Green Power Grid

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)

Green Power Grid

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.

Green Power Grid

Goals

- Understand how different renewable energy sources work
- Combine them to make a smart energy grid
- Make calculations based on data

Background

The wind and the Sun have been sources of energy for humans since ancient times. We've relied on the Sun to grow our crops and the wind to power our sailing ships for thousands of years. But ancient farmers and mariners alike knew that the Sun doesn't always shine and the wind doesn't always blow. To this day, farmers plant their crops at certain times of year so that they can receive the optimal amount of sunlight. And becalmed sailors, trapped in windless seas for days or sometimes months at a time, would run the risk of running out of food and fresh water.

Today we can use sunlight and wind to generate electricity with solar panels and wind turbines, but we're limited by the same reliability issues that troubled our ancestors. What do we do when the sun isn't shining or the wind isn't blowing? If there was a way to store excess energy at times when sunlight or wind were strong, that stored energy could be used when a solar panel or wind turbine wasn't generating as much electricity.

Modern science has developed a possible solution in the hydrogen fuel cell, a device that combines hydrogen and oxygen to generate an electric current and only produces water as a byproduct. Solar and wind energy can be used to split water into hydrogen and oxygen, and those gases can be recombined by the fuel cell. The hydrogen becomes a way to store the extra electrical energy.

The electrical grid that provides power to all the homes and businesses around the country depends on constant power being available, so a technology that can store excess power and make it available at times of high demand would be useful for any power source, but it's especially needed when the source is as intermittent as solar or wind.

Would this technique work well with both wind and solar power? Are there any advantages to one combination over the other, or is there a combination we're not considering that could work better?

In this activity, we will generate electricity with wind, solar, and fuel cell power to determine if a hydrogen energy storage system works better with a solar or wind power source.

Fuel Cell and 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?

Green Power Grid

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. Now you're ready to use the electricity from the wind turbine to generate hydrogen gas using the electrolyzer. The electrolyzer is the blue 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 wind turbine?

6. 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?

7. 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?

8. 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 from the wind turbine.

9. 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?

10. Connect the turbine to the fuel cell by using the red and black wires. Record your observations in the Data Table below: Did the fuel cell start producing hydrogen and oxygen gas? How do you know?

11. If H2 tank fills with hydrogen, disconnect the turbine and use the fuel cell to power the motor or LEDs. If the H2 tank doesn't have any gas, proceed to the next step. Record your observations below.

12. Discuss what you observed with your group and discuss what you want to change to try and get the turbine to produce more electricity: the number of blades, the angle of the blades, the type of blades, or some combination of those.

13. Disassemble your wind turbine and reassemble it with as many changes as you can think of, then reconnect it to the fuel cell. Record your observations in the Data Table below.

Observations

Green Power Grid

Data Table:

Blade Type (A, B, C):	Number of Blades:	Blade Angle (6°, 28°, 56°):	H2 gas? (Y/N):	Other Observations:

Fuel Cell and Wind 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:	H2 gas? (Y/N):	Other Observations:

What combination worked best?

Green Power Grid

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:	H2 Gas? (Y/N):	Other Observations:

What arrangement worked best?

3. What's the farthest distance you can move your fan and still generate hydrogen gas? 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 work at even farther distances.

Blade Type (A, B, C):	Number of Blades:	Blade Angle (6°, 28°, 56°):	Distance (cm):	H2 Gas? (Y/N):	Other Observations:

Green Power Grid

4. What's the fastest speed you can fill the H2 tank? Using your best configurations according to your previous data, see how long it takes to fill your tank. Record your observations below:

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

Fuel Cell and Solar Procedure:

1. Now you'll use your solar panel to power the electrolyzer in the same way that you used the wind turbine during the last experiment. Be sure you have a light source is bright enough to generate an electric current.
2. Connect the solar panel to the electrolyzer using red and black wires, just as you connected the wind turbine earlier. Record your observations below.

Observations

Green Power Grid

Fuel Cell and Solar Experimentation:

1. Discuss with your group how you could get your solar panel to generate more electricity to run the electrolyzer faster. Try different approaches to see what works best. Time how long each configuration takes to fill up the H2 tank. Record your observations below:

Trial:	What You Changed:	Time (sec):	Other Observations:
1			
2			
3			
4			
5			
6			
7			
8			

2. Hook up your solar panel to both the LEDs and the electrolyzer using red and black wires and the circuit board. This will simulate a smart energy grid, using electricity while also capturing excess energy as hydrogen. Use your best configurations according to your data and see if you can get the LEDs to light up while also generating hydrogen. Record your observations below:

Configuration:	H2 Gas? (Y/N):	LEDs Lit? (Y/N):	Other Observations:

Green Power Grid

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 and electrolyzer. 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 in its best configuration powers the LEDs and electrolyzer. Record your answers below:

Current: _____ A

Voltage: _____ V

3. Power is the current times the voltage (P = IV). Based on your data, which energy source generated the most power while running the electrolyzer and LEDs?

Green Power Grid

Analysis

1. Make a scientific claim about your electric generators.

Claim should reference the one or more generator's capabilities.
Example: "The wind turbine and fuel cell 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 while running the electrolyzer and LEDs."

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, so more can be stored as hydrogen."

4. Design an experiment that would compare the output of one of the generators you tested with another form of renewable energy. Describe your experiment below.

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

Green Power Grid

Conclusions

1. Based on your data, do you think that storing excess energy in hydrogen is a good way to deal with variable energy output from wind and solar power? Explain why.

Students can potentially answer "Yes" or "No" so long as they are able to back up their assertion using evidence from their experiments and/or information discussed in class.

2. Do you think that wind or solar power would be a better source of renewable energy for your community? Explain your reasoning.

Students could choose either option, depending on the data they collected and their knowledge of local wind/sunlight conditions. They must only be able to back up their assertion.

3. Based on your previous answer and the data you collected, would you recommend that your community be powered by the energy source you chose with a hydrogen fuel cell system? Why or why not?

Students can mention the amount of time they estimate their renewable energy source would be able to generate enough power versus the amount of time it would rely on backup from the hydrogen fuel cell. They could also advocate for a different type of power system altogether, or decide that none of these would be suitable for their community, so long as they are able to provide data that backs up these opinions.