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

Approx. 5 min. per apparatus

Lesson Time

1 – 4 class periods, depending on experiments completed

Assembly Requirements

- Small Phillips-head screwdriver
- Small hex wrench

Materials (for each lab group):

- Horizon Renewable Energy Education Set
- Electric fan
- Metric ruler
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

Renewable Energy

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.
- For this activity, your students will not need the wind turbine or solar panel parts of the lab kit.
- 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.

Renewable Energy

Goals

- Assemble different renewable energy generators
- Compare the ways in which they generate electricity
- Make calculations based on data

Background

For two weeks in December 2015, the residents of the Chinese capital of Beijing, a single city home to more people than any US state except California or Texas, had a "Red Alert" for air pollution. Thick smog from factories and the more than 5 million cars in the region had made the air unsafe for people to be outside and the government was forced to close schools and limit travel to keep the 22 million residents from being exposed to dangerous amounts of toxins in the air they were breathing. Anyone who dared to venture outside wore protective masks over their faces in an attempt to limit the damage this severe pollution caused to their body.

This is an extreme example of human dependency on fossil fuels, but it's exactly the kind of situation that scientists around the world have been trying to prevent by researching the potential of clean sources of energy to replace the coal and oil fuels that cause the pollution found in Beijing and elsewhere.

Three promising technologies are wind power, solar power, and hydrogen fuel cells. They each have limitations and drawbacks, but none of them pollute the air like their fossil fuel counterparts.

If our cars, factories, and power plants could rely on clean, renewable energy, not only would our air be cleaner but our planet would be healthier too. Without the need to mine our fuels from inside the Earth, and without the climate-altering greenhouse gases produced from exhaust, the human impact on Earth's environment would be significantly reduced.

Special semiconductors in solar panels convert the endless supply of sunlight directly into electricity. A wind turbine uses its massive turning blades to capture the energy of moving air and spin a turbine to create electricity. Hydrogen fuel cells combine hydrogen and oxygen gases in a chemical process that produces water and electricity.

Is one of these technologies a clear favorite to replace fossil fuels as a source of energy, or should we keep looking?

In this activity, we will generate electricity with these three different technologies and compare the results to determine which would be the best renewable energy source.

Wind Turbine 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

Renewable Energy

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 what you observed with your group and discuss what you want to change: the number of blades, the angle of the blades, the type of blades, or some combination of those.

9. Repeat steps 1-8 with as many changes as you can think of.

Observations

Data Table:

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

Renewable Energy

Wind Turbine Experimentation:

1. Based on your data from the previous experiment, keep the angles of the blades the same and try different numbers of different types of blades to see which works best. Record your observations below:

Number of Each Type of Blade:	Observations:

What combination worked best?

2. If you used a combination of different types of blades, try changing the arrangement of the blades (A, B, A, B or A, A, B, B, for example) to try and get the rotor to turn faster. If your rotor spun fastest with only one type of blade, you can skip this experiment.

Blade Order:	Observations:

What arrangement worked best?

Renewable Energy

3. Move your fan farther back, to reduce the speed of the wind hitting your turbine. Test different configurations of blades and record your observations below.

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

Was the best arrangement the same as at the higher wind speed?

4. What's the farthest distance you can move your fan and still turn your turbine? Use your ruler to measure how far your fan is from your turbine blades. Try different arrangements to see if you can get the turbine to turn at even farther distances.

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

Renewable Energy

Solar Panel 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. When you've connected the solar cell to the motor, you may have to give the fan a little push to get it started. The solar cell will work best in direct sunlight. What happens to the fan if you try the solar cell with other light sources?
3. Now try using the solar cell to power the LEDs. Record your observations below.

Observations

Solar Panel Experimentation:

1. You can use colored plastic gels, or different lightbulbs, to change the color of light hitting the solar panel. Do certain colors work better than others? Try using the solar panel to run the fan and LEDs while the panel is hit with different wavelengths of light and record your observations below:

Light Color:	Observations:

Renewable Energy

2. The solar panel is dark in color. Does the color of its surroundings affect how well it collects light for generating electricity? Try using the panel to run the fan and LEDs while the panel is in front of different colored backgrounds and record your observations below:

Background Color:	Other Observations:

3. Attach the solar panel to the motor and use a piece of paper or other method to shade parts of the panel and observe the effects. How much of the solar panel can you cover before the motor stops running? Does it matter which side of the solar panel is shaded?

Students should note that, depending on which side you shade, it doesn't take much at all to stop the motor. This is the result of how the individual photovoltaic cells in the solar cell are wired together.

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.

Renewable Energy

Observations

Fuel Cell Experimentation

1. Use the battery pack and fuel cell to generate hydrogen gas as before. Then attach the fuel cell to the LEDs and measure how long they run. Repeat and note any changes. Record your observations below:

Trial:	Run time (sec):	Observations:
1		
2		
3		
4		

2. Try the same experiment with the fan motor. Record your observations below:

Trial:	Run time (sec):	Observations:
1		
2		
3		
4		

Renewable Energy

Measurement

For this section, you will need a multimeter or the Horizon Renewable Energy Monitor. For an introduction to using a multimeter, click here.

1. Measure the current in amps and the voltage in volts while the wind turbine at its fastest configuration powers the LEDs. Record your answers below:

(Answers will vary, but check that they are within reason, i.e. not 100V or >1A.)

Current: ______________ A

Voltage: ____________ V

2. Measure the current in Amps and the voltage in Volts while the solar panel powers the LEDs. Record your answers below:

Current: ______________ A

Voltage: ____________ V

3. Measure the current in Amps and the voltage in Volts while the fuel cell powers the LEDs. Record your answers below

Current: ______________ A

Voltage: ____________ V

4. Power is the current times the voltage (P = IV). Based on your data, which energy source generated the most power?

Renewable Energy

Analysis

1. Make a scientific claim about your electric generators.

Claim should reference the one or more generator's capabilities.
Example: "The wind turbine would make the best source of renewable energy."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "With a configuration of three B blades at 28° on the turbine rotor, we were able to generate more current and voltage than any other generator."

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

Reasoning can draw from Background section and/or other materials used in class.
Example: "More voltage and current means more electric power is generated."

4. Design an experiment that would test how to improve the power output of one of your generators.

There are many possible answers, but students must mention the generator they chose, how they would modify it, and have clear control and experimental groups in their description.

Renewable Energy

Conclusions

1. Do you think the fuel cell, wind turbine, or solar cell makes the best source of electric energy? Explain your reasoning.

Students can choose any of the generators as long as they are able to back up their choice with data from their experiments and observations.

2. What is the biggest limitation of the power source you chose above? Why do you think it's the biggest?

Answers will vary based on the generator chosen. Anything from cloudy days, lack of wind, small storage space for hydrogen, or any number of factors may be chosen, so long as students can reference a compelling reason for their choice.

3. What could you do to possibly overcome that limitation?

Answers will again vary based on the generator/limitation chosen. Students should describe a feasible way to limit the effects of the limitation they chose such as, but not limited to: connecting many solar panels in series, storing unused energy, pressurized hydrogen tanks, etc.