HAWAI`I STATE ENERGY OFFICE

RENEWABLE ENERGY LABS

GRADES: 9-12 #2

State of Hawaiʻi

Department of Business, Economic Development, and Tourism

Hawaiʻi State Energy Office

CLEAN ENERGY EDUCATION CURRICULA and TOOLKITS

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

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

Curriculum at a Glance	
Grade Levels	9 - 12
Time Required	5 - 8 50-minute Class Periods
Activity Group Sizes	2 - 4 (varies by activity)
NGSS Performance Expectations	HS-ESS2-2, HS-ESS3-5, HS-ETS1-2, HS-LS2-7, HS-PS1-2, HS-PS3-3, Relevant NGSS HS Summary Sheets: Chemical Reactions, Earth's Systems, Engineering Design, Human Sustainability, Weather and Climate
Activity/Lab Title	**Guiding Questions**
Lab 1: Climate Data Visualization using Geographic Information Systems (GIS)	How do we know that the global climate is changing? What tools do scientists have to visualize climate change data? How can data collected from satellites (*remote sensing*) be used to predict future climate related events?
Online Extension Activity: Predict Coral Bleaching Using GIS	Use ArcGIS Online and geospatial data to create your own model to Predict coral bleaching events | Learn ArcGIS* **You will need an ArcGIS Online account to complete this activity. This can be provided by ESRI to your school or setup and managed by STEMworks*
Lab 2: Sea Ice vs Land Ice	What happens to ice on our planet when temperatures rise? How has sea ice extent changed over the years? What happens to sea levels if ice sheets and icebergs melt? What are the impacts of melting sea ice and land ice? Why is it important to transition to renewable fuel sources?
Lab 3: Biofuels STEM Challenge *(Flinn Scientific Kit)*	How do chemists collect data? How can I create a laboratory procedure based on scientific knowledge? What are biofuels?

	What is the difference between Biomass and Biofuel? Why do biofuels make sense for Hawaii?
At Home Extension Activity: Energy Monitoring	How do I read an electric bill? What can I do to reduce my electricity consumption?

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 9-12 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 how our energy consumption habits are directly related to climate change, how scientists study climate change and predict future impacts, and how chemistry can be used to transform energy from one form to another. Through experimentation, observation, data collection, and data analysis, students will build their conceptual understanding of climate change through data driven analyses and will use chemistry to test different the potential of different feedstocks for the production of biofuel. Throughout the interactive activities, they will also be exposed to fun facts, key renewable energy concepts, and career connections.

The classroom toolkit for this curriculum includes a copy of *"Climate Change and the Road to Net-Zero"* which can be used for building climate-literacy and critical thinking skills around humanity's impact on the natural world. The toolkit also includes supplies to experiment what the effects of melting land ice and sea ice are on sea level rise with enough supplies for 15 groups to make measurements and observations; and a biofuel design challenge with enough supplies for 10 groups. Throughout the activities students will practice reading and developing models, reading and collecting data, analyzing data results, identifying patterns, revising experimental designs, and presenting their reflections and solutions to their peers - just like real scientists and engineers.

We also included an online extension activity that allows you to use geospatial data and GIS software to predict future coral bleaching events. This activity can be completed in the classroom or at home. There is also an at-home extension activity about monitoring home electricity usage to engage other members of the household in the discussion of renewable energy and energy consumption habits. *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, or unexpected results, to clarify and/or seek additional information.
- Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

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, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
- Develop a complex model that allows for manipulation and testing of a proposed process or system.

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

- Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible variables or effects and evaluate the confounding investigation's design to ensure variables are controlled.

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

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
- Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.

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, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

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

- Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
- Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Career Connections

Earth/Geo Scientists

There are many different disciplines of science that study the earth and earth systems. These include, but are not limited to: atmospheric scientists, chemists, climatologists, environmental scientists, oceanographers, geologists, geographers, and more! Geoscientists often spend their time outdoors collecting data, and indoors analyzing their data and publishing results. They may also work for environmental management and engineering firms to make sure that all environmental regulations are being followed. Geoscience jobs have a wide range of salaries from $35,000 - $250,000 with an average of $97,356/ year in Hawaii.

Engineers (Chemical)

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). In Lab 3, students will get to practice thinking like **Chemical Engineers**. Chemical engineers apply scientific principles of chemistry, biology, physics, and math to solve problems in various industries such as the fuel/energy industry, food, pharmaceutical, beauty, and more. The average salary for engineers in Hawai‘i is $84,631/year.

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). Wind turbine technicians are an example of a green job with foreseeable growth.

Geospatial Analysts/GIS Scientists

Geospatial Analysts and Geographic Information System (GIS) Scientists use mapping technologies and, geospatial data, and geographic information systems (GIS) to do complex geospatial analysis. GIS specialists are in more demand than ever before with nearly every industry in need of locational data for better decision making. The yearly global value of GIS and the related geospatial industry is

$350 billion. Geospatial analysts on average make $74,000/year with higher wages in the intelligence community. In the renewable energy sector, GIS technology is used to create location intelligence around where to find energy sources and how to deliver it to people who need it by using geospatial data such as demographics,geology, terrain, weather, the built environment, and more.

Introduction

Aloha e Energy Explorers!

Welcome to this adventure into the sectors of **climate change** and **renewable energy** with a focus on **Biofuels**. Throughout the following lessons and hands-on laboratory activities, you will discover the answer to questions like these:

- **What is energy?**
- **What is the difference between weather and climate?**
- **How do we know that Earth's climate is changing?**
- **What tools do scientists use to study climate change?**
- **Why is it important to transition to renewable energy?**
- **What role can biofuels 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 and use data, science and engineering 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 sources like **fossil fuels** such as oil and gas (non-renewable), biofuels, wind power, solar radiation, geothermal (renewable), and nuclear power. **Electricity** is **a carrier** of that energy. We use electricity to carry energy through cables, wires, and circuits to power our homes and everyday electronics.

Did you know Hawaiʻi 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 the electricity generated in our state has been from renewable sources! There is still a lot of work to be done, but we're on our way and will need everyone to get onboard to be successful.

But why is this transition to renewable energy so urgently needed? As an island state, we are at the forefront of many of the negative effects of **climate change** including sea level rise, increased flooding, warming ocean waters and ocean acidification which affect marine life, shifts in rainfall patterns, drought, and the potential for increased storm severity (State of Hawaii Climate Change Portal and EPA Summary). We also know from data collected at our very own Mauna Loa

Observatory that present day climate change is directly related to the amount of **greenhouse gasses** humanity has released into the atmosphere from burning fossil fuels to power our homes, cities, vehicles, airplanes and more (Keeling Curve).

There are many ways that scientists study temperature records in the past (*paleoclimate*) including studying ice cores, ocean sediment cores, tree rings, stalagmites, and evaluating patterns in data collected from satellites. In Lab 1, you will investigate remote sensing data collected by satellites and explore various datasets, models, and dashboards to discover the tools that scientists use to study, monitor, and predict climate change patterns. In Lab two, you will test for yourself a common misconception about sea level rise to practice building critical thinking skills when evaluating information about climate change, and lastly, in Lab 3, you will use chemistry and creativity to test how fuel can be created from renewable, biological materials to help with the transition away from burning fossil fuels (also called **decarbonization**). Let's jump in!

Lab 1: Climate Data Visualization using Geographic Information Systems (GIS) *(1-2 class periods)*

NGSS Performance Expectations		
HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's system Students will evaluate various dashboards that visualize geoscience data and hone in on the Sea Ice Aware GIS. They should be able to articulate what the data patterns show and what the associated impacts are for our planet and all that inhabits it.		
This exercise focuses on the following three dimensional learning aspects of NGSS		
Science & Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using computational models in order to make valid and reliable scientific claims. - - - - - - - - - - - - - - - - ***Connections to Nature of Science*** **Scientific Investigations Use a Variety of Methods**	**ESS2.A: Earth Materials and Systems** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **ESS2.D: Weather and Climate** The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. **ESS3.D: Global Climate Change** Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable. Feedback (negative or positive) can stabilize or destabilize a system. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. - - - - - - - - - - - - - - - - ***Connections to Engineering,Technology, and Applications of Science***

- Science investigations use diverse methods and do not always use the same set of procedures to obtain data. - New technologies advance scientific knowledge. **Scientific Knowledge is Based on Empirical Evidence** - Science knowledge is based on empirical evidence. - Science arguments are strengthened by multiple lines of evidence supporting a single explanation.	manage current and future impacts.	**Influence of Engineering, Technology, and Science on Society and the Natural World** New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.
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:

- **Climate** and **Weather** are not the same. Weather is the day-to-day, short-term changes in atmospheric conditions whereas climate is the average weather over many years. Earth's *average* temperature has been increasing rapidly since the 1940s (climate.gov). Watch this Global Warming Video from NASA
- There are several known factors that can cause climate to change including: changes in the amount of energy from the sun reaching our planet, increased intensity and/or frequency of volcanic eruptions, increased rate of seafloor spreading, and changes in the amount of greenhouse gasses in the atmosphere such as carbon dioxide.

If your students have not had any other exposure to climate change lessons, you should spend extra time digging into these hyperlinks and discussing them before jumping into this lab.

Before Activity

- Breakup into teams of 2
- Each team should gather the following materials:

Materials List

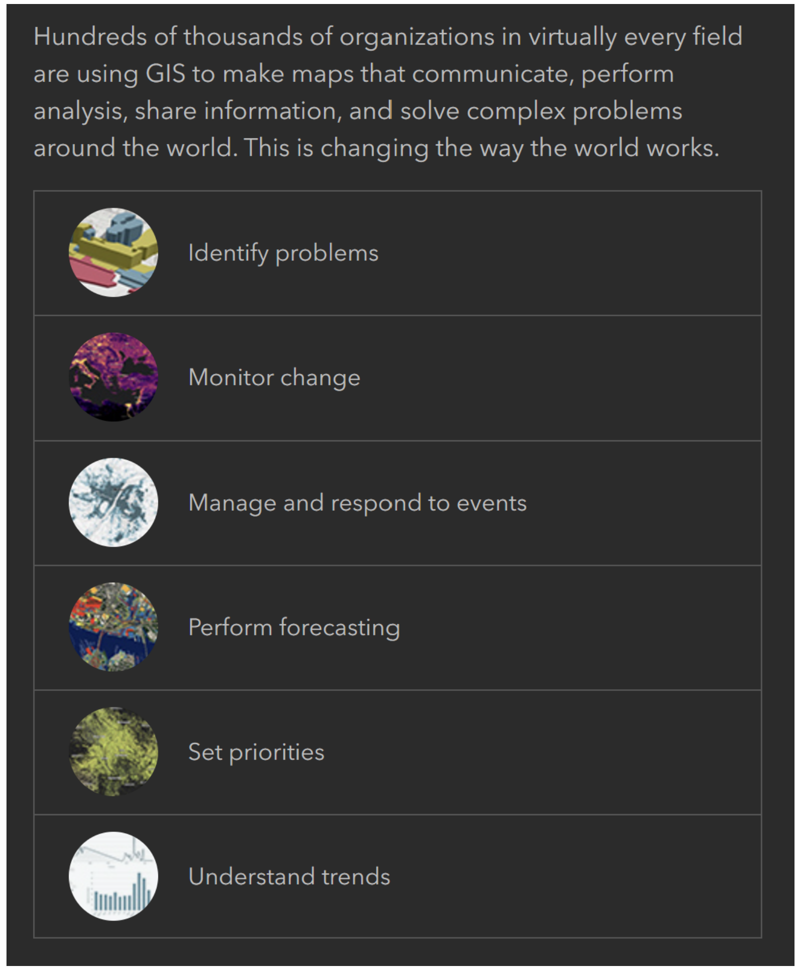
- Computer with Internet Access
- ArcGIS Online Account (Free Trial or Edu Account)

Potential Safety Issues

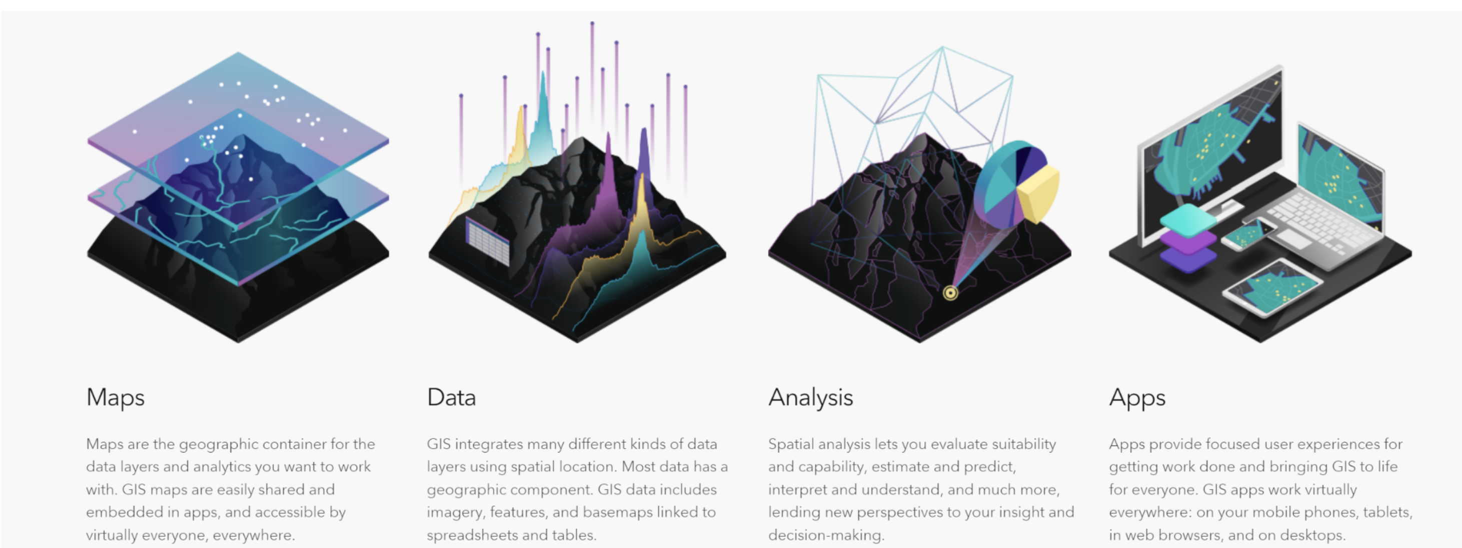
- None

Part 1: Introduction to GIS

A geographic information system (GIS) is a computer program or online software that creates, manages, analyzes, and maps all types of spatial data. GIS helps us to visualize where things are, what things are like there, and provides a foundation for data analysis to make predictions about the future. GIS is used for mapping and data analysis across many scientific disciplines and in nearly every existing industry to help users understand patterns, relationships, flows, and changes in a geographic context for improved communication, better management, and better decision making.



If you have ever used Google Maps, you are already familiar with GIS. Google maps helps you to know where you are in relation to other places you may want to go, can tell you how long it will take to get there, what is located at a particular place, and even provide data analysis such as the best route to take by foot, car or bus given current traffic conditions or where the nearest restaurant is.



- Read more about maps in The ArcGIS Book

- Read more about data in The ArcGIS Book
- Read more about analysis in The ArcGIS Book
- Read more about GIS apps in The ArcGIS Book

GIS is an essential tool in the field of **climatology**. From collecting data in the field (such as ice cores), to managing, mapping and analyzing the data, and sharing the data for everyone else to learn from and use. GIS can help us discover patterns and trends such as where warming is occurring on land and at sea, where ice sheets are melting and at what rate, and using past data to identify patterns to make predictions about the future. GIS can also help us assess potential climate impacts such as how many homes, businesses and roads will be flooded if sea levels rise by 4ft.

- See NOAA's Coastal Flood Exposure GIS Tool).
- Check out Esri's GIS for Climate Change for some more examples of how GIS is used for studying Climate Change.

One of the best things about GIS is that it is very easy to get started with no-code applications using ArcGIS Online. Are you ready to create your own maps? Let's try.

Procedure

1. Log into your ArcGIS Online Student account or create a free trial account at www.arcgis.com

https://learn.arcgis.com/ has hundreds of tutorials to help anyone master GIS and spatial data analysis. The best way to get started is to see how easy it is to make a map using existing data.

2. Go to this link to learn how to access data on the Living Atlas and use existing data to create ten different maps: Make a map in a minute (arcgis.com)
3. Follow the tutorials for each of the ten maps:
    - Make a volcanic activity map
    - Make a drought map
    - Make a pipeline map
    - Make a snow map
    - Make a severe weather map
    - Make a flood map
    - Make a smoke and air quality map
    - Make a hurricane map
    - Make a fire map
    - Make an earthquake map

Post-Activity Assessment:

1. Now that you have had a chance to see how easy it is to get started with mapping natural and manmade features using data collected from satellites and made available for anyone to use via the Living Atlas, how do you think geospatial data could be used to help everyone better understand the effects of climate change? ______________________________________

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   ____

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   (*answers will vary, but should make the connection between data such as GIS can be used to help us see changes in drought patterns over time and what communities and industries are impacted by drought).*

2. Maps and geographic information displayed on GIS web applications like ArcGIS online are a fantastic way to communicate information with others. What natural resource or climate change story would you be interested in sharing? What geospatial data would you need to have to tell the story effectively? ____

   ____

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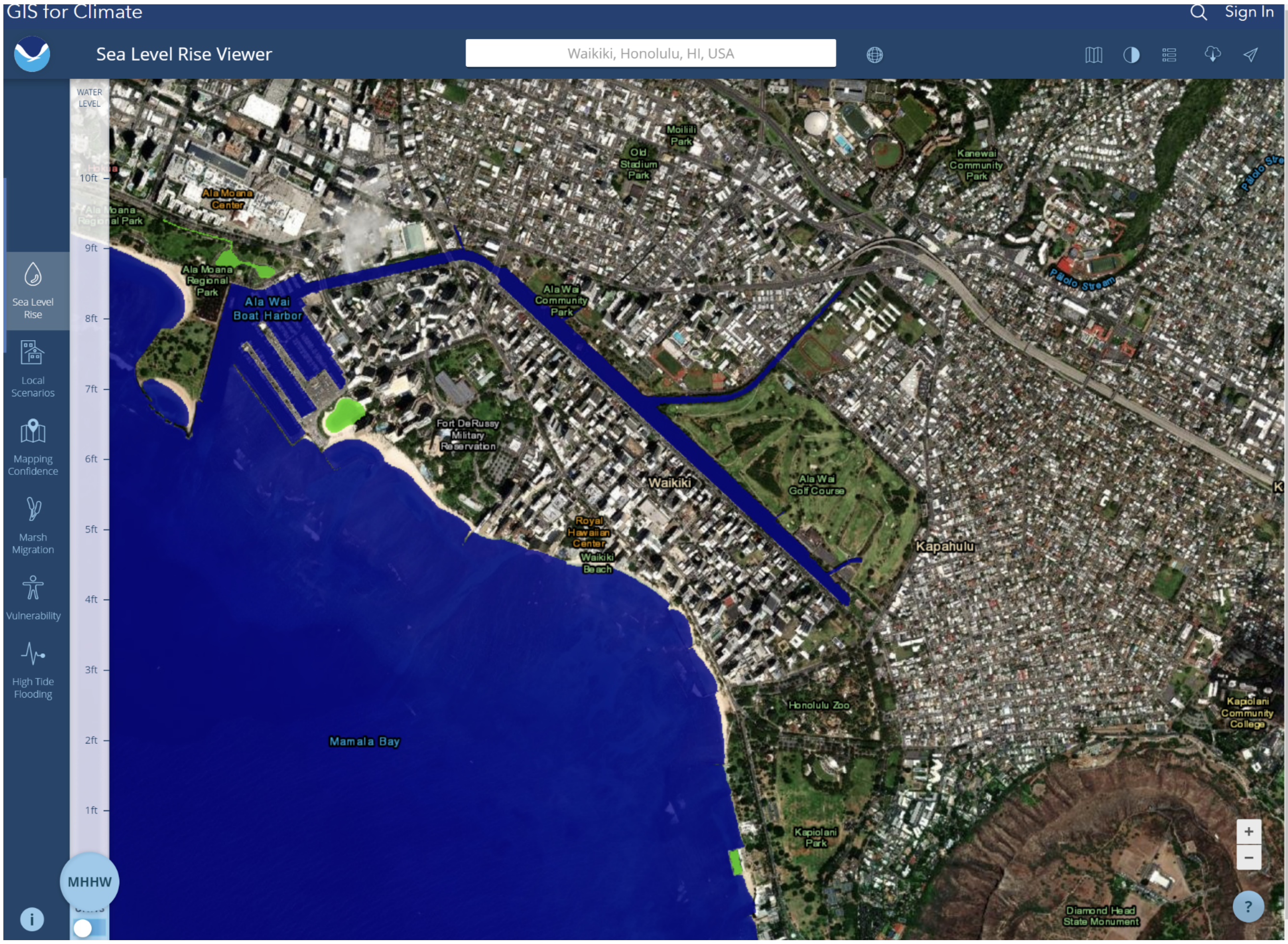
   (*answers will vary, but should make the connection between data that would be needed and the question that they would like to answer or story they would like to tell. For example, "I would like to tell my family about how sea level rise may flood our home in 20 years. To do this, I would need a GIS showing a predicted sea level rise flood layer in 20 years, and the point where my home is located.)*

Part 2: Data Visualization via Web Applications

Climate data may be presented in many forms such as deep time series charts, and complex geospatial patterns displayed on maps. Web applications can often provide an easier and more interactive way to view data, understand basic patterns, or decide if the data can support a deeper analysis in a glance. These applications are part of a growing collection of resources that provide quick access to climate information to researchers, planners, and the general public. Let's take a look at some example web applications.

Procedure

1. Go to [Applications | GIS for Climate (arcgis.com)]
2. Click on the [NOAA Sea Level Rise Viewer]
3. Pan and zoom into an area close to where you live in Hawaii or use the search bar at the top.

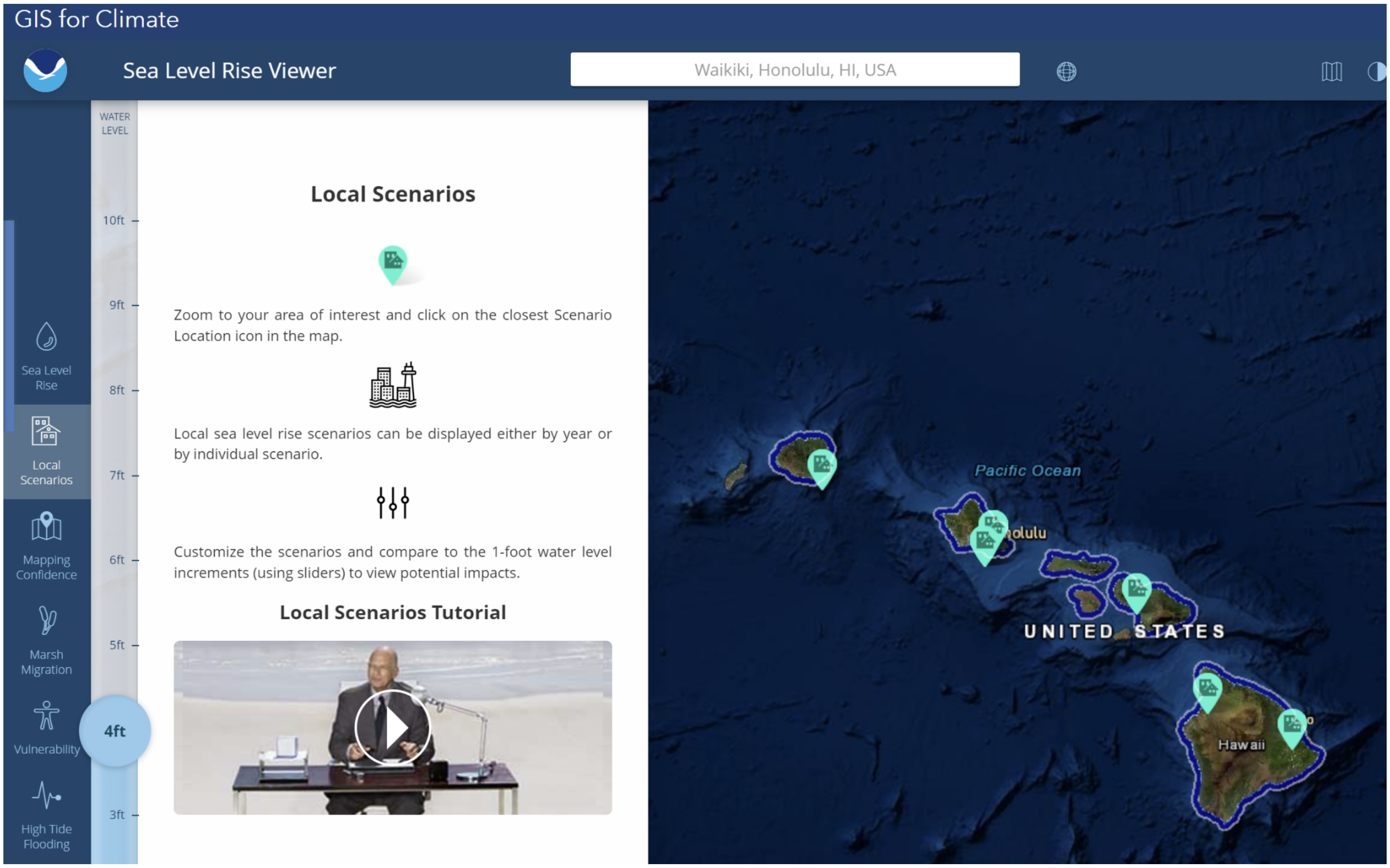


4. Move the [Mean High High Water] line to 4ft.
5. The blue data layer represents areas that will be flooded if sea level rises by 4ft.

Is the area you selected vulnerable to sea level rise? ______________________________________

(answer will vary depending on if the selected a coastal zone or an area inland)

6. Now take a look at a local scenario for your island. Find the green local scenario pin that is closest to you.



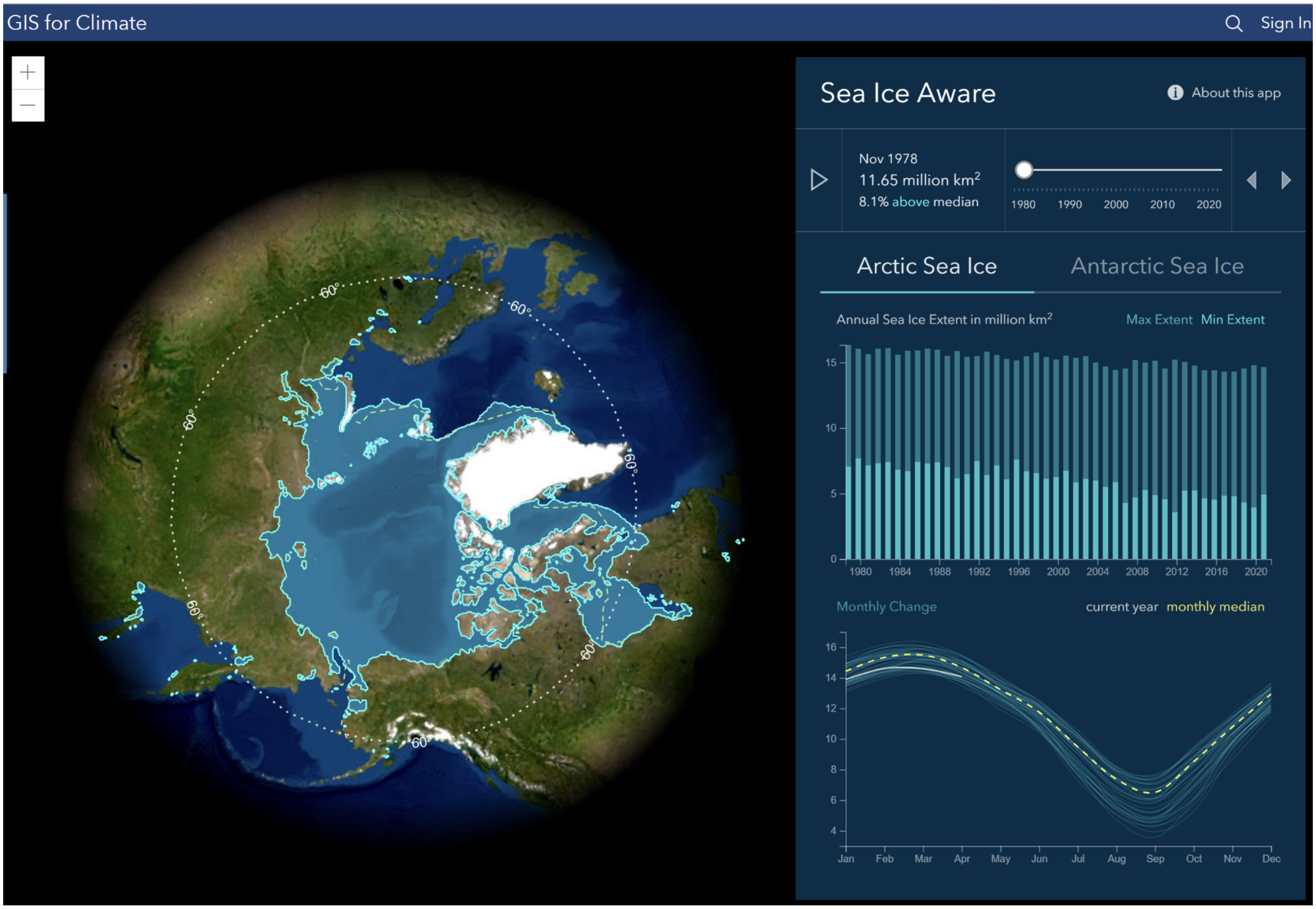
7. At the top, click on the "View By Year Tab"

When is it predicted that the local area you selected will experience 4ft. of sea level rise using the "Intermediate High" scale? ____

(answer will vary. For Honolulu Scenario it is ~2085)

One of the biggest contributors to sea level rise is melt water from melting glaciers. When atmospheric, land surface and ocean temperatures increase, as a result of the greenhouse effect, glaciers will melt, adding freshwater to the ocean and causing sea levels to rise. Let's take a look at another application.

8. Click on the [Sea Ice Aware Application](#)



Using the timeline at the top, how does the sea ice extent for the Arctic Sea compare between 1980 and 2020? ____

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How about Antarctic Sea Ice from 1980 to 2020? ____

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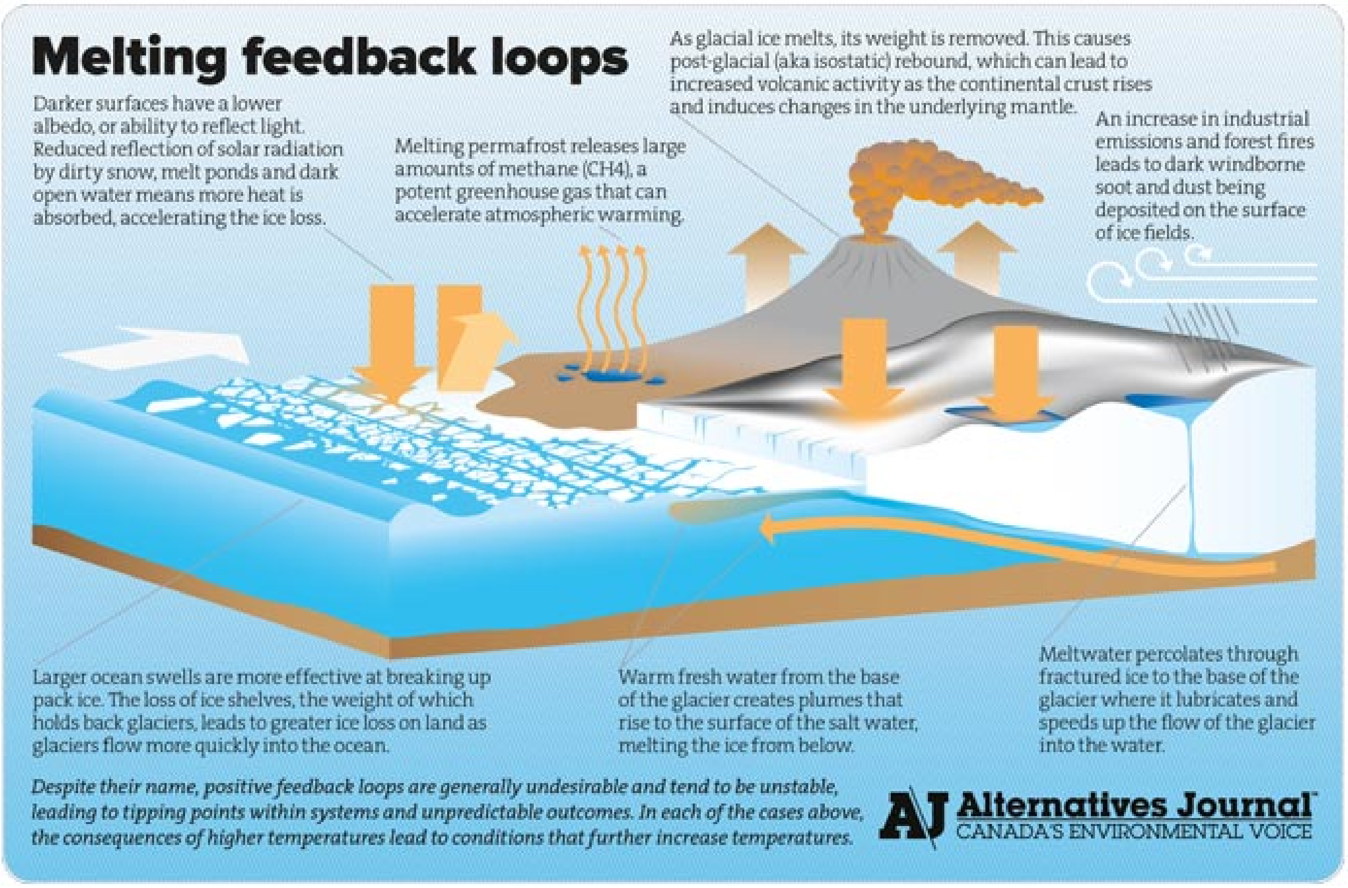
Key Concepts: The earth system is a very complicated, interconnected system between the atmosphere, biosphere, cryosphere, hydrosphere, and geosphere. Once change in one of these systems will inevitably result in a positive (cycle speeds up) or negative (cycle slows down) feedback in our planet's effort to restore equilibrium. As we burn fossil fuels and release greenhouse gasses into the atmosphere, we begin to see a reduction in ice sheets with high albedo, melting permafrost releases methane (a potent greenhouse gas) and has other effects that perpetuate further melting of glaciers. This runaway snowball effect is called a “positive feedback loop” despite it having negative consequences.



An example of a negative feedback loop (with positive outcomes) would be planting more vegetation to reduce the amount of carbon dioxide in the atmosphere. Plants and soils sequester about 1/3rd of the carbon dioxide released into the atmosphere each decade. During photosynthesis, plants suck in carbon dioxide from the air and produce their own food, and oxygen as a bioproduct. Planting vegetation is an example of a negative feedback loop in that it could help slow down climate change.

We have many sources of data that can help us to understand, monitor, and predict the impacts of human behavior on climate change. As you observed in this activity, there are GIS tools to help us visualize sea level rise, loss of sea ice, vegetation changes, surface temperature changes, and more. GIS has been an extremely instrumental tool in many climate change related research.

Common Misconception: After learning about the greenhouse effect, students may think that greenhouse gasses are “bad” or “dangerous”, but in reality, without greenhouse gasses, our planet would be too cold for life as we know it to survive. The greenhouse effect is a natural phenomenon that helps keep our planet suitable for life. The problem is that with the rapid addition of greenhouse gasses to the atmosphere from burning fossil fuels (and land cover changes) are increasing the concentration of some of the greenhouse gasses to dangerous levels.

Renewable Energy Connection: A very large percentage of our carbon footprint in Hawaii comes from the transportation sector in the form of jet fuel to fuel airplanes and military aircrafts, and diesel to fuel our vehicles. One way that we can reduce our fossil fuel consumption, and thus emissions, is to move toward electrification of our transportation and/or to swap out fossil fuels for other fuels such as biofuel (ethanol). Using biofuels in diesel engines helps to reduce our greenhouse gas emissions and has the added benefit of not needing any technological modifications to engines or diesel powered power plants. Using plants or algae to create biofuels have the added benefit of helping to sequester carbon dioxide through the process of photosynthesis.

Optional Online Extension Activity: Use ArcGIS Online and geospatial data to create your own model to Predict coral bleaching events | Learn ArcGIS*

In Lab 1, one of the applications that you looked at showed predicted sea level rise scenarios and the second application looked at loss of sea ice over time. It is important to learn to think critically about any data you observe. Do you think the loss of sea ice contributes significantly to sea level rise? Why or why not? ____

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(Answer will vary and all answers are okay)

Let's run an experiment to collect some data to find out.

Lab 2: Sea Ice vs. Land Ice *(1-2 class periods)*

<table>
<tr><th colspan="3">NGSS Performance Expectations</th></tr>
<tr><td colspan="3">HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other earth systems.

HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.</td></tr>
<tr><td colspan="3">This exercise focuses on the following three dimensional learning aspects of NGSS</td></tr>
<tr><td>Science & Engineering Practices</td><td>Disciplinary Core Idea</td><td>Crosscutting Concepts</td></tr>
</table>

Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. **Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. **ETS1.B: Developing Possible Solutions** When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. *(secondary)* **ESS2.A: Earth Materials and Systems** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **ESS2.D: Weather and Climate** The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable. Feedback (negative or positive) can stabilize or destabilize a system. - ***Connections to Engineering,Technology, and Applications of Science*** **Influence of Engineering, Technology, and Science on Society and the Natural World** New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.
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 *Activity (**adapted from NASA JPL*):

- Make sure you know how to read millimeters on your ruler (mm)
- Freeze water in the ice cube trays provided. Take care that the water level is even across all the cubes.
- Breakup into groups of two-three. There are enough supplies for 15 groups.

Materials List

- 2 Cups
- 1 Wooden Block
- 1 Timer
- 2 Ice Cubes from the ice cube trays provided (*wait to remove the ice cubes from the freezer until you are set up and ready to go*).

- Water (*not included)*
- 1 Permanent Marker (*not included*)
- Ruler (*not included*)

Potential Safety Issues

- Be careful not to spill any of the water. If you do, clean it up quickly.

Pre-Activity Assessment

1. Think about our planet. Make a list of a few places where ice occurs in nature and identify if that ice is on land or in the sea. If you do not know, conduct a web search to find out.

	Where Ice Occurs	**Land Ice**	**Sea Ice**
1			
2			
3			
4			

(The Greenland and Antarctic ice sheets, and inland mountain glaciers are land ice. The ice in the Arctic is frozen seawater and considered sea ice.)

2. You may have heard or read that melting ice at the poles is contributing to sea level rise. Do you think it makes any difference if the ice that is melting is on land or floating in the sea? Make a prediction about what each type of ice will do to the water level in the cup, then fill in the data table below (model) to compare what you predicted to what you observed.

Type of Ice	**Prediction** *(what will happen to the water level?)*	**Observation** *(what happened to the water level)*
Ice on land		
Ice floating		

Procedure

Setup

1. Label one cup “Sea Ice” and one cup “Land Ice”.

2. Put the wooden block in the “Land Ice” cup to represent land.
3. Add an icecube to each container. In the land ice cup, put the ice cube on top of the wooden block
4. Add cold water to the sea ice cup until the ice cube is floating.
5. Add cold water to the land ice container until the water level is equal to the water level in the sea ice cup. Be sure to have your eyes horizontally level with the water line.

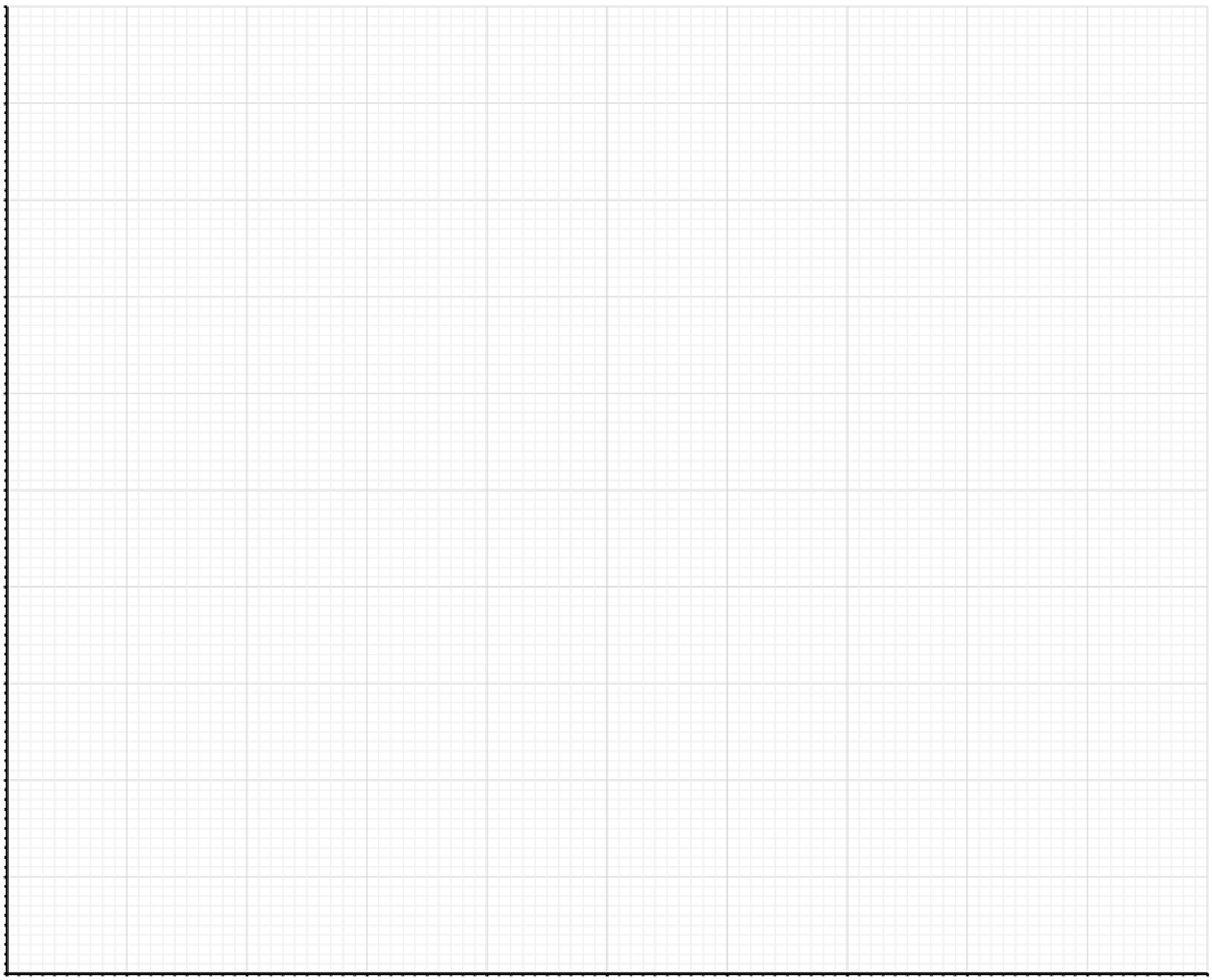
Begin Data Collection

6. Use a ruler to measure the water level in millimeters (mm) for each container and record the data in the data table below.
7. Take measurement at regular intervals until both ice cubes have melted.

Measurement	Sea Ice Water Depth (mm)	Land Ice Water Depth (mm)
Initial Measurement		
2 minutes		
4 minutes		
6 minutes		
8 minutes		
10 minutes		
12 minutes		
14 minutes		
16 minutes		
18 minutes		
20 minutes		

Data Analysis

8. Use the measurements you recorded to create a line graph representing the water level in each cup.



Post-Activity Assessment

Think about what your data observations mean for melting ice around our planet and how it contributes to sea level rise.

1. In which container did the water level rise more? ____

   ____

(the land ice)

2. How does this compare to the predictions you made before the experiment? ______________

____

(answers will vary)

3. Do melting icebergs floating at sea contribute to sea level rise? ______________

____

(Not much. Students should have observed that the water level in the sea ice cup did not change much if at all. In reality, floating ice is fresh water and less dense than salty sea water. When fresh water is added to seawater, the fresh water will take up a very slightly larger volume than seawater would.)

4. How about melting glaciers on land such as Greenland ice sheets? ______________

____

(Melting glaciers are the primary cause of sea level rise).

5. What are some things that you can do to help reduce fossil fuel emissions? ______________

____

____

____

6. Thinking as a global citizen, what actions or solutions can you dream of to help bring big changes to the current climate crisis? ______________

____

____

____

Key Concepts: Glaciers are large sheets of ice and snow piled up over land. They are found in mountain ranges across the world and the giant ice sheets of Greenland and Antarctica. As the average global temperature rises, glaciers are melting at an alarming rate. The meltwater runs into the ocean, contributing to sea level rise.

Another contributor to sea-level rise is the increase in volume that occurs when water is heated. This is called **thermal expansion**. Both thermal expansion and ice melt are the results of the rise in global average temperatures on land and sea known as climate change. It is important to note that the solid earth, atmosphere, biosphere, and oceans are all deeply interconnected and one change in any of these systems can affect the patterns in another part of the earth system.

Common Misconception: Climate change skeptics will sometimes use the example of ice cubes melting in a cup of water to show that melting ice is not a problem. Because the ice is already in the water, the volume of water that is displaced is about the same after the phase change from ice to water. However, this argument does not consider the massive sources of meltwater from land based sources that are running into the ocean.

Renewable Energy Connection: The resulting effects of climate change on sea level rise, water temperature, ocean chemistry, storm severity, and drought patterns are direct threats to the entire earth system and all that inhabits this planet. It is important to be familiar with how the earth system works and how to critically evaluate climate change related claims and data. Our best hope for reducing the negative impacts of climate change is to make a rapid and dramatic change in our energy fuel sources and consumption habits.

Extra Resources:

1. Video on Antarctic Land Ice Height Change
2. Intergovernmental Panel on Climate Change IPCC Mitigating Climate Change Report

The search for renewable energy sources to replace fossil fuels has resulted in many energy-related innovations developed by scientists and engineers. **Biofuels** are fuels from living organisms such as plants and algae. Using chemistry, we can take living organisms, and use a process called **fermentation** to produce **ethanol**, which may be blended with gasoline to make “gasohol.” One advantage of gasohol over regular gasoline is that it burns cleaner, resulting in fewer harmful emissions into the atmosphere. Today, nearly all of the gasoline sold in the U.S. contains some percentage of ethanol. Let’s explore this fermentation process for ourselves.

Lab 3: Biofuels STEM Design Challenge (3-Class Periods)

NGSS Performance Expectations
HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the

outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. **HS-ETS1-2** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering **HS-PS3-3** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

This exercise focuses on the following three dimensional learning aspects of NGSS		
Science & Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. ● Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. ● Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**ETS1.A: Defining and Delimiting Engineering Problems** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. **ETS1.C: Optimizing the Design Solution** ● Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. **PS1.A: Structure and Properties of Matter** ● The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **PS1.B: Chemical Reactions** ● The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**Energy and Matter** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. ***Connections to Engineering,Technology, and Applications of Science*** **Influence of Science, Engineering and Technology on Society and the Natural World** Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. **Patterns** ● Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
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:

Respiration is the process that converts food into usable energy and is carried out by individual cells. Cells may undergo two types of respiration. One requires oxygen called **aerobic respiration** and the other, called **anaerobic (without air) respiration**, does not. **Fermentation** is the word commonly used for anaerobic respiration.

As cells consume glucose (C6H12O6) and produce energy, additional compounds are made. When no oxygen is present, the fermentation reaction may produce carbon dioxide (CO2) and alcohol as seen in the chemical equation below.

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH + \text{energy}$$

Yeast is the most common organism used in the production of **ethanol** (ethyl alcohol). Yeast can be dried, inducing a dormant state, until it is activated. Warm water and a food source are all that is required to “awaken” or activate the yeast. Carbohydrates from plants, called ***biomass***, are used as a food source for yeast during fermentation.

Fun Fact! *There is an oil refinery in Sweden, that uses biofuel made from bakery items that are expired.* St1 Biofuels Etanolix ethanol plant inaugurated in Sweden | EthanolProducer.com

Before Activity:

- Have students split up into teams three *(assuming 30 students in your classroom*)

Materials List - For this activity, each team will need the following materials:

INCLUDED

- 1.5 g Cornstarch
- 1.5 g Sucrose, C12H22O11
- 0.5 g Active Dry Yeast (You can refill with yeast packs from the supermarket)
- 3 3” x 4” Zip Lock Bags
- Small Water Balloons
- 1 Push Pins
- 2 Small Rubber Bands
- 1 Sample Tubes with Green Caps
- 3 Small Weighing Dishes

- Timer
- String
- Tape

NOT INCLUDED

- Warm Water (40-43°C)
- Hot Plate
- Balance
- 250-mL Beaker
- 10-mL Graduated cylinders, 50-mL graduated cylinders, 100-mL graduated cylinders
- Scoop or spatula
- Permanent marker
- Ruler
- Thermometer

Potential Safety Issues

- Do not taste or eat the yeast or sucrose. Chemicals should never be consumed.
- Safety goggles should be worn when working with chemicals, heat, and or glassware.
- Always wash your hands well with soap and water before and after any experiment.
- Always check federal, state, and local regulations before disposing of any chemicals down the drain. The solutions in this lab are all safe to dispose of down a drain with high waterflow.

Potential Obstacles

- Yeast will die at temperatures above 55 °C.
- The ideal amount of yeast solution used in the sample tubes is 7 mL with the rest of the tube filled with the sucrose solution. <u>It is important to fill the tubes completely to remove any air.</u>
- Keeping the sample tubes in a water bath at a temperature between 34 °C and 37 °C will yield the fastest results. Students may share water baths.
- If students are using the balloon method, collecting data for two balloons is preferred to reduce the risk of a faulty balloon. If time allows, groups may repeat their experiment. Otherwise, teams may pair up and combine their data.
- Stretching the balloons before the activity will allow the balloon to fill easier and faster with CO2 (for example, a balloon circumference of about 11 cm may be reached about 10 minutes faster).
- If students are capping the water collection tube and allowing the gas to rise within the tube, make sure they have poked holes in the cap.

Procedure

Part 1: Introduction to Fermentation

1. Get three ziplock bags and label with a marker:
    a. Control
    b. Cornstarch
    c. Sucrose
2. Using a balance and a weighing dish, measure 0.5 g of yeast and add to the **control** bag.
3. Using a balance and a weighing dish, measure 0.5 g of **cornstarch** bag and add to the cornstarch bag.
4. Using a balance and a weighing dish, measure 0.5 g of **sucrose** and add to the sucrose labeled bag.
5. Measure 50 mL of warm water using the graduated cylinder and **add to the control bag.**
6. Repeat for the cornstarch bag and sucrose bag.
7. Using the balance and separate weighing dishes, add the following quantities to each bag:
    a. Control— do not add anything
    b. Cornstarch— add 1.5 g of cornstarch
    c. Sucrose— add 1.5 g of sucrose
8. **Remove as much air as possible** and seal the zipper bags. You can use transparent or masking tape to seal around the top corners to prevent leaking.
9. Mix the contents of each bag by gently patting your fingers together on both sides and along the length of the bag.
10. Lay the bags flat on a paper towel on the lab bench and start the timer.
11. After 10-minutes, measure and record the dimensions (width and length) of any gas bubble that forms in the data table below and continue collecting data every 5 minutes thereafter for 25 minutes.

Note: As gas is produced, the bags will swell and the pressure increase may cause the bags to leak if not sealed completely. Look for any liquid on the paper towel and re-seal with tape if needed.

Control Sample		
Time (min)	**Gas Bubble Dimensions Length and Width (cm x cm)**	**Observations**
10		
15		
20		
25		

Cornstarch		
Time (min)	**Gas Bubble Dimensions Length and Width (cm x cm)**	**Observations**
10		
15		
20		
25		
Sucrose		
Time (min)	**Gas Bubble Dimensions Length and Width (cm x cm)**	**Observations**
10		
15		
20		
25		

Post-Activity Assessment

1. Consider the products of fermentation as described in the Background section. Which product caused the bags to expand during the experiment? Where was the location of the gas bubble in the bag? ____

   ____

   ____

   (*Carbon dioxide gas caused the bags to expand.The gas bubble was at the top of the bag, near the center.)*

2. Why do you think the gas collected in this location? ______________________

   ____

   ____

   (The CO2 gas is less dense than the surrounding liquid mixture and rises to the top of the bag.)

3. Why is it necessary to use warm water to mix the yeast and food source?

(Yeast requires two conditions to be activated from the dried state, one of which is warm water and the other a food source.)

4. Examine the gas bubble dimensions from the data table. Which food source yielded the greatest quantity of gas?

(Sucrose produced the greatest quantity of gas. The bubble that formed was much larger than the bubble in the cornstarch or control bags.)

5. Explain why cornstarch and sucrose did not produce the same amount of gas.

(The yeast is not able to use the cornstarch as a food source because it is a complex carbohydrate that requires enzymes to break it down into simpler sugars that the yeast can metabolize.)

6. Why do you think a small gas bubble was visible in the control bag?

(Student answers will vary. A small amount of sugar is in the dry yeast mixture, allowing for a minimal amount of fermentation. The bag may have still contained some air after being sealed shut.)

7. What is the purpose of the control in this experiment?

(A control is used to compare results of the experimental group(s) to ensure that any difference is the result of the manipulated variable and not some other factor.)

Part 2: Design Challenge *(Allow 1-class period to plan procedure and 1-class period to test)*

Chemical Engineers and **Experimental Chemists** in various fields often have to come up with new laboratory procedures to yield results from chemical reactions to solve problems or create new materials. In this design challenge, your team must create a procedure for collecting and quantifying the amount of carbon dioxide produced during fermentation.

Part 2, Day 1

1. Based on the results from Part A, which food source is a better choice for producing large quantities of carbon dioxide? ______________________________ *(sucrose)*

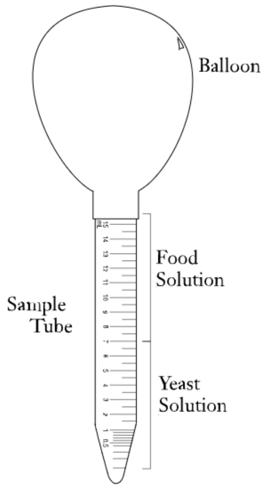
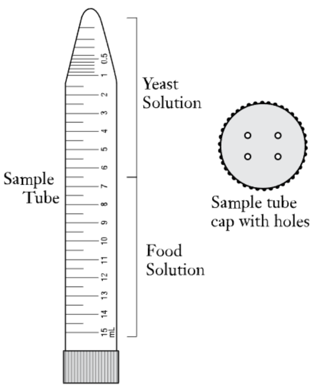
2. Maintaining an ideal temperature range during the fermentation process can be a difficult task. The optimum temperature range for yeast fermentation is between 32–35 °C. Every degree over this range depresses fermentation. Given this information how will you control the temperature during the carbon dioxide collection? ______________________________

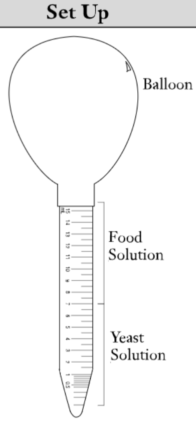
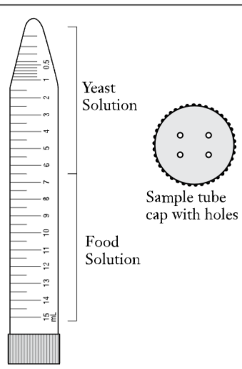
   ____

   ____

   (Using a water bath, consisting of a beaker of water on a hot plate with a thermometer, will allow the optimum temperature range to be monitored and controlled.)

3. How might the setups pictured below be used to capture the carbon dioxide from fermentation? How would the amount of carbon dioxide be measured in each method? What possible sources of error would need to be taken into account for each method? Fill in the following table:

Setup	Method to Collect Data	Process to measure collected Carbon Dioxide	Possible Errors
			
			

Set Up	Method to Collect	Process to measure collected CO_2	Possible Errors
	*Place 7 mL of yeast solution into sample tube, fill to very top with sucrose solution, cap and invert to mix contents. Remove cap, stretch balloon mouth over tube and secure with rubber band. Place tube into water bath (34–37°C).*	- *Collect CO_2 in balloon and measure circumference of balloon with string and ruler, calculate volume of sphere ($V=4/3 \bullet \pi r^3$)* - *Collect CO_2 in the balloon, tie off and use water displacement to determine volume*	- *Balloon malfunction* - *Water bath temperature fluctuation* - *Loss of gas when removing balloon from sample tube* - *Balloon not perfect sphere* - *Water displacement method will include balloon* - *A small amount of air may be present in the balloon*
	*Using the push pin, put 4 holes into the cap. Place 7 mL of yeast solution into sample tube, fill to very top with sucrose solution. Cap and place thumb over holes and invert tube to mix contents. Place inverted tube into a water bath (34–37°C).*	- *As fermentation occurs CO_2 will rise up the sample tube and push the yeast/sucrose solution out through the holes in the cap into the water bath. The sample tubes are marked with volume graduations and the volume of CO_2 can be read directly.*	- *Water bath temperature fluctuation* - *Spillage*

4. The results of each group's gas-collecting method will be compared. What variables will need to be controlled in each method for a fair comparison? Which variables are not able to be controlled with each method? ____

____

____

(Controlled variables for both methods include the amount and concentration of yeast and sucrose solutions, and the amount of time allowed to collect the CO2. The water bath temperature and yeast/sucrose solution temperature may fluctuate slightly, but will be controlled within a few degrees using a water bath and thermometer. Controlled variables for the balloon method include type/size balloon and method of measurement. Each group should stretch out and inflate the balloon once prior to use. Variables that are not controllable include temperature fluctuation if allowed to get too hot or too cool. The activity of yeast from one solution to the next may vary.)

5. Explain why the second method requires holes in the cap. ____________________________

____

____

(As fermentation occurs, the CO_2 produced will rise toward the top of the sample tube. The expanding gas will push the liquid down. The liquid must be allowed to escape in order to reduce pressure build up, allowing fermentation to continue.)

6. Write a step-by-step procedure for collecting the carbon dioxide gas produced from fermentation. Construct a data table that clearly shows the data that will be collected and the measurements that will be made. ____

____

____

(*student answers will vary*)

Part 2, Day 2 - Pre-activity Preparation

1. To prepare the yeast solution for the Design Challenge, measure out 7g. of yeast and 150 mL of warm water (40–43 °C).
2. Mix the yeast and the warm water using a 250-mL beaker.
3. Keep the yeast solution on a hot plate on a low setting, maintaining a temperature near 40 °C. **Note:** If the water temperature rises above 43 °C, remove the beaker for a few minutes.

1. Prepare the sucrose solution using the following ratio: 2 g sucrose per 10 mL of water.
2. Each group will need a minimum of 10-mL of the sucrose solution

Procedure:

1. Select one of the two setups from yesterday to test today.
2. Create a data table to record the amount of carbon dioxide collected during your experiment.

Draw or Type Your Data Table in the Box Below. Use this data table to record your measurements and observations.

Notes:

Post-Activity Assessment:

1. How did your group determine the amount of carbon dioxide gas collected during your experiment?

   ____

   ____

   ____

   (*Student answers will vary.)*

2. Compare your results with a group that used a similar method of CO2 collection. Explain the similarities and differences in the results.

   ____

   ____

   ____

   (*Student answers will vary.)*

3. Describe possible errors involved and their effect on the results.

   ____

   ____

   ____

   (*Student answers will vary. Some foam may be present at the interface of the liquid and gas in the tube, making the exact volume of gas from the gas displacement method difficult to measure.)*

4. Compare your results with a group that used a different method of CO2 collection.Which group was able to collect more carbon dioxide gas? (**Reminder:** 1 cm3 = 1 mL)

   ____

   ____

   ____

   (*Student answers will vary. Differences may result from the amount of time the experiment was allowed to run, as well as possible sources of error with either method. The balloon is capable of collecting a greater volume of gas than the sample tube.)*

5. Which method do you think is a more accurate way to measure the amount of CO2 gas produced?

   ____

   ____

(The gas displacement method is likely to be more accurate. More errors are likely with the balloon method.)

6. Although not visible or tested for, what other compound was present inside the tube?

   ______

   (Ethanol (ethyl alcohol) is also produced during fermentation.)

7. The release of gasses from burning fossil fuels is a factor in the rise of the Earth's average surface temperature, known as global warming. How might using more biofuels impact global warming?

   ______

   (Biofuels burn cleaner than regular gasoline made from fossil fuels, reducing the amount of gas emissions that contribute to global warming.)

8. Why is biofuel considered a renewable energy source?______

   (Answers will vary, but should be along the lines of Biofuel comes from plant material, and new crops may be planted at a replenishable rate.)

9. Why was it important to remove as much air as possible from each ziplock bag (step 5)? ____

   (Fermentation is an anaerobic process. It occurs when oxygen is not present. If air is left in the bag, then the yeast may undergo aerobic respiration instead until the oxygen is depleted.)

10. What are the pros and cons of using ethanol as an energy source? Do your own research and summarize your findings below:

Pros of Biofuels	Cons of Biofuels
Green energy -comes from natural sources	Not enough land space to grow crops to generate biofuels
Renewable form of energy- constantly replenished by nature	Global decline in food production-As more land is directed towards biomass production
Helps keep the environment clean- low level of greenhouse gas emissions	Can cause prices of staple crops to increase due to decreased availability of land
Improved utilization of land and waste	Might lead to global hunger and malnutrition due to inflating food prices
Reduction in landfill sites	Can put a strain on water resources-High water demand for the cultivation of biomass and in the production process
As efficient as gasoline	Most vehicles are not equipped to utilize biofuels
A large number of sources are available for the production of biofuels	Huge startup investment required
Reduces burden on a single energy resource especially fossil fuels	High production cost
Employment generation due to increased local production	Not preferred by many as it can erode some metals, rubber, and plastic parts
Economic security – countries can become self-sufficient by providing for themselves	Might lead to deforestation to make way for biomass crops
Comparatively safe technology that is easier to implement as well	Funding required for research and development
Easily blends with existing fuels	Biodiversity loss as land consumption pattern changes
Lower pollution compared to burning fossil fuels	Not viable when compared to solar and wind power

Source

Key Concepts: Biofuels are fuels that we can produce using organic materials such as corn, sugarcane, vegetables, soybean oil, algae, animal waste, food waste, cooking oil waste, cellulose, and more. They can be in solid, liquid or gaseous form. Sugar cane and sugar beets are sources often used, as the sugar is easily consumed by the yeast cells. Starches from grain and grasses require enzymes to break down the more complex starch molecules to simpler sugar molecules the yeast can use. Corn and switchgrass are popular crops grown for biomass. Here are a few examples of biofuels and the raw materials that were used to produce them:

- Ethanol: Made from crops with high sugar and starch content (carbohydrates) such as corn and sugarcane.
- Biodiesel: Made using vegetable oils, used cooking oils, and animal fats.
- Green diesel: It is derived from algae, wood, crop residues, and sawdust.
- Biogas: Carbon dioxide and methane gas obtained from animal manure and other organic waste.

In these lab experiments, students created ethanol through the process of fermentation. Since determining the presence of ethanol is a complex process, the amount of carbon dioxide gas produced over time was used as an indication of fermentation. Ethanol is the most commonly used biofuel, and it can be made from nearly any plant. Some plants are better than others though because each plant will produce a certain number of gallons of biofuel per acre of agricultural lands. In the US, we mostly use corn to create ethanol.

Common Misconceptions: Biomass vs. Biofuel - **Biofuel** and **biomass** are general terms for renewable fuel created from organic matter, including wood and other plants, algae, or waste such as restaurant grease or animal fats. **Fossil fuels**, in contrast, are long dead organisms that have been under geological pressure deep underground for millions of years. To generate electricity, biomass can be "directly burned" for heat to create steam or gasified to burn and create steam. **Biomass** may also be converted into liquid biofuels, such as biodiesel or biogas. **Biofuel** can be processed through various systems to create biodiesel which can be used interchangeably with or totally replace petroleum-based diesel. In Hawaii, biomass for electricity has included sugar cane bagasse (the fibrous residue left after sugar is extracted), forest products and trash. For decades sugar plantations on all islands in Hawaii burned sugar cane bagasse to create process heat and electricity for their own use and sold the excess to the utility on their island. This not only provided a high level of renewable electricity to Hawaii but helped extend the viability of the sugar industry by giving the plantations another income stream. At some times in the past as much as half the electricity on the smaller Hawaiian Islands was supplied in this way. However, this type of biomass power declined as the sugar mills shut down. With landfill gas, the anaerobic (i.e., lack of oxygen) decomposition of refuse creates a gas that is collected and directed to a gas turbine to produce electricity. In the past, landfill generated methane gas provided electricity from Kailua's Kapaa Quarry on Oahu. The plant was closed after a major equipment failure. - Biomass | Hawaiian Electric

Renewable Energy Connection: To reduce our dependence on imported oil and our environmental impacts from burning fossil fuels, our communities across Hawaii must make the most of all available local resources, including solar, wind, hydro, geothermal, ocean energy -- and biofuels. Biofuels can provide an alternative to petroleum-based fuels. Ethanol, a biofuel produced from biomass such as corn, is frequently blended with gasoline to produce a “cleaner” burning fuel. Extra Video Resource: Biofuels 101

Why Do Biofuels Make Sense for Hawaii? Hawaii currently uses mostly liquid fuels to generate electricity and it is possible to make the switch to biofuels to make the most use out of our existing power plants. For example, electricity generation units that currently use natural gas can be modified to use biofuel instead as part of attaining Hawaii's 100 percent renewable goal. Some other benefits of biofuels:

- Biofuels can be stored and used in present power plants.
- Biofuel will likely be purchased under contracts that make the cost more stable and predictable. Further, a dollar for local biofuel creates jobs and boosts farming here. A dollar spent on imported fuel leaves our state economy.
- Reliable biofuel energy available on demand helps support other renewables on our grids. Wind and solar need back up because the wind does not always blow and the sun doesn't always shine. We can use biofuels in existing and new firm electricity generators as part of a portfolio of renewable resources.
- Biofuels are cleaner and greener than most fossil fuels, helping to shrink our carbon footprint by controlling greenhouse gas emissions.

Deeper Dive - Read more here about the links between Hawaii’s Agricultural Sector and Biofuels in Hawaii: Biofuels | Hawaiian Electric

Conclusion

Climate change, largely driven by the emission of greenhouse gasses from burning fossil fuels, is at our doorstep. We know this from years and years of data collection, paleoclimate research, and predictions using patterns detected from modeling and GIS applications. Our state is expected to experience loss of infrastructure, habitats, and cultural resources, from rising seas and will see more frequent and more severe storms and flooding. Ocean acidification will negatively affect coral and sea life, which in turn will negatively affect our fish resources and economy. In order to reduce the speed and severity of climate change, we must rapidly reduce our greenhouse gas emissions from burning fossil fuels.

Renewable energy resources including solar, wind, biofuel, hydropower, and geothermal, are ultimately our best options to continue to power our homes, schools, communities, and the transportation sector. Using renewable energy will help us to reduce our environmental impacts 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, still need to consider our energy consumption habits and create an action plan for conserving energy.** Note that while renewable energy sources such wind or solar power are often referred to as “clean energy” because they do not emit greenhouse gasses, the hardware and materials needed to create wind turbines and solar panel often come from nonrenewable resources to manufacture things like the blades, motors, panels, and wires to transport the electrical energy. Turbines and PV panels also need to be shipped into our state since we do not manufacture them locally.

No single person or technology is going to solve all of 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 efficient renewable energy resources. In the future, we will continue to need scientific and engineering breakthroughs in the energy sector, and maybe someone, **possibly you**, will help.

Mahalo nui loa for joining us on this energy exploration into the world of wind power. 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 *Vocabulary words do not explicitly appear in the NGSS standards, because the NGSS focus on a deep understanding of the concept behind a vocabulary word. Vocabulary can be introduced and applied, as needed, for instructional purposes.*

- Aerobic Respiration: the process by which organisms use oxygen to turn fuel, such as fats and sugars, into chemical energy
- Anaerobic Respiration: the type of respiration through which cells can break down sugars to generate energy in the absence of oxygen
- Biomass: plant materials and animal waste used as fuel.
- Biofuel: liquid fuel produced from renewable sources such as algae, plants, grains, vegetable oils, and animal fats. This is a cleaner-burning fuel than petroleum-based diesel. Ethanol is the most commonly used biofuel for energy and transportation.
- Biogas: gas made from something that was once alive.
- Carbon: An element found in all living things, soil, and rocks.
- Carbon Cycle: Circulation of carbon atoms through the Earth systems as a result of photosynthetic conversion of carbon dioxide into complex organic compounds by plants, which are consumed by other organisms, and return of the carbon to the atmosphere as carbon dioxide as a result of respiration, decay, and combustion of fossil fuels.
- Carbon Dioxide: a gas formed by burning fossil fuels, the rotting of plants and animals, and the respiration of animals and humans.
- Climate: The *long-term averages* of conditions in the atmosphere, ocean, ice sheets, and sea ice described by statistics such as average, means, and extremes.
- Climate Change: significant and persistent change in the mean state of the climate or its variability in response to changes in some aspect of Earth's environment. These could be

changes in Earth's orbit around the sun, rearrangement of the plate motions (plate tectonics), and anthropogenic forcings such as modification of land cover and atmospheric chemistry.

- 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.
- 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.
- Electricity: flow of electrical power or charge.
- Ethanol: a colorless, flammable liquid (alcohol) made from a variety of biomass materials called feedstocks.
- Feedback: The process through which a system is controlled, changed, or modulated in response to some output. Positive feedback results in an amplification or speeding up of a system's output. A negative feedback reduces the output of a system.
- Fermentation: a chemical reaction that breaks down food and other organic matter converting sugars into acids.
- 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.
- Greenhouse gasses: gasses that trap heat and contribute to warming temperatures including water vapor, carbon dioxide, carbon monoxide, and methane.
- Hypothesis: What do we think or predict the answer will be.
- Innovation: a new invention or way of doing something.
- 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.
- Runaway Greenhouse Effect: when a planet's atmosphere gets hotter and hotter, never cooling down because there are too many greenhouse gasses in the atmosphere.
- 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.
- Weather: Specific conditions of the atmosphere at a particular place and at a particular time measured in terms of temperature, precipitation, cloudiness, humidity, pressure, and wind speeds.

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

This week, your child learned all about **energy transfer** and **renewable energy generation,** specifically **Wind Power.** They had the opportunity to build their own wind turbine, test its power output performance, and improve their design by following the engineering design process.

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 the members of your household:

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

   ____

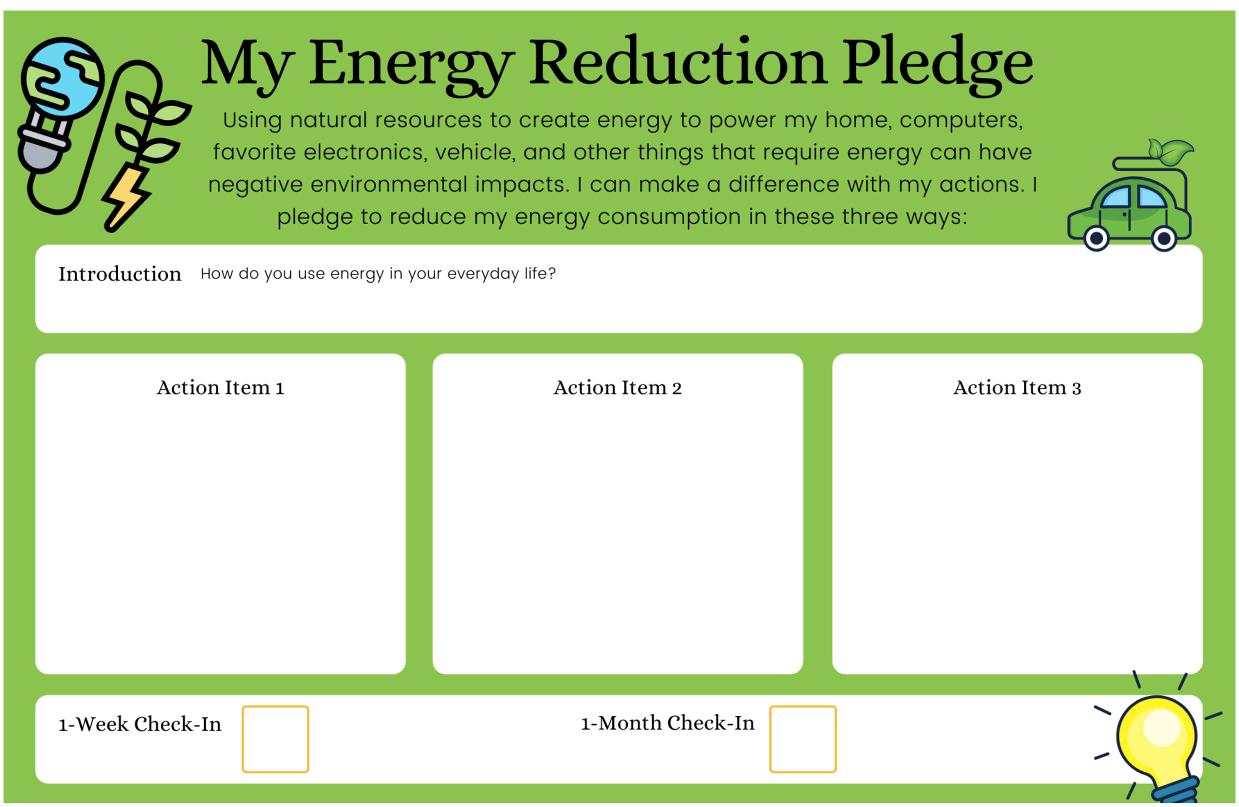
   ____

   ____

   ____

   (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 benefit your community? ____________________

____

____

4. How will reducing your energy consumption 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 actions

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

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

7 **MESSAGES**

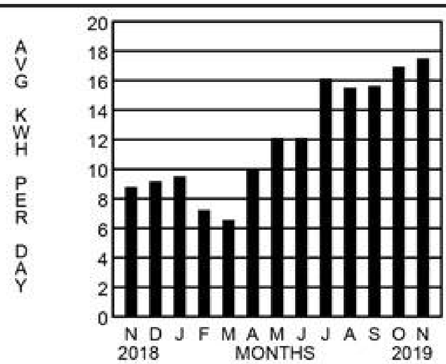
In November, MyCheckFree will no longer be our e-bill/payment provider. Enroll in Paperless Billing at www.hawaiianelectric.com/myaccount. Use our free One-Time Payment option in mid-November.

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.

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