Renewable Energy

Next Generation Science Standards

NGSS Science and Engineering Practices:

- ☑ Asking questions and defining problems
- ☐ Developing and using models
- ☑ Planning and carrying out investigations
- ☑ Analyzing and interpreting data
- ☑ Using mathematics and computational thinking
- ☑ Constructing explanations and designing solutions
- ☑ Engaging in argument from evidence
- ☑ Obtaining, evaluating, and communicating information

NGSS Cross-cutting Concepts:

- ☐ Patterns
- ☐ Cause and effect
- ☑ Scale, proportion, and quantity
- ☐ Systems and system models
- ☑ Energy and matter
- ☑ Structure and function
- ☐ Stability and change

NGSS Disciplinary Core Ideas:

- ☑ ESS3.C Human Impacts on Earth Systems
- ☑ ESS3.D Global Climate Change

Initial Prep Time

Will vary substantially depending on number of experiments, 5-20 minutes per group

Lesson Time

1 – 5 class periods, depending on experiments completed

Assembly Requirements

- Scissors
- Small Phillips-head screwdriver (in Energy Box)
- Small hex wrench (in Energy Box)

Materials (for each lab group):

- Horizon Energy Box
- Reagents:
  - Distilled water
  - Ethanol
  - Table salt
  - Ice
- AA Batteries
- Various beakers
- Hotplate or other heating device
- Electric fan
- Hairdryer or small space heater
- Measuring Devices:
  - Metric ruler
  - Celsius thermometer
  - Balance
  - Protrator
  - Stopwatch

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Lab Setup

- We recommend completing step 1 in Experiment 2 and steps 1 and 2 in Experiment 3 in the Assembly Guide for each electrolyzer so your students do not have to assemble the fan, cut tubing, or fill the electrolyzer initially.
- Lab includes small parts that can go missing easily. Set up a resource area for each lab table or for the entire class to minimize lost pieces.
- If you don't have access to a multimeter or Horizon Renewable Energy Monitor, omit the Measurements section of this activity.

Safety

- Battery packs can short out and heat up if the red and black contacts touch each other while the unit is in the on position. Be sure to keep them off when not in use.
- Using regular tap water instead of distilled water will severely shorten the lifespan of the fuel cells. Distilled water can be found at most pharmacies or drug stores.
- Running electric current through dry fuel cells or attaching the battery packs backwards can destroy the fuel cells. Be sure to always connect red to red and black to black.
- Beware of water spills, and don't be surprised if someone tries to start a syringe water fight.

Notes on the Renewable Energy Science Kit:

- Direct sunlight, or a strong electric light, is necessary for operation. Overcast and indirect sunlight may not provide sufficient energy. Be sure any artificial light source is close to the solar panel.
- Be sure to line up the gaps on the inner cylinders of the H2 and O2 tanks so that bubbles can escape.
- You may need to inject more water into the O2 side of the cell if the electrolysis reaction is being sluggish. Wait 3 minutes and then try again.

Common Problems

- The motor's fan sometimes needs a little push to get started.
- If there's hydrogen left but the motor doesn't run, you may have to purge the fuel cell. Unplug the black plug and then quickly replace it to purge impure gases.
- If the water level doesn't change after purging the cells, make sure the gaps on the base of the inner cylinders are open so that water can fill them.

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Goals

- Assemble and experiment with different types of renewable energy generators
- Understand the advantages and disadvantages of different generators
- Make calculations based on data

Background

For most of human history, almost all energy was renewable. Heat and light were created by burning biomass, first in wood fires and then in wood-burning stoves. Transportation was provided by our own feet or by animals such as horses. Wind drove our ships and ran our mills. Spinning water wheels powered our industries. Though oil and coal had been known about since ancient times, it wasn't until the Industrial Revolution that they became important energy sources.

Even in the earliest years of the 20th century, coal and oil were relatively minor parts of the average person's energy usage. Though factories powered by coal were commonplace by then, most light was still provided by candles and home heating by fireplaces and stoves. Electricity changed all of that almost overnight.

By the 1920s, most homes in cities were electrified, and electric streetcars were transporting passengers down the streets of New York, Chicago, and hundreds of other cities. But nearly all of that electricity was being generated from coal or oil power plants that were pouring pollution into the air. The early solution to this was simple: build the power plants far from the cities, where not many people would complain about the pollution. But a far larger problem soon presented itself.

As we've learned more about the Earth's climate system, we've come to realize that those power plants, as well as cars and factories, have been pumping an invisible pollutant into the air: carbon dioxide. Though it's odorless and colorless, it acts as a greenhouse gas to trap heat and cause the entire planet to warm up.

So after more than a century of exploiting fossil fuels for our energy needs, the world is once again turning to renewable sources of energy, but this time with all of the knowledge of modern science behind it. Our new forms of renewable energy borrow from the old (we still use wind and burn biomass, for example) and utilize new materials to generate energy in ways that would seem like magic for people from centuries past, such as thermoelectric and fuel cell generators.

But each of these new technologies has its own limitations and drawbacks, even though none of them produce the harmful pollution of fossil fuels. So are any of them appropriate substitutes for our existing energy sources or are there options we haven't considered that would work better?

In this activity, we will generate electricity with many different renewable energy generators and determine which of them make good sources of electricity and which need to go back to the drawing board. Some of them can be modified in many ways, others have few variables we can change, but we will try to maximize their electrical output to compare them. We will use the results of our experiments to begin compiling our energy portfolio.

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Fuel Cell Procedure

1. You can use the electricity from the battery pack to generate hydrogen gas using the electrolyzer. The electrolyzer is the square with "H2" and "O2" printed on either side. What do you think will happen if you connect it to a source of electricity like the battery pack?

2. Your electrolyzer is also a hydrogen fuel cell that can generate electricity from hydrogen and oxygen. It has two small tubes attached to it. Is there anywhere else on the fuel cell that you could attach the longer tubes?

3. Look at the remaining pieces of your kit. If the fuel cell splits water into hydrogen and oxygen gases, what could you use to trap the gases so they don't float away? Connect the tubes of your fuel cell so that you can trap the gases. To generate hydrogen, you'll need to supply an electric current. You can do this with the battery pack or the solar cell. Try both. Which is better at producing hydrogen? How do you know?

4. When you've produced hydrogen, you can use the fuel cell to power the motor just like you did with the solar cell. Plug the motor into the fuel cell and it should start turning. Note in your observations if you see any difference in how the motor works with the fuel cell instead of the solar cell.

Observations

Fuel Cell Experimentation

1. How can you increase the output of your hydrogen fuel cell? Discuss with your group what you could change and use the Horizon Renewable Energy Monitor to determine how the output of your fuel cell changed. Try many different changes to maximize the current, voltage, and power. Record your results in the table below.

Ideas for variables to change:

Fuel cell temperature, amount of hydrogen used, etc.

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Trial:	Changed Variable:	Voltage (V):	Current (A):	Power (W):
Control	Nothing			
1				
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At your best configuration, what is the longest time you can get your generator to run?

Solar Procedure

1. Use your solar cell to power the small motor that controls the fan. You'll need to connect the solar cell to the fan using wires to carry the electricity. Why do you think you need two wires?
2. Move the solar cell so that it's facing your light source. The solar cell will work best in direct sunlight. What happens to the fan when you expose the solar cell to a light source?
3. Now try using the solar cell to power the LEDs. Record your observations below.

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Observations

Solar Experimentation

How can you increase the output of your solar panel? Discuss with your group what you could change and use the Horizon Renewable Energy Monitor to determine how the output of your solar panel changed. Try many different changes to maximize the current, voltage, and power. Record your results in the table below.

Ideas for variables to change:

Angle of panel, distance to light source, type/color of light used, color of background, etc.

Trial:	Changed Variable:	Voltage (V):	Current (A):	Power (W):
Control	Nothing			
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At your best configuration, what is the longest time you can get your generator to run?

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Wind Procedure

1. Look at the three different types of blades available (labeled A, B, and C). How are they similar? How are they different? Discuss with your group which type of blade you think would work best with your turbine and record your observations below.
2. Select the type and number of blades you want to test. Why do you want to test this type of blade first? Do you think it will be better or worse than the other types?
3. Check that the blades are in the same position using the three notches near the white bases of the blades. Rotate the individual blades if needed to get all the blades into the same position. Would your turbine still work if the blades were in different positions?
4. Insert the blades into the Rotor Base and put the Blade Holder and the Blade Assembly Lock, then attach the Blade Unit to the metal shaft of the turbine. Can your blades be positioned backwards? How do you know if there's a "right way" for a blade to be positioned?
5. Connect the base of the turbine to the LED lights using the black and red wires. Why do you think the lights need two wires to work?
6. Turn on the fan and position it in front of the turbine. It will work best if you keep the fan close to the turbine and line up the center of the fan with the center of the turbine. Why would changing the position of the fan affect the wind hitting the turbine?
7. Record your observations in the Data Table below: Did the lights turn on? Were they dim or bright?
8. Discuss with your group what you could change about your wind turbine, then make your changes and record your results in the data table below.

Observations

Wind Data Table

Blade Type (A, B, C):	Number of Blades:	Blade Angle (6°, 28°, 56°):	Observations:

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Wind Experimentation

How can you increase the output of your wind turbine? Discuss with your group what you could change and use the Horizon Renewable Energy Monitor to determine how the output of your turbine changed. Try many different changes to maximize the current, voltage, and power. Record your results in the table below.

Ideas for variables to change:

Number of blades, blade angle, type of blades, different patterns/combinations of blades, distance of fan, etc.

Trial:	Changed Variable:	Voltage (V):	Current (A):	Power (W):
Control	Nothing			
1				
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At your best configuration, what is the longest time you can get your generator to run?

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Salt Water Battery Procedure

1. Look at the two parts of the battery and how they fit one inside the other. Does it matter which way you put one inside the other? How will you get them apart once you put them together?
2. The large flat piece with the blue top is the anode for our experiment. Electrons will be flowing out from the anode into a wire once you start the battery. Where would you attach a wire on the anode? What color of wire do you think you should you use?
3. Measure out 15 mL of salt water using the graduated cylinder and use the syringe to transfer it to the bottom part of the battery. Why do you think we don't fill it up all the way?
4. Take your anode and clip it into the bottom part of the battery. Where should you put wires to let electrons start flowing through your fuel cell?
5. You have two red wires, but only one needs to connect the battery to the fan motor. Where would you put the other red wire?
6. Attach the black and one red wire to the fan. Attach the other red wire to two red sockets on the front and back sides of the anode. This should start the fan running. Write down anything you observe in the Observations section below.

Observations

Renewable Energy

Salt Water Battery Experimentation

How can you increase the output of your salt water battery? Discuss with your group what you could change and use the Horizon Renewable Energy Monitor to determine how the output of your battery changed. Try many different changes to maximize the current, voltage, and power. Record your results in the table below.

Ideas for variables to change:

Solution concentration, solution temperature, volume of solution, etc.

Trial:	Changed Variable:	Voltage (V):	Current (A):	Power (W):
Control	Nothing			
1				
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3				
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At your best configuration, what is the longest time you can get your generator to run?

Renewable Energy

Capacitor Procedure

1. Look at the super capacitor. It's the long cylinder with one red and one black plug on one end. What wires do you think you should attach to it?
2. Once you've got wires attached to the super capacitor, you'll connect the other end of those wires to the potentiometer (po-ten-ti-OM-et-er). That's the dial with red, yellow,
3. and green sections. Where do you think you'll attach the red and black wires? Will it matter which plugs you use?
4. The potentiometer will tell you when you've filled the super capacitor with energy, but you'll need the hand-crank generator to do that. Looking at the generator, how do you think you should attach it to the potentiometer?
5. If you've got your generator hooked up to the potentiometer, turn the hand-crank in a clockwise direction to transfer power to the super capacitor. (WARNING: Do not spin it in a counter-clockwise direction or you will damage the super capacitor!) What do you observe as you spin the hand-crank?
6. As you fill the super capacitor, you'll notice the dial on the potentiometer moving. How will you know when it's full?
7. When you've filled the super capacitor, disconnect the potentiometer from the super capacitor and connect the fan to the super capacitor using the red and black wires. The fan should start moving as soon as it's connected.

Observations

Renewable Energy

Capacitor Experimentation

How can you increase the output of your capacitor? Discuss with your group what you could change and use the Horizon Renewable Energy Monitor to determine how the output of your capacitor changed. Try many different changes to maximize the current, voltage, and power. Record your results in the table below.

Ideas for variables to change:

Charging time, level shown on potentiometer

Trial:	Changed Variable:	Voltage (V):	Current (A):	Power (W):
Control	Nothing			
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At your best configuration, what is the longest time you can get your generator to run?

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Thermoelectric Assembly

If generator is already assembled, go to the Procedure section.

1. Look at the thermoelectrical system (the two connected containers with red and black wires on the top). Which of the other parts do you think will attach to it?
2. How does the thermoelectrical system fit into its base? Does it matter how you attach them?
3. Why do you think the seals are colored red and blue? The thermoelectrical system's wires are also different colors. Do you think there's a right and wrong side to put each seal? Write down anything you've observed in the Observations section below.

Thermoelectric Procedure

1. Fill two beakers with water, one hot and one cold.
2. Before you fill your generator, be sure to put cold water in the side with the red wire and hot water in the side with the black wire, or all of your results will be backwards!
3. Open the tops of the two containers to fill your generator with hot and cold water.
4. Close the lids and insert the thermometers into the seals, pushing them down gently but firmly until they're almost touching the bottom of the containers.
5. Start the stopwatch and record the temperatures of each thermometer in the table below.
6. Connect the red and black sockets on the generator to the fan with the red and black wires and observe what happens.
7. Disconnect the wires from the fan and connect the generator to the LED lights instead. Observe what happens.
8. After 2 minutes have gone by, record the temperature again, then repeat steps 6 and 7.
9. Repeat step 8 until you've filled in the table below.

Observations

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Thermoelectric Experimentation

How can you increase the output of your thermoelectric generator? Discuss with your group what you could change and use the Horizon Renewable Energy Monitor to determine how the output of your generator changed. Try many different changes to maximize the current, voltage, and power. Record your results in the table below.

Ideas for variables to change:

Temperature of either side, adding salt to increase temperature difference, volume of water in either side, etc.

Trial:	Changed Variable:	Voltage (V):	Current (A):	Power (W):
Control	Nothing			
1				
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At your best configuration, what is the longest time you can get your generator to run?

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Ethanol Procedure:

1. Your ethanol fuel cell is attached to a fuel tank, which will be moving the ethanol solution into the fuel cell when you remove the clamp on the tube. For now, leave it there and look at your fuel cell.
2. Where do you think you'd find the products of your chemical reaction exiting the fuel cell?
3. Attach the red and black wires to the fuel cell. Then attach the other ends of the wires to the fan. Why do you think we need two wires?
4. Open the clamp on the fuel tank tube to let ethanol solution into the fuel cell.
5. Once liquid flows out of the unclamped tube, replace the clamp on the fuel tank tube. What happens to the fuel cell and fan? Record your observations below.
6. To clean out your fuel cell after use, fill the syringe with distilled water and disconnect the fuel tank tube from the fuel cell.
7. Attach the syringe to the fuel cell and push the distilled water into the fuel cell.
8. Disconnect the syringe and its tube from the fuel cell and fill the syringe with air.
9. Use the syringe to push air into the fuel cell. Your fuel cell is now ready to be used again.

Observations:

Renewable Energy

Ethanol Experimentation:

How can you increase the output of your ethanol fuel cell? Discuss with your group what you could change and use the Horizon Renewable Energy Monitor to determine how the output of your fuel cell changed. Try many different changes to maximize the current, voltage, and power. Record your results in the table below.

Ideas for variables to change:

Solution concentration, solution temperature, air temperature, volume of solution, etc.

Trial:	Changed Variable:	Voltage (V):	Current (A):	Power (W):
Control	Nothing			
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At your best configuration, what is the longest time you can get your generator to run?

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Data Summary:

You've tested a lot of different types of renewable energy electric generators. Review the data you've collected and fill in the answers to the following questions.

Highest recorded current: __________A generated by the _________________.
(type of generator)

Highest recorded voltage: __________V generated by the _________________.

Highest recorded power: ___________W generated by the ________________.

Longest running time: ____________sec generated by the _________________.

Analysis

1. Was one of your generators better than all of the others? Make a scientific claim about your renewable energy generators.

Claim should reference one or more generator's capabilities.
Example: "No generator was clearly better than all the others."

2. What evidence do you have to back up your scientific claim?

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The salt water battery was able to run for much longer time than the others but produced a much lower voltage, current, and power. The highest current we measured came from the wind turbine, while the capacitor had the highest voltage and the solar panel produced the highest power."

3. What reasoning did you use to support your claim?

Reasoning can draw from Background section and/or other materials used in class.
Example: "Since no one generator was best at all the categories, there wasn't one that was a clear favorite."

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4. Design an experiment that would test how efficiently each generator changes its fuel (hydrogen, sunlight, ethanol, wind, etc.) energy into electric energy. Describe your experiment below.

There are many possible answers, but students must explain how they would measure energy efficiency, and have clear control and experimental groups in their description.

Conclusions

1. Based on your data and your observations of how each of these technologies work, which one do you think would work best as a source of power for a car? Explain your reasoning.

Answers can vary, as long as students are able to back up their assertions with data from their observations/experimentation sections. For instance, there is a good reason that no cars are powered by wind turbines.

2. Are there any technologies among the ones you investigated that would definitely not be useful as a large-scale power source for a town or community? Explain your answer.

Again, answers can vary, as long as students are able to back up their assertions with data from their observations/experimentation sections. For example, generators that provided very low current or those that weren't able to run for a long time might not be ideal.

3. Among the sources of electricity that you feel would be useful for a town or community, which technology or technologies do you feel would be most useful for your community? Explain what characteristics of your community make your choices the most logical.

Again, answers can vary, as long as students are able to back up their assertions with data from their observations/experimentation sections as well as their own knowledge about the constraints of their locale: weather/climate, population, geography, etc.