of matter and on drawings, including physical forms, that represent atoms - does not include use of atomic masses, balancing equations, or intermolecular forces.] *Students are asked to conduct a simple, but **dramatic**, chemical reaction that will eat up aluminum foil. They will witness a redox (oxidation-reduction) reaction, and be asked to draw a representation of what happened to all of the atoms in this experiment.* MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Assessment is limited to analysis of the following properties: density,

melting point, boiling point, solubility, odor, flammability]. *Students will need to record their observations of changes in properties of a substance that confirms that a chemical reaction has taken place. In this case, they'll be looking for changes in properties in the aluminum foil.*

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

Science & Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models 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. ● Develop a model to describe unobservable mechanisms. **Analyzing and Interpreting Data** Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. ● Analyze and interpret data to determine similarities and differences in findings. ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena -** Laws are regularities or mathematical descriptions of natural phenomena. **Scientific Knowledge is Based on Empirical Evidence -** Science knowledge is based upon logical and conceptual connections between	**PS1.B: Chemical Reactions** ● Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. ● The total number of each type of atom is conserved, and thus the mass does not change. **PS1.A: Structure and Properties of Matter** ● Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.	**Energy and Matter** ● Matter is conserved because atoms are conserved in physical and chemical processes. **Patterns** ● Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
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

- *Take a minute to discuss the information on pages 4-5 of the electrochemistry manual. This manual uses cooking pancakes as an example of chemical changes. You may want your students to come up with a list of chemical changes they have observed in their everyday life.*
- *You may want to go over what makes up an atom and that molecules are one or more atoms that are stuck together like water (H20).*

Before the Activity

- Have students select their teams
- Make sure there is enough space for the experiment in the center and for each student to make observations

- Gather the materials listed below (page 6 of the KiwiCo Manual)

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

- Mess Matt
- Beaker
- Cup
- Scoop
- 1 Stir Stick
- Copper Sulfate
- Sodium Chloride
- Aluminum Foil
- Hot water *(not included)*
- Scissors *(not included)*

Potential Safety Issues

- This is a quick and dramatic chemical reaction. Do not have your eyes too close to the cup.
- This reaction will produce heat, do not touch the cup during the reaction.
- Be careful that you do not knock over the cup with the solution in it.
- Be careful to make enough of a "bowl" shape in the aluminum foil so that the solution neither overflows or falls through gap between the foil and the cup (there shouldn't be any gaps between the foil and the plastic cup)

Potential Obstacles

- *If the water is too cold, the reaction may not be dramatic. You have enough supplies to run this experiment twice so you may want to test different water temperatures.*

Procedure

1. Layout the mess mat
2. Follow Steps 1-6 in the KiwiCo Manual (pages 6-8).

Embedded Activity Assessment:

1. What color is the copper sulfate and salt solution? ___________________ *(blue)*

Procedure Continued:

3. Follow Steps 7-9 in the KiwiCo Manual (page 9) - make mental and physical notes. **NOTE- THIS REACTION WILL HAPPEN QUICKLY SO BE READY TO MAKE OBSERVATIONS.**

Embedded Activity Assessment Continued:

2. How long did it take for the reaction to start? ______________________ *(immediately)*

3. How long did it take for the reaction to eat through the aluminum foil ___________*(10 seconds)*

4. Describe what you saw as the reaction started __________________________________

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5. What do you see in the beaker when the reaction is done? ________________________

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6. What does the aluminum foil that is left look like? ________________________________

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   Answers will vary but it should look like it has holes in it and black like it has been burned (oxidized). If you see red, that is rust.

Optional Extension Challenge: Repeat the experiment with cold water instead of hot water. How does this change the reaction? ____

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(Slower, less dramatic, if very cold water, might not work well at all.)

Clean up - throw away the aluminum foil and the materials in the beaker. **Rinse the beaker, cup, and stir stick in cold water and keep these items to use again.**

Post-Lab Assessment

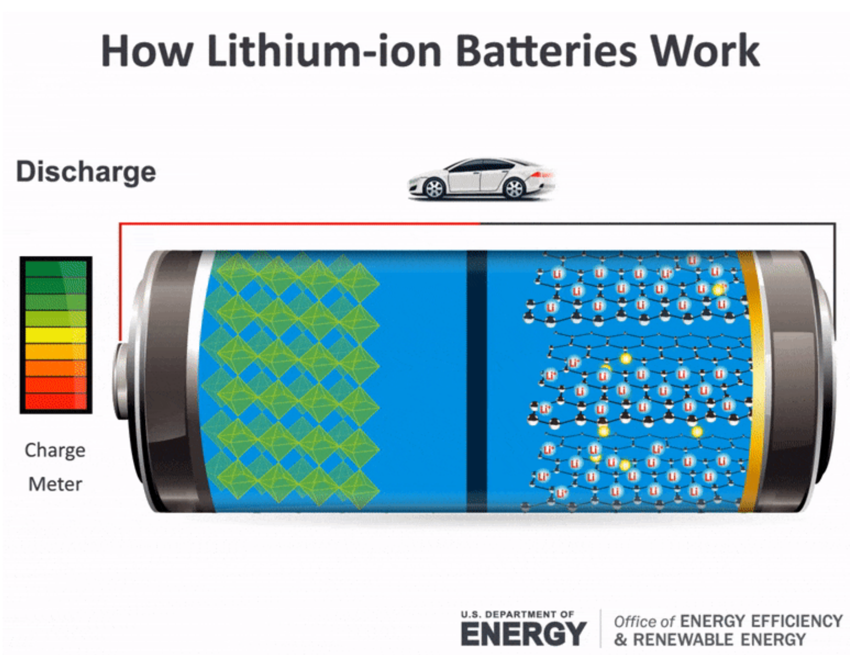
You just observed a chemical change and made aluminum foil disappear! Or did you!? While it may appear that the aluminum foil disappeared, it is actually still there, just in a different chemical form. A fundamental fact in chemistry (law) is that we cannot increase or decrease the amount of matter present in the universe. That means before, during, and after this chemical reaction, the number of copper atoms and aluminum atoms stayed the same. Draw a picture or model below that illustrates this **conservation of matter.**

(Some of the aluminum atoms are now a part of the solution in the beaker and the copper atoms in the copper sulfate solution formed the reddish-brown materials that you see.)

Key Concepts: This reaction was an example of two different chemical reactions called oxidation-reduction or “redox” for short. Redox reactions are extremely common in nature. In an oxidation reaction, an atom will lose electrons and the lost electrons have to go somewhere which is why a reduction reaction always occurs as well. Reduction reactions involve an atom gaining electrons. In this experiment. The aluminum was in an oxidation state (lost electrons) and the copper was in a reduction state (gained electrons). Combustion or burning is another example of a redox reaction. Most redox reactions involve the transfer of oxygen atoms, hydrogen atoms, or electrons. *Fun Fact - Have you ever seen an old book where the pages have turned yellow or even brown? The paper is actually burning in slow motion via a redox reaction.*

Renewable Energy Connection: Batteries produce electric current from electrochemical oxidation and reduction reactions. A battery essentially converts chemical energy into electrical energy. If you take a look at a battery, you will notice that it has a negative node (-) and a positive node (+). At the negative electrode, an oxidation reaction takes place and electrons flow out of the cell, through a circuit, and return to the battery at the positive electrode.

Batteries are going to play an enormous role in our renewable energy future from storing electrical, wind and hydropower energy to powering electric vehicles in the transportation sector. Can the QR code below to see an animated .gif for the graphic below.



In Labs 3 and 4, you will make your very own batteries! But first, let’s learn how to use your voltmeter and explore **voltage** and **electric potentials** of various **conductive** materials.

Lab 2: Voltage Tests *(1 class period)*

NGSS Performance Expectations
Voltage The NGSS focuses on a conceptual understanding of core ideas. **Voltage**, **resistance**, and **current** describe the movement of a charge, and more broadly, the transfer of energy. These words and their respective symbols and definitions can be introduced and applied for instructional purposes as needed. Oxidation/Reduction The NGSS do not include specific names of chemical reactions and instead focus on conceptual understanding of how chemical reactions occur. This ensures that students have a conceptual understanding that they can apply to any type of chemical reaction. Classes of chemical reactions such as oxidation and reduction, acid and base, or decomposition and synthesis can be used in instruction depending on the context, but instruction should ensure that students have an understanding of the underlying concepts. Related PEs and Bundles: MS-PS1-2 Matter and its Interactions
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

- *A voltmeter tells you the voltage between two points. You can think of voltage as electrical pressure - it is what moves electrons through a circuit. See the KiwiCo manual page 21.*
- *You may want to practice testing the Voltmeter with an AA battery. See page 26 of the KiwiCo manual for a few suggestions.*

Before the Activity

- Have students select their teams
- Make sure there is enough space for the experiment in the center, and for each student to make observations. Every student should participate in taking measurements.
- Gather the materials listed below (page 16 of the KiwiCo manual)

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

- Mess Matt
- Beaker
- Clips
- Voltmeter
- Carbon strip
- Zinc strip
- Aluminum foil
- Steel wool
- Sodium chloride (salt)
- warm water *(not included)*
- Permanent Marker *(optional - not included)*

- AA battery *(optional - not included)*

Potential Safety Issues

- None. This is a very safe experiment.

Potential Obstacles

- The alligator clips must be fully in contact with the metal strip being tested.
- Make sure metal strips are partially submerged in the water/solution.
- Make sure the metal strips are not touching each other.

Procedure

1. Lay out the mess mat
2. Follow Steps 1 - 5 in the KiwiCo manual (pages 16-18)

Embedded Activity Assessment

1. What voltage did you measure?
   Magnesium-carbon in **plain** water ________________________________

Voltage (V) = Current (I) x Resistance (R). Volts are a measure of *potential energy*. The higher the volts, the more potential energy is stored.

3. Follow Steps 6 in the KiwiCo Manual (page 19)

   2. What was the highest voltage you read for Magnesium-carbon in **salt** water? _______

   3. What do you think will happen when you swap the wires? Make a prediction: ________

   ____

   ____

4. Follow Steps 7-8 in the KiwiCo Manual (page 20). Was your prediction correct? ____________
5. Follow Steps 9 - 14 in the KiwiCo Manual (pages 22-25)

   4. What voltage did you see for copper-zinc in salt water ____________________ (*~0.4*)

   5. How does the copper-zinc voltage compare to the magnesium-carbon voltage?
   ____________________________________ (*less*)

6. Fill out the following table with the voltages you measure. Remember, if you get a zero reading, swap the wires, and make sure the clips are in good contact with the metal strips. *(Note: Fe is the iron in your steel wool)*

C	Cu	Fe	Zn	Al	Mg	
						C
						Cu
						Fe
						Zn
						Al
						Mg

7. Which combination gives the highest voltage reading? ______________________________
   (Mg-C)

8. Which combination gives the lowest voltage reading? ______________________________
   (Cu-C)

9. Which combination of metals would you use to power a clock and why? ______________

   ____

   ____

   ____

   Hint - Remember that the higher the volts, the more potential energy is stored.

Optional Extension - Test other materials in your classroom such as coins, pencil lead, jewelry, anything that you don't mind putting in saltwater.

Key Concepts: In this experiment you created a closed circuit using metal strips, wires, and a conductive solution. **A circuit is like a racetrack for electrons**. If there is a break in the circuit at any point, then electrons cannot flow through the track. That's why if your alligator clips were not in good contact with the metal strip, or the metal strip was not in the saltwater solution, you would get a 0 voltage reading.

If you can break an electron free from an atom and force it to move, you can create electricity. The voltmeter is a tool that allows you to measure the voltage of the electrical current running through the circuit. 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. In this experiment electrons flow from the elements with higher electric potential to elements with lower electric potential.

Also in this experiment, the conductive solution that was used was saltwater. When the sodium-chloride was mixed into the water, it broke down into sodium ions and chloride ions. An **ion** is just an atom or molecule that loses or gains electrons. **Ions are fantastic at moving electrons around.** This is why the saltwater solution filled with ions allows electricity to move through the circuit efficiently. *Look back at your pure water vs saltwater voltage measurement.* The voltmeter readings tell you that there are electrochemical reactions happening. Just like you observed in Lab 1: Aluminum eater, these electrochemical reactions in this experiment are also redox reactions that are moving electrons around.

Renewable Energy Connection: The greater the difference in electric potential between the two metals, the more energy you can get from those combinations of elements. This is important fundamental knowledge to have if you want to use redox reactions to create a battery. Also, just like in this experiment, the salt ions in seawater can be used to move electrons around to generate an electric current. There is a startup company in Hawaii, Polu Energy, that is testing the possibility of using seawater and groundwater to produce renewable energy for small-scale energy needs.

Polu Energy Video Link

Next, in Labs 3 and 4, we're going to build on these voltage experiments to build a coin cell battery that will power a LED flashlight and a saltwater solution powered clock! Let's dive in!

Lab 3: Coin Cell Battery Flashlight

<table>
<tr><th colspan="3">NGSS Performance Expectations</th></tr>
<tr><td colspan="3">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.

Students will build a coin cell (voltaic pile) powered flashlight aka an electrochemical battery that will power a LED. Their constraints will be the materials provided in the kit. They may need to troubleshoot their designs and make changes until the LED lights up properly.</td></tr>
<tr><td colspan="3">This exercise focuses on the following three dimensional learning aspects of NGSS</td></tr>
<tr><th>Science & Engineering Practices</th><th>Disciplinary Core Idea</th><th>Crosscutting Concepts</th></tr>
<tr><td>Asking Questions and Defining Problems
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.
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.</td><td>ETS1.A: Defining and Delimiting Engineering Problems
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.</td><td>Energy and Matter
Energy can be transferred in various ways and between objects.
- - - - - - - - - - - - - - - -
Systems and System Models

Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems.

Influence of Science, Engineering, and Technology on Society and the Natural World
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.</td></tr>
</table>

		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, 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

- *You may want to do a quick refresher on what electricity is. Here is an excellent tutorial with some simple animations: [What is Electricity? - learn.sparkfun.com]*

Before the Activity

- Break up into teams
- Gather the following materials:

Materials List - For this activity, each group will need (KiwiCo Manual page 28):

- Mess Mat
- Beaker
- Scoop
- Stir Stick
- Chipboard Disks
- Sandpaper
- Black Sticky Foam
- Gray Sticky Foam
- Black Double-Stick Foam
- Plastic Tube
- Voltmeter
- Connector Wires
- Switch
- LED
- Sodium Chloride (salt)
- Copper Disks
- Zinc Disks
- Warm Water *(not included)*
- Scissors *(not included)*

Potential Safety Issues

- None

Potential Obstacles

- Sanding the copper and zinc discs will take some time. Students will need to be patient and will need to make sure the shiny protective coating is heavily scratched up. If they get tired, they should take turns.
- Do not mix the two discs up. Zinc discs are gray and the copper discs are orange.

Procedure

1. As before, start by laying out the mess mat.
2. Follow Steps 1-9 in the KiwiCo Manual (pages 28-31). Pay special attention to tips in red font.

Embedded Activity Assessment

Did you get a voltage reading of 0.3 to 0.6 volts? ____________________ If not, make sure the red alligator clip is touching the copper disc and the black one is touching the zinc.

3. Repeat Steps 4-9 to make a total of five cells.
4. Check each cell with the voltmeter. If any cell does not produce a voltage, you'll need to troubleshoot. Troubleshooting is an important part of the engineering process. See the troubleshooting tips on page 32 of the KiwiCo manual.
5. Follows Step 11 (KiwiCo manual page 32). Make sure that all the cells are facing in the same direction so that the copper and zinc are always back to back.
6. Test the voltage of your voltaic pile. It should be about 1.0V (if higher, that's great!)

You just built a 1.0V battery! Way to go engineers! Now we need to wire this battery up in a circuit to power the LED. This time, our circuit will have an on-off button that will break the circuit to turn the light off, or complete the circuit to turn the light on.

7. Follow Steps 12 - 30 in the KiwiCo manual (page 33 - 38). Pay careful attention to text in the red font.

Post-Activity Assessment

1. Did your coin battery powered flashlight work the first time? _________ If not, what steps did you take to troubleshoot the problem? What troubleshooting action(s) worked to solve the problem?____

   ____

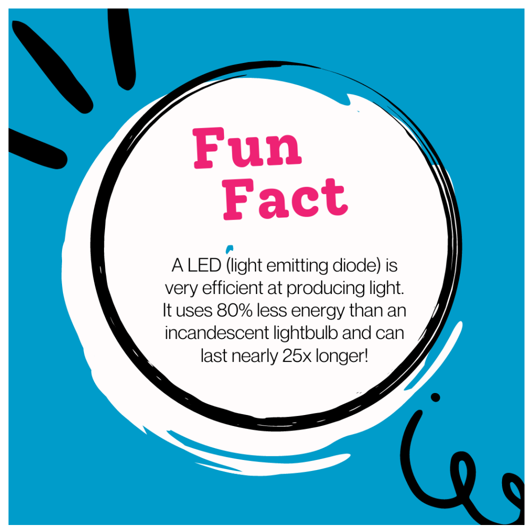
   ____

   (answer will vary)
2. All Electrical components require a certain amount of voltage to work properly. In this test, you saw that your LED needed at least 1.0V to light up. Over time, your LED's beam of light will weaken. Why do you think this is? ____

(As the cells dry out, there will not be any ions in solution to help move the electrons along.)

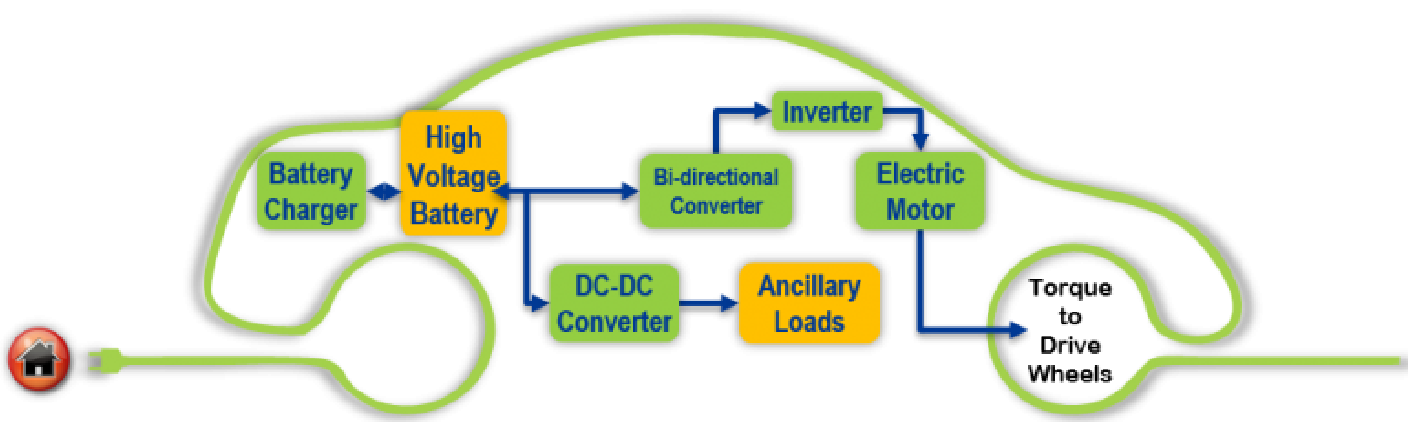
Key Concepts: This activity builds upon the basic electrochemistry concepts that were learned in Labs 1 and 2 and added in an introduction to the engineering design process. The constraints in this exercise were the materials that were available in the kit. Engineers always have constraints in terms of materials, and will often have to troubleshoot an assembly, sometimes through multiple iterations of troubleshooting, in order to get their design to perform as needed. Sometimes when something does not work the first time, students are tempted to give up because it “doesn’t work”. With just a few modifications, it is often possible to develop a solution to solve a problem. This takes practice, patience, and persistence.

Career Connection: In this activity, 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.



Renewable Energy Connection: In this engineering experiment, you recreated a version of the very first battery, known as a voltaic pile, that can supply a continuous electric current to a circuit. It was invented by an Italian doctor and scientist in 1780. You can read about Luigi Galvani and how he came up with his invention on pages 40 - 41 of the KiwiCo manual.

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.

Extra Resource: How batteries work - Adam Jacobson - YouTube

Alright Electrochemists. Are you ready for the **grand**, **final**, **challenge**? Let's put everything that we have learned together to build a saltwater powered clock!

Lab 4: Saltwater Powered Clock *(1 class period)*

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. *Students will build a saltwater power clock with constraints being the supplies they have on hand.* MS-PS1-5 Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. [Emphasis is on the law of conservation of matter and on drawings, including physical forms, that represent atoms - does not include use of atomic masses, balancing equations, or intermolecular forces.] *Students are asked to draw a model of their clock showing what is going on on a molecular level in terms of electrons.*		
This exercise focuses on the following three dimensional learning aspects of NGSS		
Science & Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models 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. • Develop a model to describe unobservable mechanisms. ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** Laws are regularities or mathematical descriptions of natural phenomena. **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based upon logical and conceptual connections between evidence and explanations.	**ETS1.C: Optimizing the Design Solution** 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. **PS1.B: Chemical Reactions** Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is	**Systems and System Models** Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. **Energy and Matter** Matter is conserved because atoms are conserved in physical and chemical processes. **Patterns** Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

	conserved, and thus the mass does not change.	
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.		

Before the Activity

- Break up into teams
- Gather the following materials:

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

- Vials
- Clock Base
- Black Sticky Foam
- Black Double-Stick Foam
- Beaker
- Scoop
- Stir Stick
- Sandpaper
- LED Clock
- Voltmeter
- Alligator-clip wire
- Sodium Chloride (salt)
- Copper Strips
- Zinc Strips
- Warm Water (*not included*)

Potential Safety Issues

- None

Potential Obstacles

- Just like in Lab 3, students will need to scratch off the shiny surface of the copper and zinc strips. This may take a little time.
- It is important to read each step very carefully and to take your time to make sure everything is oriented in the proper direction, order, and are lined up correctly.

Procedure

1. You already know what to do - lay down your mess mat
2. Follow Steps 1 -18 in the KiwiCo Manual (pages 44 - 50)

Embedded Activity Assessment

1. Grab the voltmeter and pick one of the vials to test. Clip the black wire to the zinc strip and the red wire to the copper strip. Is the voltmeter reading close to 0.75V ? ____________________

   If not, take some time to troubleshoot your configuration. Are the wires securely clipped to the strips? Are the strips touching each other? Review Steps 9-16 if needed to make sure each step was done correctly.

3. Follow Steps 19 - 24 in the KiwiCo Manual (pages 50 - 52)

2. Did your clock turn on? ____________________ If not, troubleshoot your design. If so, **CONGRATULATIONS**! You made electricity with chemistry!

Post-Activity Assessment:

1. How many attempts did it take you to get your clock to work?__________________________

2. Reflection: What lessons did you learn along the way? ________________________________

____

____

____

Draw a picture or model below that illustrates what electrons are doing in your saltwater powered clock.

Optional Extension Activity: You can use other items in place of the saltwater solution. Grab a lemon, orange, even a potato, and stick the two different strips into them. Just like in the saltwater solution, do not let the metal strips touch. Clip the voltmeter to the strips. How does the voltage of the item you chose compare to the saltwater battery?

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 through the **engineering design process**. Where you built your batteries, tested them, and made configuration revisions as needed to create a working clock. Way to make the best of the pieces (constraints) you had to work with!

Common Misconceptions/Career Connection: 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 Connections: Hydroelectricity from mechanical energy, thermal conversion energy, and chemical energy all all free, clean and renewable. Scientists and engineers around the world are researching ways we can improve our technologies to harness “Blue Energy” to help supply our electricity needs. In the future, we will continue to need scientific and engineering breakthroughs in the energy sector, and maybe someone, **possibly you**, will help.

Conclusion

Renewable energy resources are ultimately our best option to continue to power our homes, schools, and community 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.

Note that while renewable energy such as hydroelectricity, solar and wind power are often referred to as “clean energy”, the raw materials needed to create batteries, solar panels, windmill hardware may come from nonrenewable resources. These include materials like lithium for batteries and 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 to reduce the rate of our raw material extraction.

Mahalo nui loa for joining us on this energy exploration into the world of hydroelectricity, electrochemistry, 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

- *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).*
- 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:

- Atom: the smallest particle that makes up all matter.
- Batteries: used to store energy.
- Chemical Energy: energy that can be harnessed from chemical reactions like the combustion of fossil fuels, metabolism when you eat food, or batteries.
- Circuit: a conductive pathway that electricity can flow through.
- Conserve: to use less of something like electricity or water.
- Constraints: The limitations placed on a possible engineering solution.
- 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.
- Iterative Design: As you create something, continue to think about new ideas and ways you can make improvements.
- Engineering: the use of science and math in the design and construction of things.
- Energy: the ability to change things or do work.
- 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 by turning a magnet inside a coil of wire.
- Hydropower: energy that comes from the force of moving water
- Innovation: a new invention or way of doing something
- Kinetic Energy: the energy of something in motion
- Nonrenewable: an energy source that is not able to be replenished as quickly as it is used.
- Potential Energy: energy waiting to make something happen like water stored in a dam.
- Reclamation: The process of returning land to its original condition or better.

- 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.
- Solar Power: energy from the sun that is converted into electricity.
- Technology: tools, methods, and systems used to solve a problem or do work.
- Tidal Turbines: Imagine a windmill deep underwater. The turbines spin from the changing directions of waterflow instead of airflow.
- 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.
- Voltage: Electrical pressure that makes electrons move on or off an atom giving them an electrical charge.
- Volts: a unit of electrical potential also known as electromotive force.
- Water Cycle: the movement of water from land to bodies of water, into the atmosphere, and back to earth.

At Home Extension Lessons: (*Homework*)

1. Electricity Reduction Experiment

This week, your child learned all about hydropower, chemistry, electricity, and electrochemistry. They had the opportunity to explore what components in their school use electricity; different sources of energy from water; how electricity is produced; how circuits work through hands-on activities; and they even engineered (designed, built, and tested) their very own battery used to power a LED, and a saltwater powered clock

They also learned 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, 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? ________________________

   ____

   ____

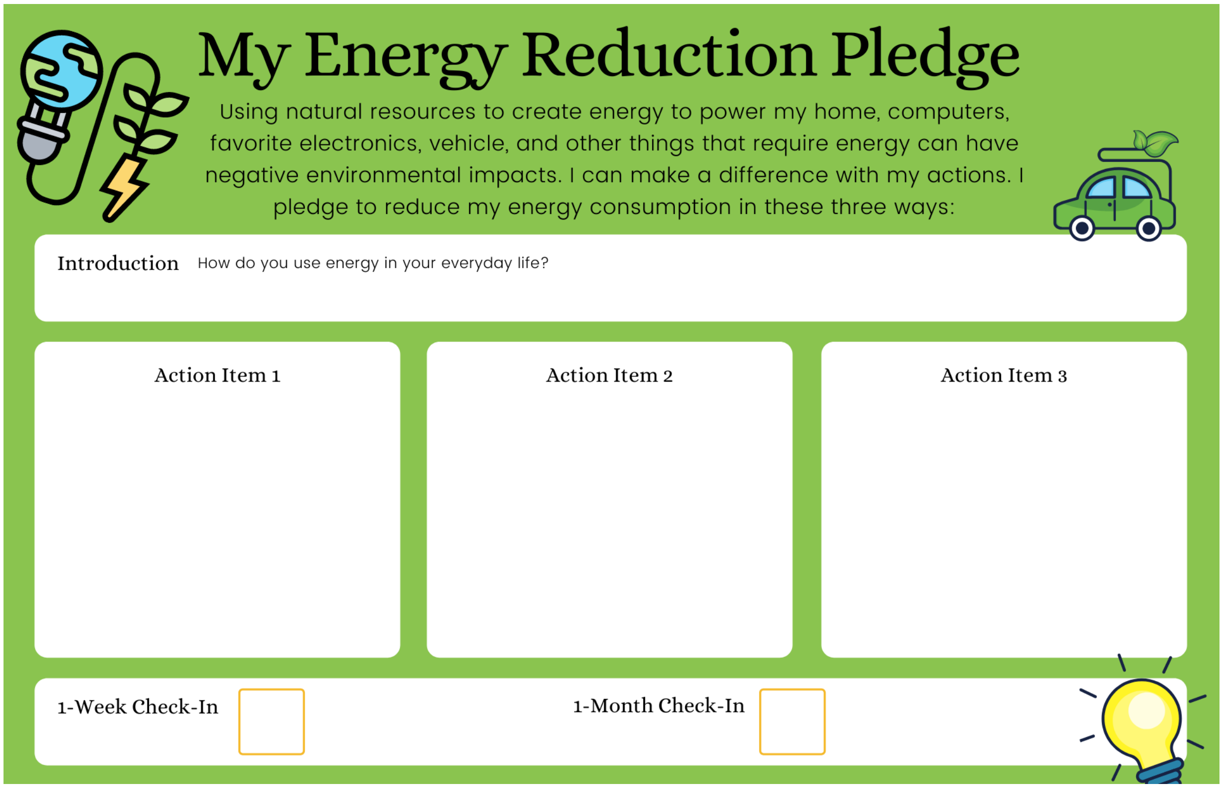
   ____

   ____

   ____

   (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? ________________

____

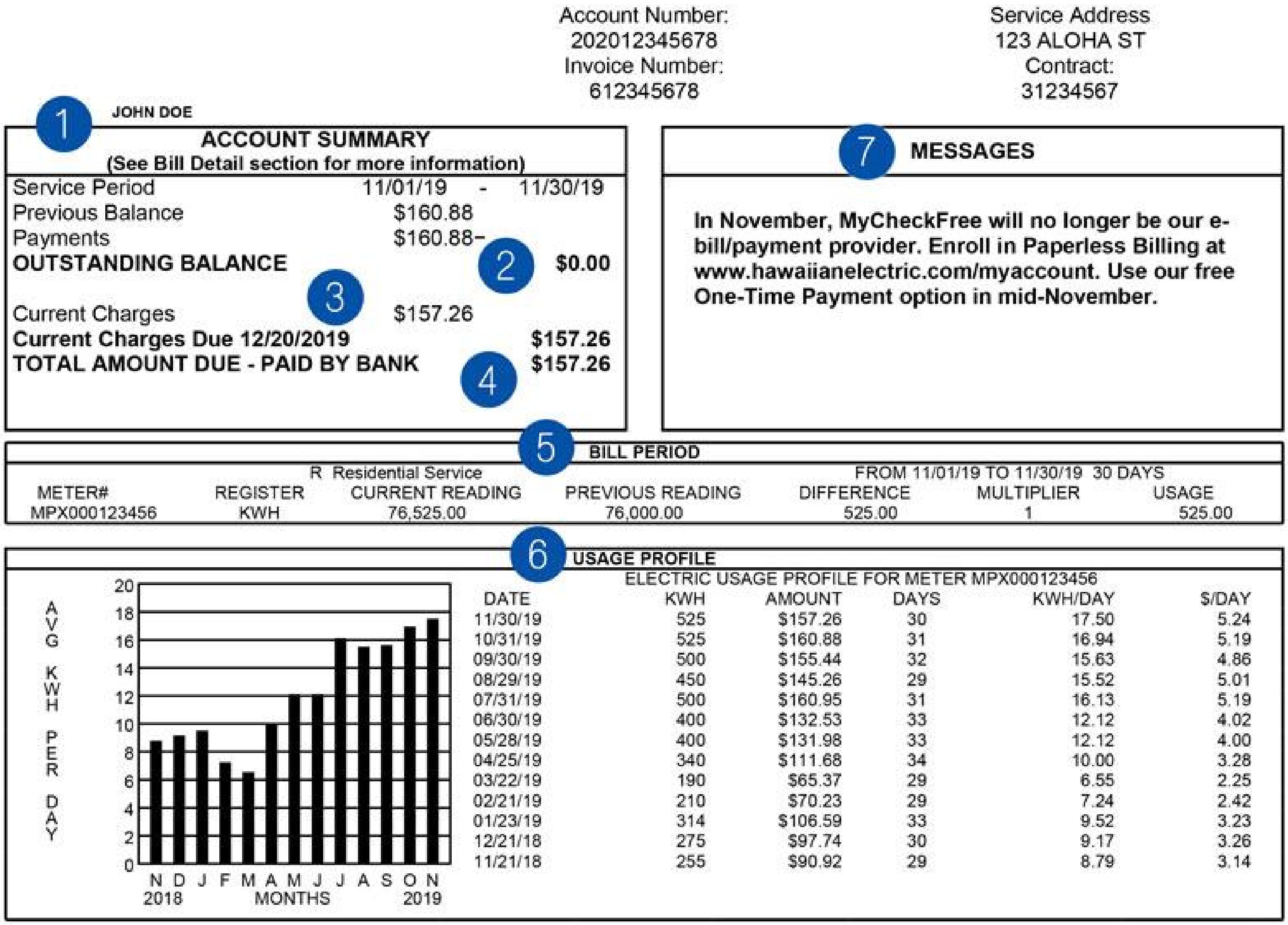
____

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 ʻohana, 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

1 JOHN DOE

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	2	**$0.00**
3		
Current Charges	$157.26	
Current Charges Due 12/20/2019		**$157.26**
TOTAL AMOUNT DUE - PAID BY BANK	4	**$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.

2. Cookie Mining & Reclamation Experiment

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:

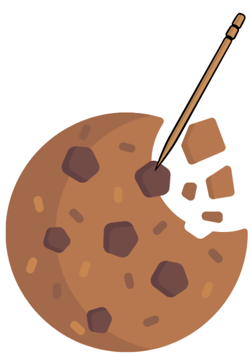
- Fossil Fuels like Coal and Petroleum (we burn for electricity generation)
- Copper (used for wires and electrical hardware)
- Rare-Earth Minerals (for electronics)
- Steel & Iron (used for wind turbines)
- Lithium (used in batteries)

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. Be careful with sharp objects.
- 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.stemworksHawai'i .org](http://www.stemworksHawai'i.org) [energy.Hawai'i .gov](http://energy.Hawai'i.gov)