# Problem Based Learning Unit

FCJJ 37 - Renewable Energy Science Kit


Horizon Educational

HORIZON ENERGY CURRICULUM

PBL Unit

# Climate Change Activity

# Climate Change Activity

## Objective:

Students will use online resources to determine how Earth's climate is changing and what effects those changes might have on people around the world.

## Time required:

60 minutes

## Materials required:

Laptops or tablets with internet connectivity

## Overview:

Online resources are built directly into the student activity as links. The activity can be completed in small groups or as individuals, depending on your technology availability. Alternatively, the activity and the online resources can be printed for individual students or small groups if necessary.

Instructor-directed whole-group or small-group discussions for formative assessment can also take place as students work through different sections of the activity. Students hand in completed answer sheets at the conclusion of the activity.

At the conclusion of this activity, students will select the final product they want to hand in as described on the final products sheet. Alternatively, you may decide on a final product for all students and explain its requirements.

## Goals for Student Understanding:

✓ Cabon dioxide ($CO_2$) is a major contributor to global climate change.
✓ The amount of $CO_2$ in the atmosphere has varied over time.
✓ The rate of the modern increase in $CO_2$ is unprecedented in the climate record.
✓ The amount of atmospheric $CO_2$ is extreme compared to the most recent 400k years.
✓ Human industrial output of $CO_2$ is the likely cause of this sudden, uncharacteristic rise.

## Notes on This Activity:

- Article for "Carbon and Climate" has 3 difficulty levels, available by clicking tabs at the top of the article. Questions are built around the "Easy" difficulty, but students who have a better grasp of the science should feel free to read the more difficult versions for a challenge.
- Feel free to substitute or otherwise alter questions to meet needs of your particular students.
- Additional written materials about global climate change are available in Horizon's online Renewable Energy E-Book (free user registration required)

# Climate Change Activity

## Answer Key:

Carbon dioxide ($CO_2$) is often called a "greenhouse gas," meaning that it's responsible for warming the Earth's climate. But how do we know that? Read this article to find out what makes $CO_2$ a greenhouse gas and then answer the questions below.

**1.** According to the article, what don't climate scientists agree on when it comes to global climate change?

**They don't agree on how much the amount of greenhouse gases increases the temperature.**

**2.** In your own words (and with a drawing if you want), describe how the greenhouse effect works.

**Answers will vary. Sample response:**

**Ultraviolet energy from the Sun hits the Earth and changes into infrared radiation, which gets trapped by greenhouse gases because it's a different wavelength. The gases reflect the energy back to the Earth, making it warmer than if it was just hit with the energy from the Sun.**

**3.** Explain in your own words the evidence presented in the article that presents $CO_2$ as being the biggest source of warming among all of the greenhouse gases.

**Answers will vary. Sample response:**

**The article showed the data on what spectrum of radiation was absorbed and $CO_2$ had the biggest peak on the graph by a long way. It also mentions that $CO_2$ has been increasing in the atmosphere as the Earth's temperature has been rising.**

**4.** Do you think the author presents a good argument for $CO_2$ being responsible for increased global temperatures? Explain your reasoning.

**Students will have different opinions and reasoning. Good question for whole- or small-group discussion.**

# Climate Change Activity

## Carbon Over Time:

How much carbon dioxide was in Earth's atmosphere in the past? And how do we know? Scientists have found many ways to determine what the Earth's atmosphere was like in the past.

**1.** On this page, 1. click through each of the graphs that are displayed. According to the graphs, what is the highest concentration of ppm of $CO_2$ in our atmosphere over the last 400,000 years and when did that occur?

**~400 ppm, happening right now.**

**2.** If you look at the longest timescale and ignore the most modern data (the red and bright blue dots), what would the highest concentration of $CO_2$ over the last 400,000 years be?

**~300 ppm**

## Effects of Global Climate Change

**1.** If $CO_2$ is increasing in the atmosphere, what changes we would expect to see in global temperatures and the overall climate?

**We would expect to see temperatures rising and climates getting hotter around the world.**

**2.** How do you think these changes in temperature and climate would impact humans?

**Places that were used to colder weather would get hotter, sea levels would rise as ice melts, and animals and plants would have their habitats changed.**

**3.** Many changes in the world have been blamed on changes in the climate. Use internet searches to estimate what the chances are that the following occurrences are caused by climate change and indicate your results in the table: **(X=most correct, o=acceptable)**

| | Not At All | Possible | Likely | Almost Certainly |
|---|---|---|---|---|
| Rising Sea Levels | | | o | X |
| Colony Collapse Disorder | o | X | | |
| Extreme Storms and Hurricanes | | o | X | o |
| Increased Earthquakes | X | o | | |
| Increased Animal and Plant Extinctions | | | o | X |
| Expansion of Deserts | | | o | X |

# Climate Change Activity

**4.** Among the issues in the previous question that you found were "Likely" or "Almost Certainly" caused by global climate change, which do you think has the greatest effect on human life? Why?

**Student opinions will vary. Use this and other questions to stimulate whole- and small-group discussion.**

**5.** If the issue that you chose in the previous question were to get worse, how would people in your region and the whole country be affected? What would need to be done to adapt?

**See above**

## Action:

Discuss with your group and write your answers to these questions below.

**1.** Do you think people are doing enough to combat global climate change? Why or why not?

**Student opinions will vary. Use this and other questions to stimulate whole- and small-group discussion.**

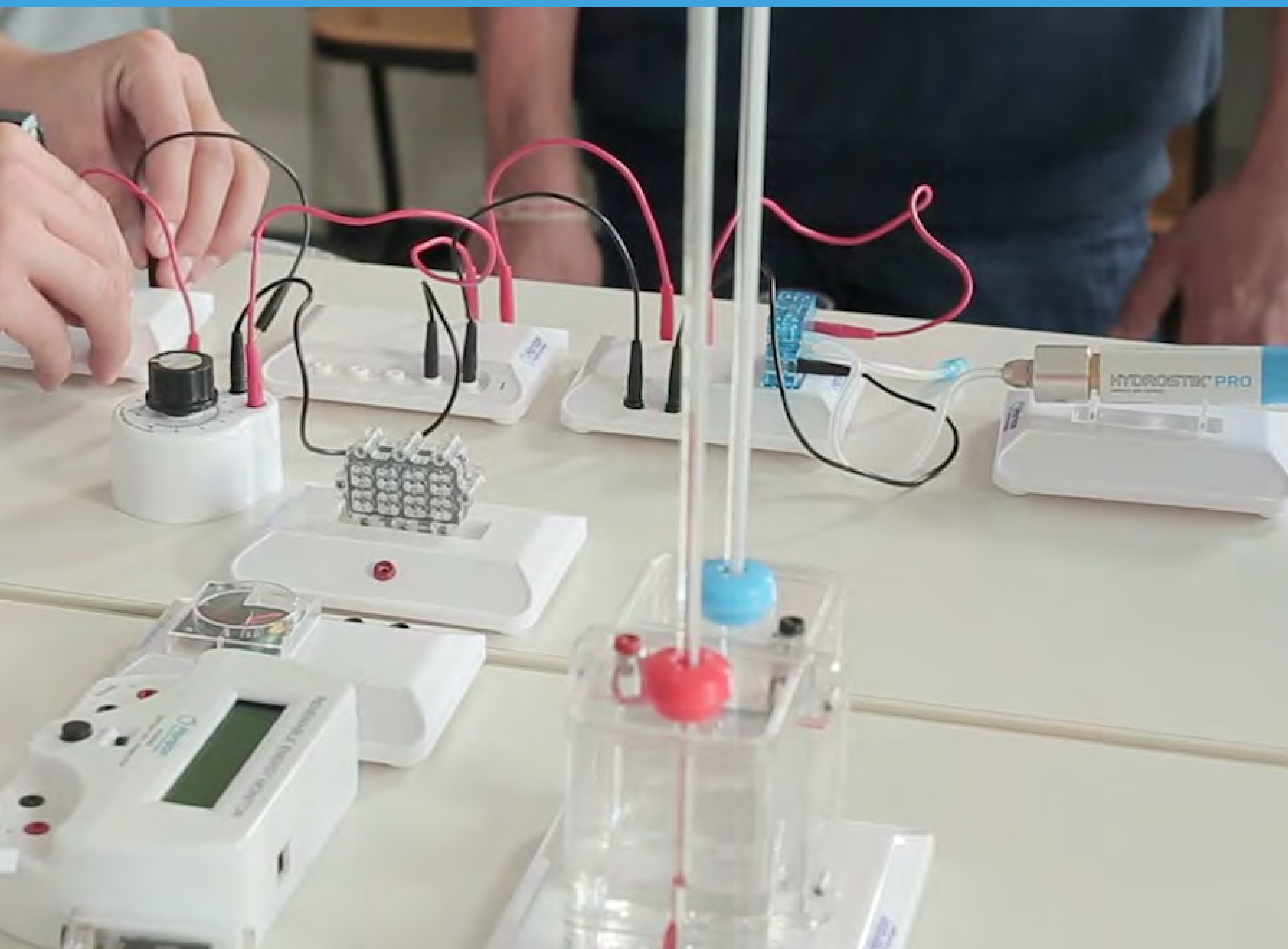
**2.** If you could encourage people to do one thing to combat global climate change, what would it be?

**See above**

**3.** What would electricity generation look like in a world where non-polluting sources of fuel were used?

**See above**

# Hardware Experiments



# Electric Circuits

## 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:**

- ☑ PS3.D: Energy in Chemical Processes and Everyday Life

## Initial Prep Time

Approx. 5-10 min. per apparatus

## Lesson Time

1 – 2 class periods, depending on experiments completed

## Assembly Requirements

- Scissors

**Materials (for each lab group):**

- Horizon Renewable Energy Science Kit
- Distilled water
- AA batteries
- Protractor
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

# Electric Circuits

## 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 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.

# Electric Circuits

## Goals

- Build a complete circuit with a solar panel
- Power a motor and electrolyzer with a solar panel
- Measure voltage and amperage in different circuits

## Background

Electricity has fundamentally changed the history of humanity. Steam may have powered the industrial age, but electricity has powered every age since. It would be impossible to eat, work, travel, communicate, or create music or art like we do today without electricity.

Electricity is nothing more than the movement of electrons. Within the right materials, called conductors, electrons are no longer attached to single atoms but can move freely between them. Metals are the best conductors, and copper is one of the best conducting metals. Silver is even better, but it's much more expensive, so most electrical wires are made of copper.

For an electric current to move through wires, though, it needs to be pumped. Just like water through a pipe, there must be pressure that pushes the electrons in one direction or the other. We could fill a pipe with water, just as the copper atoms still have their electrons all around them, but without a pressure to move them they won't go anywhere. In electrical circuits, we call this pressure a voltage. Voltage is measured in volts.

When a voltage is applied to an electric circuit, electrons begin to move in one direction. This produces an electric current. We measure current, the amount of moving electrons, in amperes or amps for short. Some electric current moves in just one direction, and we call that direct current (DC). Other currents move back and forth very quickly, many times a second, and we call that alternating current (AC).

There are two ways that two or more devices can be hooked up to an electric current: in series and

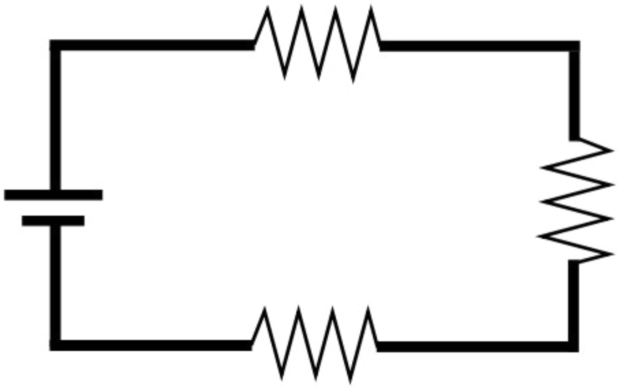


*Fig. 1 Series circuit (with 3 resistors)*

in parallel. When devices are attached in series, there's only one complete circuit and the devices are attached next to each other like lights on a Christmas tree. (See Fig. 1)

When devices are attached in parallel, the circuit splits current to each individual device and reconnects to the power source. (Fig. 2)

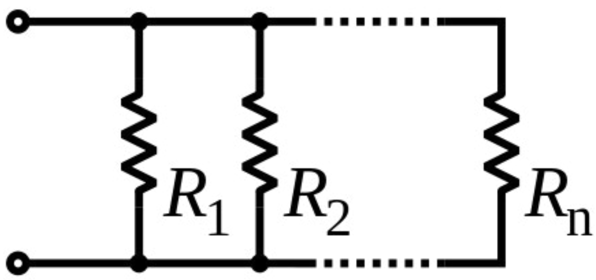



*Fig. 2 Parallel circuit (of n resistors)*

During this activity, we will use a solar panel to generate DC electricity, see how we can change the amount of current it produces, and attach devices to the circuit in series and in parallel.

# Electric Circuits

## 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. You can use the electricity from the solar panel 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 solar cell?
4. 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?
5. 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?
6. 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?
7. 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

## Experimentation

1. With the motor attached, try tilting the solar panel so that it changes the angle of the light that hits it. Can you tilt it far enough that the motor stops running? Does it matter which direction you tilt the panel? Using a protractor, measure the biggest angle at which you can still run the motor.

**Maximum angle will change based on type of light source. A powerful light source may be able to keep an almost perpendicular solar cell running. Students should present data to determine whether one direction of tilt is better or worse than another.**

# Electric Circuits

2. Attach both the motor and electrolyzer to the solar panel in series and record your observations below:

**Weak light sources might not be able to run both at all, stronger light sources will run both, but visibly slower than each independently.**

3. Now attach them both in parallel. How can you split the electricity between the two devices? How does their performance compare to when they were attached in series? Record your observations below:

**Students should use the circuit board to attach the devices in parallel. They should note the relative performance of each device compared to the previous configuration**

## 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 running the motor. Record your answers below:

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

Current: ______________ A

Voltage: ____________ V

2. Measure the current in Amps and the voltage in Volts while running the motor and electrolyzer in series. Record your answers below:

Current: ______________ A

Voltage: ____________ V

3. Voltage is equal to the current multiplied by the resistance ($V = IR$), so according to your data what is the combined resistance in ohms of the electrolyzer and motor?

Resistance: _____________ Ω

# Electric Circuits

4. Measure the current in Amps and the voltage in Volts while running the motor and electrolyzer in parallel. Record your answers below:

Current: _____________ A

Voltage: ___________ V

## Analysis

1. Make a scientific claim about what you observed while using your circuits.

**Claim should reference characteristics of series and/or parallel configurations.**
*Example: "Series circuits supply less current to each device attached to them."*

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

**Evidence should cite data in Observations and/or Experimentation sections.**
*Example: "We measured the current as 0.19 Amps when the devices were in parallel and 0.05 Amps when the devices were in series."*

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

**Reasoning can draw from Background section and/or other materials used in class.**
*Example: "We know that a series circuit adds up the resistances of all devices and that V=IR from Ohm's Law."*

4. Use your observations to design an experiment you could run to increase the amount of electricity generated by the solar panel. Describe your experiment below.

**Many answers are possible, but students should include ways of measuring the electrical output and clear control and experimental groups in the description.**

# Electric Circuits

## Conclusions

1. Based on your observations did the electrolyzer and motor get more electric current when they were hooked up in series or in parallel? How do you know?

**Be sure that student answers cite data from their observations during the series and parallel experiments.**

2. Does hooking up more devices to an electrical circuit in series increase or decrease the electric current in the circuit? Explain your answer.

**Students should have observed the decrease in electric current when an additional device in series was connected and answers here should reference those observations.**

3. Which is the best way to attach both the motor and electrolyzer with the solar cell at the same time: series or parallel? Explain your answer.

**Either is acceptable, as long as students can back up their answer with data from their experiments.**

# Green Power Grid

## Next Generation Science Standards

**NGSS Science and Engineering Practices:**

- ☐ Asking questions and defining problems
- ☐ Developing and using models
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- ☑ Analyzing and interpreting data
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- ☐ 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.
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## 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°): | $H_2$ gas? (Y/N): | Other Observations: |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
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| | | | | |
| | | | | |
| | | | | |

## 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: | $H_2$ 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: |
|---|---|---|---|---|---|
| | | | | | |
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# 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: |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
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## 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: |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
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# 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.**

# Energy Conservation and Transformation

## 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:**

☑ PS1.B: Chemical Reactions

## Initial Prep Time

Approx. 10 min. per apparatus

## Lesson Time

1 – 2 class periods, depending on experiments completed

## Assembly Requirements

- Scissors
- Small Philips screwdriver

**Materials (for each lab group):**

- Horizon Renewable Energy Science Kit
- Distilled water
- AA batteries
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

# Energy Conservation and Transformation

## 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 solar panel or wind turbine parts of the lab kit.
- Please note that the PEM fuel cell's membrane should be kept from drying out. It's best to seal it in a plastic bag between uses. Before students use the cell, be sure it's filled with water and that the two small pieces of tubing are attached.
- Some of the parts of the car are quite small (such as tube caps) and can be lost easily. Setting up resource areas on lab tables with labeled containers for each group's pieces can prevent loss of these small parts and help keep the parts of each group's kit separate.
- 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.

# Energy Conservation and Transformation

## Goals

- Understand how chemical reactions work
- Perform a reversible reaction
- Make calculations based on data

## Background

Chemical reactions are the processes that create every compound in the universe. When two or more atoms form a bond, or break bonds and form new ones, a chemical reaction takes place that totally changes the characteristics of the materials involved.

Some chemical reactions are ones where simple substances are combined to make new, more complex compounds (synthesis) or where complex molecules are broken down into simpler molecules (decomposition). Water, one of the most common substances on Earth, is easily synthesized from hydrogen and oxygen, and also can be easily decomposed back into hydrogen and oxygen.

We can write out these reactions using chemical symbols like this:

$$2\,H_2 + O_2 \rightarrow 2\,H_2O$$
$$2\,H_2O \rightarrow 2\,H_2 + O_2$$

A hydrogen fuel cell can accomplish both of these reactions by using electricity. Running an electric current through the fuel cell when it's filled with water causes the water to split into hydrogen and oxygen. If the fuel cell is attached to a motor while oxygen and hydrogen are present, it will combine them into water and produce an electric current that powers the motor. To learn more about how a hydrogen fuel cell works, click here.

To find out more about how these chemical reactions work, we'll use the hydrogen fuel cell to power a small car, first by producing hydrogen and oxygen gas, then using those gases to generate electricity.

## Procedure

1. Once the fuel cell starts producing hydrogen and oxygen gas from water, we will need to trap the gases to be able to use them for the reverse reaction. How can the gases be trapped using the materials provided?
2. The Oxygen side of the fuel cell needs to be filled with water. Observing the hydrogen fuel cell, why do you think only one side needs to be filled with water? Do you think it matters if the water is injected into the top or bottom outlet?
3. How can we tell how much gas has been generated from our reaction?
4. Does it matter how the battery pack is attached to the fuel cell? Why or why not?
5. If you're ready to capture the gases produced by the fuel cell, attach the battery pack. Observe what happens and record your observations below.

# Energy Conservation and Transformation

## Observations

## Experimentation

1. You've produced hydrogen and oxygen from water. Now, connect the fuel cell to the motor. What happens?

**Students should notice the fan begins to turn and can make note of any particular aspect of the fan's performance: sound of the motor, how long it runs, etc.**

2. Generate more hydrogen and oxygen using the fuel cell, as before. Can you tell how much hydrogen you've generated? What is the volume of hydrogen produced?

**Students should use the mL markings on the cylinders to answer. Responses will vary, but should not exceed 10mL.**

3. What is produced faster: hydrogen or oxygen? Why do you think this is?

**Hydrogen is produced faster (more accurately, a larger volume of hydrogen is produced) due to the ratio of hydrogen to oxygen in water.**

4. How would you make more gas with this reaction? Devise an experiment that you could run to increase the amount of hydrogen and oxygen you produce. Describe your experiment below.

**Gas could be stored in larger tanks, the current could run for a longer time, multiple fuel cells could be used, and more may be acceptable answers.**

# Energy Conservation and Transformation

## 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 generating hydrogen and oxygen. 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. Voltage is equal to the current multiplied by the resistance ($V = IR$), so according to your data what is the resistance of the fuel cell?

Resistance: ___________ Ω

3. Measure the current in Amps and the voltage in Volts while combining the hydrogen and oxygen to produce water. Record your answers below:

Current: ____________ A

Voltage: __________ V

4. Does it take more energy to split the hydrogen and oxygen or combine them? Explain your reasoning.

**Measurements of current and voltage should both be higher when splitting the water than when recombining it. This would imply that more energy is required to split it than to recombine it.**

# Energy Conservation and Transformation

## Analysis

1. Make a scientific claim about what you observed while running the fuel cell.

**Claim should reference the reaction of electrolysis and/or synthesis of water.**
*Example: "There is energy stored in the bonds of a water molecule."*

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

**Evidence should cite data in Observations and/or Experimentation sections.**
*Example: "The energy to break water molecules into hydrogen and oxygen was higher than the energy to synthesize water."*

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

**Reasoning can draw from Background section and/or other materials used in class.**
*Example: "The Law of Conservation of Energy says that the extra energy must be stored somewhere since it can't be destroyed."*

4. Use your observations to design an experiment you could run to increase the amount of electricity generated by the fuel cell. Describe your experiment below.

**Change pressure/temperature of the water/gases, construct fuel cell with different materials, change the shape of the anode/cathode, and more are all ideas that could be tested. Students should identify control and experimental setups, and define the variable to be tested.**

# Energy Conservation and Transformation

## Conclusions

1. How would you describe what happened during the decomposition and synthesis reactions you just observed in terms of the energy involved?

**Energy is required to break the bonds that holds a water molecule together, so the electric energy from the battery can be used to split the water molecule. The chemical reaction of combining hydrogen and oxygen converts stored chemical energy back into electric energy.**

2. Did all of the energy in the hydrogen transform into electrical energy? If not, where else did it go?

**Heat from reaction, energy of new chemical bond, molecule vibrations, and others may be acceptable answers.**

3. What kinds of measurements could you make to confirm that energy was conserved during these reactions?

**Measuring small changes in temperature, measuring the forces applied to the car by the motor, measuring the electric current in the motor and battery, and more may be acceptable answers.**

# Redox Reactions

## 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:**

- ☑ PS1.B: Chemical Reactions

## Initial Prep Time

Approx. 10 min. per apparatus

## Lesson Time

1 – 2 class periods, depending on experiments completed

## Assembly Requirements

- Scissors
- Small Philips screwdriver

**Materials (for each lab group):**

- Horizon Renewable Energy Science Kit
- Distilled water
- AA batteries
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

# Redox Reactions

## 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.

# Redox Reactions

## Goals

- Understand how redox reactions work
- Perform an electrolysis reaction
- Make calculations based on data

## Background

For every action, there's an equal and opposite reaction, even at the atomic level. When electrons travel between atoms, opposite reactions occur: reduction and oxidation. Reduction takes place when an atom gains an electron (the negative electron reduces the atom's overall oxidation state), while oxidation takes place when an atom loses one. So the movement of even just one electron between atoms requires both reactions. Since they're two halves of a larger reaction, they're often referred to collectively as reduction-oxidation, or redox.

The word "oxidation" was first used to describe an actual reaction with oxygen, which was one of the first oxidizing reagents recognized by scientists. Even when other substances were found to behave similarly, the term stuck. Now anything that causes the loss of electrons is said to be an oxidizer.

"Reduction" originally meant the physical loss of mass that occurred when a metal ore such as metal oxide was heated to extract the metal. A larger mass of ore was "reduced" to yield the pure metal. It was only later that scientists realized that metal atoms gained electrons during the process, so now any gain of electrons is referred to as reduction.

A simple redox reaction can be demonstrated through the electrolysis of water, decomposing it into hydrogen and oxygen, which can be accomplished by running an electrical current through the water. A reversible fuel cell can accomplish this, while also being able to reverse the reaction and generate an electric current while recombining hydrogen and oxygen into water.

The half-reactions of oxidation and reduction take place at two electrodes: the anode and cathode. The anode is the positive electrode, where electrons come out of the water and oxygen gas appears. The cathode is the negative electrode, where electrons enter the water and hydrogen gas appears. You can read more about electrodes here.

The hydrogen protons can pass through the membrane in between the anode and cathode, joining the electrons that traveled through the wire to the other side. A full explanation of how a fuel cell works can be found here.

In redox reactions, we write out the electrons in the half-reactions so we can balance them not just by the atoms, but also by the electric charges. The half-reactions for electrolysis are as follows:

**Cathode (reduction):**

$$2\ H_2O(l) + 2e^- \rightarrow H_2(g) + 2\ OH^-(aq)$$

**Anode (oxidation):**

$$4\ OH^-(aq) \rightarrow O_2(g) + 2\ H_2O(l) + 4\ e^-$$

How does a redox reaction work and how can it be used as a source of energy? During this activity we will try to use redox reactions to power a fuel cell car.

# Redox Reactions

## Procedure

1. The fuel cell is labeled H2 and O2 on either side. Which side is the cathode? Which is the anode? How do you know?
2. Once the fuel cell starts producing hydrogen and oxygen gas from water, we will need to trap the gases to be able to use them for the reverse reaction. How can the gases be trapped using the materials provided?
3. Knowing your half reactions, where should the water be introduced into the fuel cell? Does it matter which side? Does it matter whether the water is injected into the top or bottom outlet?
4. How can we tell how much gas has been generated by our reaction?
5. Does it matter how the battery pack is attached to the fuel cell? Why or why not?
6. If you're ready to capture the gases produced by the fuel cell, attach the battery pack. Observe what happens and record your observations below.

## Observations

## Experimentation

1. You've produced hydrogen and oxygen from water. Now, connect the fuel cell to the motor. What happens?

**Students should notice the fan begins to turn and can make note of any particular aspect of the fan's performance: sound of the motor, how long it runs, etc.**

2. Write the balanced reaction for the recombination of hydrogen and oxygen below:

**$2H_2$ + O2c$2H_2O$**

# Redox Reactions

3. Generate more hydrogen and oxygen using the fuel cell, as before. What is the volume of hydrogen produced?

**Students should use the mL markings on the cylinders to answer. Responses will vary, but should not exceed 10mL.**

4. What is the ratio of hydrogen to oxygen generated? Does your measurement match the theoretical ratio?

**Answers should be roughly 2:1 to match the theoretical ratio.**

5. Assuming standard temperature and pressure, how many moles of hydrogen gas have you generated? How many molecules of hydrogen are in your cylinder?

**Students should use the Ideal Gas Law (PV = nRT) and their volume measurement from above.**

6. How would you maximize the yield of this reaction? Devise an experiment that you could run to increase the amount of hydrogen and oxygen you produce. Describe your experiment below.

**Change pressure/temperature of the water/gases, construct fuel cell with different materials, change characteristics or materials of the anode/cathode, and more are all ideas that could be tested. Students should identify control and experimental setups, and define the variable to be tested.**

# Redox Reactions

## 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 while generating hydrogen and oxygen. Time how long it takes to fill your hydrogen cylinder. Record your answers below:

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

Current: ______________ A

Time: ____________ sec

2. One Amp is equivalent to 6.242x1018 electrons per second, so how many electrons were flowing through your wires while you generated hydrogen?

**(Amps from above) x (6.242x1018) x (Seconds from above)**

3. If you fill the cylinder, how many moles of hydrogen have you produced? How many atoms of hydrogen would that be?

**Students should use the Ideal Gas Law (PV = nRT) and the volume of the cylinder to find moles. That answer is then multiplied by Avogadro's number to get a number of atoms.**

4. Does each electron flowing through your wire correspond to an atom of hydrogen produced by this reaction? Explain your reasoning.

**Compare the number of electrons calculated above to the number of atoms calculated. Are they roughly equivalent?**

# Redox Reactions

## Analysis

1. Make a scientific claim about what you observed while running the fuel cell.

**Claim should reference the electrolysis and synthesis reactions they observed.**
*Example: "Stoichiometry accurately predicts the ratios of products in electrolysis."*

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

**Evidence should cite data in Observations and/or Experimentation sections.**
*Example: "We measured 10mL of hydrogen and 5 mL of oxygen from our reaction."*

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

**Reasoning can draw from Background section and/or other materials used in class.**
*Example: "We know from the chemical formula of water that the ratio of H:O should be 2:1."*

4. Based on your observations, how could you tell that a reaction was taking place during electrolysis and synthesis?

**Two key observations: bubbles form during electrolysis and travel through the tubes, generation of an electric current during synthesis. Other answers are also acceptable.**

# Redox Reactions

## Conclusions

1. Using the cathode and anode equations from the Background section, what would be the overall reaction during electrolysis?

**$2H_2O \rightarrow 2H_2 + O_2$**

2. Does the synthesis of hydrogen and oxygen require more activation energy than the electrolysis reaction?

**Students should cite their data and/or materials used in class to support their answer.**

3. Describe the way that electrons move during the electrolysis and recombination reactions in the fuel cell. Which side of the cell is the anode and which is the cathode in each reaction?

**Students should recognize that the anode and cathode "flip" during the different reactions because electrons flow in two different directions.**

# 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 $H_2$ and $O_2$ tanks so that bubbles can escape.
- You may need to inject more water into the $O_2$ 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: |
|---|---|---|---|
| | | | |
| | | | |
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| | | | |

# 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: |
|---|---|---|---|---|
| | | | | |
| | | | | |
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# 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.**

PBL Unit

# Energy Portfolio

# Energy Portfolio

How will you share what you've learned about electricity supplied by renewable energy? Choose from the following final products that you will prepare:

## Video presentation:

Write, direct, and star in your own short documentary. Take video while you perform experiments and record video testimonials of you and your lab group as you learn about renewable energy.

## Newspaper article:

Summarize your findings for the general public and explain renewable energy in a style that conveys the importance of further research and interest in global climate change.

## Letter to mayor or city council:

Explain to your local leaders what you've discovered in your experiments and suggest actions that you feel your community should take to combat global climate change locally.

## Research paper:

Compile all of your experiments and data into a comprehensive research paper, fit for publication in an academic journal. Compare your results to the findings of other scientists investigating similar questions around the world.

## PSA poster:

Create a visual artifact that will convince people that they should take some sort of action in their lives, based on your findings on renewable energy.

## Scientific lecture:

Build a PowerPoint or other kind of visual presentation and write an accompanying speech to showcase your findings to the rest of the scientific community.

# Energy Portfolio

See the rubric for detailed information on what your product must include. When you've chosen your product, fill in the information below:

I, ________________________________________(student name) will complete a

__________________________(product) as my final project for this unit on renewable energy.

I understand the due date for this project is no later than ____________________(deadline).

Signed:____________________________________ Date:___________________