Problem Based Learning Unit

FCJJ 40 - Horizon Energy Box

PBL Unit

Climate Change Activity

Climate Change Activity

Objective:

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

Background:

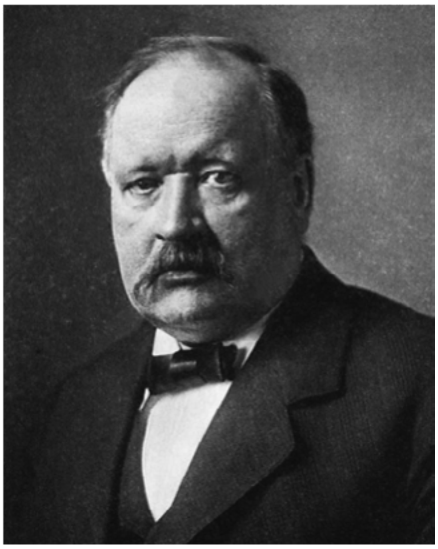
Is our planet getting warmer? Even if it is, does it matter? And how do we know that we're the ones responsible for it? It seems like everyone has an opinion about the idea of climate change, but what do we know for sure? During this activity, we'll be looking at many different sources of information to try and get at the scientific facts behind climate change.

First, what exactly do we mean by "global climate?" Global of course means we're talking about the entire planet Earth. And climate is basically the average of all the weather that happens in a particular part of the world over the course of a year.

Climate should not be confused with weather, which describes the current conditions in a single place. Weather can be different in two places just a short distance apart: it may be raining here even though it's sunny just a mile away, for example.

Since climate is concerned with the average weather over an entire year, these small differences at one moment in time don't matter as much. And since global climate is the average of climates from around the world, local observations don't count as much either. Just because it's raining for us right here doesn't mean the whole planet is getting more rain than usual, after all.

Many people view the idea of global climate change as a recent development. As early as 1896, though, there was an idea that carbon could have a key role to play in changing the Earth's climate. That was the year that a Swedish scientist named Svante Arrhenius calculated that doubling the amount of carbon dioxide in the atmosphere would increase global temperature by 5 to 6°C. At the time, the amount of carbon dioxide humans were producing was very small (most people still got around on horses) so Arrhenius thought that it would take thousands of years.



Svante Arrhenius

Arrhenius would probably be surprised at just how much carbon dioxide we've put into the atmosphere in the century since he warned about the possibilities of global climate change because of carbon dioxide. But how do we know how the Earth's atmosphere is changing? And what's causing it? We'll look at some scientific data to find out.

Climate Change Activity

Carbon and Climate:

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?

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

3. Explain in your own words the evidence presented in the article that presents CO2 as being the biggest source of warming among all of the greenhouse gases.

4. Do you think the author presents a good argument for CO2 being responsible for increased global temperatures? Explain your reasoning.

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, 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?

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?

Sources of Carbon:

How does all this carbon get into the atmosphere? To understand the movement of carbon, we need to understand where it's stored on Earth, how it moves from one place to another, and how fast those movements happen.

This diagram shows the fast carbon cycle, the movement of carbon over the course of just one year. The numbers are in billions of tons of carbon per year. You don't need to understand all the processes going on here, but look at the red numbers, which indicate human-generated changes in the carbon cycle.

1. According to the diagram, what processes that move carbon have humans changed and how?

2. According to the diagram, how much carbon is added to the atmosphere annually due to human activity?

Climate Change Activity

Effects of Fossil Fuels:

1. According to this page, what is the cause of acid rain?

2. According to this page, what are the sources of hazardous air pollutants?

Effects of Increased Atmospheric Carbon:

1. If CO2 is increasing in the atmosphere, what changes we would expect to see in global temperatures and the overall climate?

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

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				
Colony Collapse Disorder				
Extreme Storms and Hurricanes				
Increased Earthquakes				
Increased Animal and Plant Extinctions				
Expansion of Deserts				

Climate Change Activity

4. To summarize what you've learned in the last two sections, what are the effects of burning fossil fuels on the Earth's atmosphere and environment?

Action:

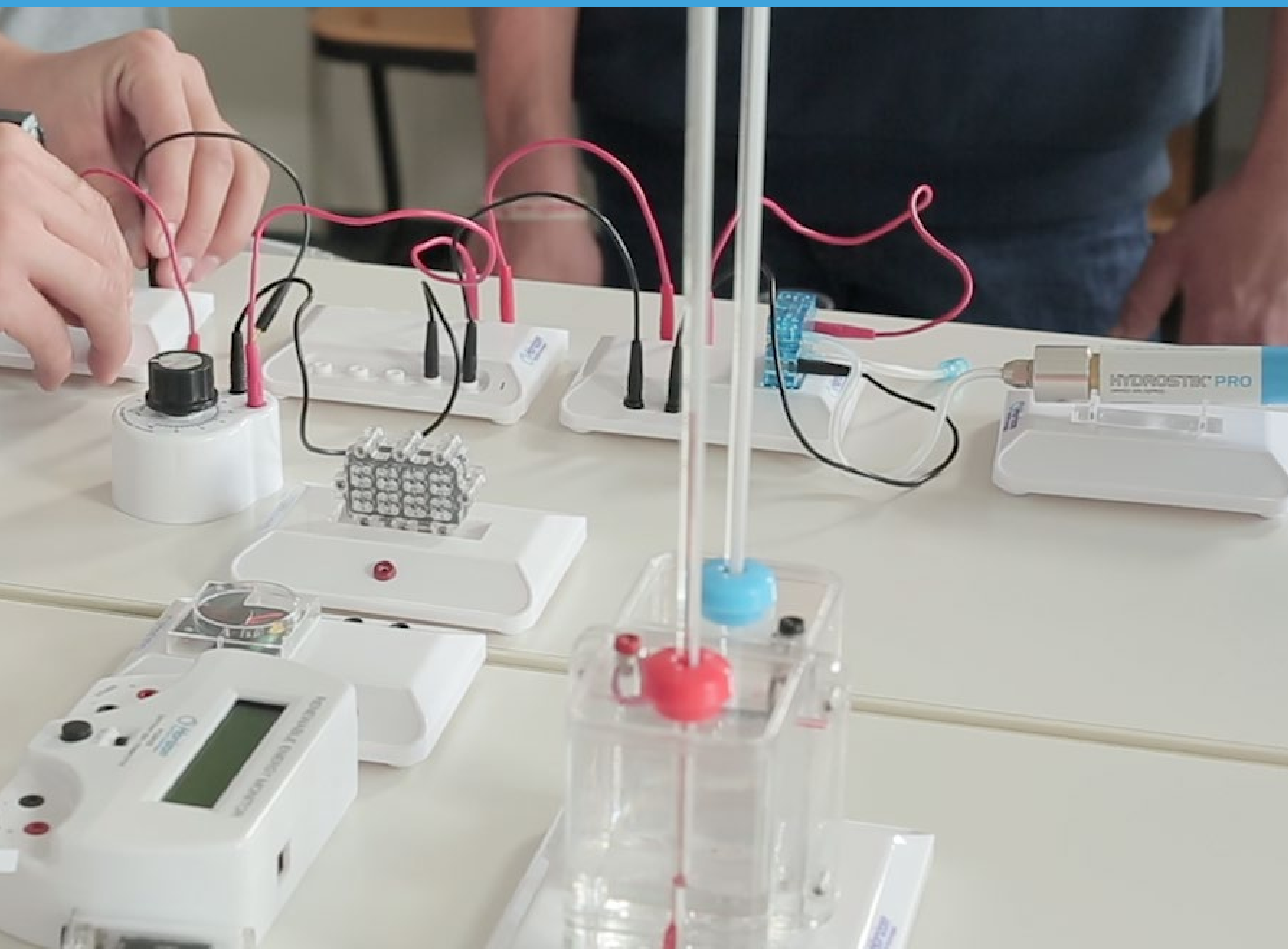
Discuss with your group and write your answers to these questions below.

1. Do you think people are doing enough to decrease our use of fossil fuels? Why or why not?

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

3. How do you think your community would change if it used more non-polluting sources of energy?

Hardware Experiments



Electricity

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:

- ☑ PS2.A: Forces and Motion
- ☑ PS3.B: Conservation of Energy and Energy Transfer

Initial Prep Time

Approx. 5 min. per apparatus

Lesson Time

Approx. 1 class period

Assembly Requirements

- None

Materials (for each lab group):

- Horizon Electric Mobility Experiment Set
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

Electricity

Lab Setup

- Your students will need the chassis, the red and black wires, the capacitor, and the hand-crank generator to build their supercapacitor cars.
- 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

- Students must attach the capacitor to the hand-crank generator correctly and only turn the crank clockwise once it's connected. We recommend close supervision the first time students attempt this part of the procedure.
- Safety goggles should be worn at all times.

Notes on the Super Capacitor Science Kit:

- The hand-crank generator is durable, but not indestructible. Try to discourage students from being too enthusiastic in their cranking to prevent breakage.
- There's not too much current from the generator, but students will usually figure out how to zap themselves and their peers by touching contacts or ends of wires. This isn't really a safety issue, but may quickly become annoying.

Common Problems

- If no electricity is flowing, check that all connections are properly wired and try again.

Electricity

Goals

- ✓ Use a generator to make an electric current
- ✓ Store electric charge in a capacitor
- ✓ Power a car with the capacitor

Background

More than any other technological advance, electricity has shaped our modern world. Nearly everything you do in an average day, from turning on a light in the morning, to driving to school or work, to listening to music or watching movies, would be impossible without electricity.

Electricity is actually nothing more than the movement of electrons, the tiny subatomic particles that orbit the nucleus of every atom at almost the speed of light. When large numbers of electrons move in one direction, we call that an electric current. But if large numbers of electrons don't move, but instead pile up in one place, we say that we've built up an electric charge.

If you've ever felt your hairs stand on end from static electricity, you've felt an electric charge building up on your skin. When you get an electric shock from touching metal or another person, that charge moves and turns into a short-lived electric current.

Electricity can move in two ways. It can proceed in a single direction around a circuit, or it can move back and forth many times a second, never moving any one electron far from its origin but transmitting electric energy over long distances.

Alternating current(AC), the movement of electrons back and forth in a circuit, is very useful for generating and transporting electricity. The current that comes out of a wall socket anywhere in the world is an alternating current. But direct current (DC), where electricity travels in one direction, is used in nearly all of our electronic devices such as computers, phones, or tablets.

A capacitor is a perfect tool for exploring electricity because it is capable of storing electric charge, which it will then gradually release as electric current. Capacitors do this by stopping electric current from passing through them. When a current is applied to a capacitor, through a generator or battery, the current is forced to build up in the capacitor instead of flowing through it, as the current would do with a lightbulb, motor, or other electrical device.

All that built-up current sits in the capacitor as electric charge, which can then be released as an electric current in the reverse direction if the capacitor is hooked up to an electric circuit.

During this activity, we will use a hand-crank generator to build up electric charge on a supercapacitor (a capacitor with the ability to hold a large amount of electric charge) and we will use that charge to run an electric car.

Procedure

1. Connect the capacitor to the hand-crank generator using the set of red and black wires.

2. Gently turn the hand-crank clockwise to generate current and charge the capacitor. Charge the capacitor for at least 60 seconds.

Electricity

3. Disconnect the hand-crank generator from the capacitor and connect the capacitor to the plugs on the front of the frame. Secure the capacitor in the middle of the frame.

4. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame and the car will start moving. Record your observations below.

Observations

Experimentation

1. How much time does the car run for each turn of the generator? Count how many times you turn the generator and then use a stopwatch to measure the amount of time the motor runs once you connect it to the supercapacitor. Record your results below:

Trial:	Turns:	Time (sec):	Observations:
1			
2			
3			
4			

According to your data, how many seconds of running time do you get per turn of the generator?

Electricity

2. Will the capacitor keep its charge when disconnected, or does it lose charge over time? After charging the capacitor for an equal number of generator turns, disconnect it and wait before hooking it up to the motor. Record what happens below:

Trial:	Idle Time (sec):	Motor Time (sec):	Observations:
1			
2			
3			
4			

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. Raise the front wheels off the ground and record the highest current in amps and highest voltage in volts produced while the capacitor is powering the motor. Record your answers below:

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

Current: ______________ A

Voltage: ____________ V

2. Voltage is equal to the current in amps multiplied by the resistance in ohms (V = IR), so according to your data what is the resistance of the motor in ohms?

Resistance: _____________ Ω

3. Capacitance (C) is measured in farads. Look closely at your capacitor and you'll find that it lists its capacitance. Record it below:

Capacitance: _____________ F

Electricity

4. Since C = q/V where q is the charge and V is the voltage, how many coulombs of charge does your capacitor hold?

Charge: _____________ C

5. One coulomb of charge is equal to approximately 6.242×1018 electrons. How many electrons are stored in your capacitor?

_______________ e-

Analysis

1. Make a scientific claim about what you observed while running your capacitor-powered car.

Claim should reference characteristics of electric current.
Example: "Electric charge slowly drains from the capacitor when it's not being used."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "We turned the generator the same amount of times for each trial. When we left the capacitor alone for 60 seconds, the car ran for 30 seconds. When we left it alone for 120 seconds, the car ran for 23 seconds. The longer we left the capacitor, the shorter the car ran."

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

Reasoning can draw from Background section and/or other materials used in class.
Example: "If it ran the car for less time, the capacitor must have contained less electrical energy."

Electricity

4. Design an experiment that could test the relationship between the size of the capacitor and the current it produces when discharging. Describe your experiment below:

Many answers are acceptable. Students should include ways to change the size of the capacitor or use different capacitors and indicate how they would measure the current produced. There should be clear control and experimental groups described.

Conclusions

1. Why did the car eventually stop moving? Construct an explanation of what you observed using what you know about electricity.

Students can use the concept of minimum voltage or the idea of finite charge moving over time to explain how the current dissipated.

2. Could a capacitor be a useful source of electricity for an electric car? Why or why not?

"Yes" or "No" are both acceptable answers as long as students can justify their responses with data.

3. Based on your observations, does the capacitor lose its charge over time?

Students should cite their data from the Experiment section to support their answer.

4. Based on your results, do you think fuel cells are a good energy source for cars?

Students may take either position on this question, provided they are able to cite information from their experiments to back up their stance.

Electric Circuits

Next Generation Science Standards

NGSS Science and Engineering Practices:

- ☐ Asking questions and defining problems
- ☐ Developing and using models
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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

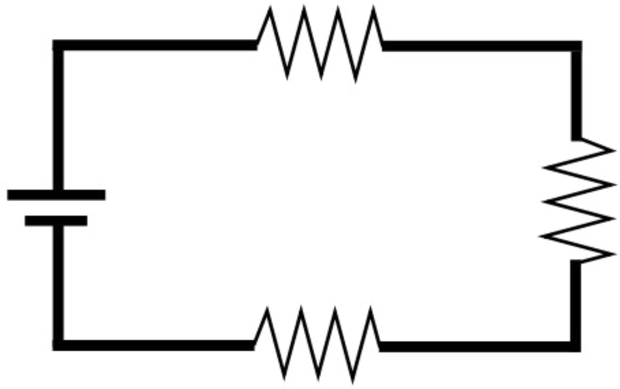

Fig. 1 Series circuit (with 3 resistors)

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)

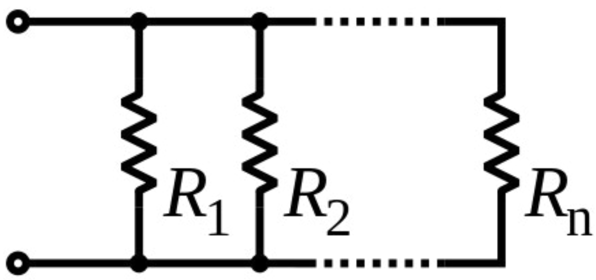

Fig. 2 Parallel circuit (of n resistors)

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.

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
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- ☐ 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.

Electrochemistry

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:

- ☑ PS2.A: Forces and Motion
- ☑ PS3.B: Conservation of Energy and Energy Transfer

Initial Prep Time

Approx. 5 min. per apparatus, plus time to heat water to 90°C.

Lesson Time

1 – 2 class periods, depending on experiments completed

Assembly Requirements

- Hot plate, or other heating apparatus

Materials (for each lab group):

- Horizon Electric Mobility Experiment Set
- Distilled water
- Table salt
- Celsius thermometer
- Various Beakers
- Balance
- Horizon Renewable Energy Monitor or multimeter (optional)

Electrochemistry

Lab Setup

- Students will need the chassis, red and black wires, the salt water battery (white bottom and blue top), and syringe to assemble the salt water battery.
- The bulk of preparation will be in making a large batch of heated water. Each lab group will need samples of about 25mL per experiment, so plan accordingly.
- Initial concentration should be 15mg salt/25mL water. Initial solution temperature should be about 90ºC (194ºF).
- If you want to perform the Concentration experiment, students will need balances to measure out grams of salt and graduated cylinders for measuring out water.
- If you're performing the Temperature experiment, you'll need multiple hot plates or other heating device with adjustable temperature, or multiple beakers and thermometers that can be left off of the heat for different lengths of time to create batches at gradually lower temperatures.
- 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

- Hot water can easily cause burns. Students should wear protective gloves or mitts when handling containers of hot water.
- Safety goggles should be worn at all times.

Notes on the Salt Water Cell:

- The fuel cell and anode should be rinsed out with distilled water between uses.
- White magnesium hydroxide may precipitate on the magnesium anodes, but it can be safely washed off.
- Store the anode and cell separately in a dry place.

Common Problems

- If all your wired connections are good and there's still no electricity, try cleaning the magnesium plate.

Electrochemistry

Goals

- Assemble and run a salt water battery
- Maximize the generated electric current
- Make calculations based on data

Background

Electrochemistry is a branch of scientific study that has been around for hundreds of years. Almost as soon as experiments with electricity were developed, it was recognized that there were chemical processes that could produce an electric current.

Now we know that electrochemistry is involved in your own brain, and that the thoughts, feelings, and memories you have would not be possible without a near-constant movement of electrically charged ions in and around the cells of your brain.

Electrochemistry is closely related to redox reactions. All electrochemical reactions involve two electrodes: an anode and a cathode. The anode is defined as the electrode where oxidation occurs and the cathode is the electrode where the reduction takes place. So the anode is negatively charged and the cathode is positive.

In our battery, the anode is made of magnesium, while the cathode is actually the air around it, so the overall reaction is:

$$2Mg + O_2 + H_2O \rightarrow Mg(OH)_2$$

Between the two electrodes is an electrolytic solution of salt water. Can we change the electrical output of the battery simply by changing the solution?

During this activity, you will use different solutions of salt in water determine the effects on the battery's electric current.

Procedure

1. Get salt water solution from your teacher and put it in the graduated cylinder. Make sure to get at least 25mL. And be careful, it's hot!
2. Using the syringe, transfer 15mL of the salt water solution into the bottom of your battery.
3. Snap the blue top of the battery onto the white bottom.
4. Attach one red wire to two red plugs on the left and right sides of the battery at the back.
5. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame.
6. Connect the loose wires from the battery to the other plugs on the front of the frame.
7. Use the stopwatch to time how long your car takes to complete the track. Repeat and record your results in the table below.
8. When you're finished with the salt water battery, rinse the top and bottom with distilled water.

Electrochemistry

Observations

Data Table

Trial	Time (sec):	Observations:
1		
2		
3		

Experimentation

1. Run your battery like you did in the Procedure section, but this time measure out different volumes of salt water to see what happens to the motor. Record your observations below.

Volume (mL):	Time (sec):	Observations:
5		
7		
10		
12		
15		
18		

2. How can you maximize the amount of electric current generated by your battery? Using the volume that worked best in the previous experiment, work with your group to think of ways that you can make the motor move faster by generating more electricity. Change the characteristics you think might have an effect and record your observations below:

Electrochemistry

Trial:	Time (sec)	Observations:
1		
2		
3		
4		
5		
6		
7		
8		

Some examples of things students could try: different concentrations of salt water, different solution temperatures, different wires, different air temperatures, different air humidity.

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. 1.Raise the front wheels off the ground and measure the current in Amps and the voltage in Volts while running the battery with different volumes of salt water. Record your answers below:

Volume (mL):	Current (A):	Voltage (V):
5		
7		
10		
12		
15		
18		

Electrochemistry

2. Voltage is equal to the current multiplied by the resistance (V = IR), so according to your data what is the resistance of the fan motor?

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

Resistance: ___________ Ω

3. Construct an explanation of what you observed as you tested salt water solutions of different volumes.

Analysis

1. Make a scientific claim about what you observed while running your battery.

Claim should reference the cell's volume or current output.
Example: "The ideal amount of salt water solution for the salt water battery is 15mL."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The biggest current we measured for 15mL of solution was 0.195 Amps. At 18 mL, it was 0.167 Amps and at 12 mL it was 0.152 Amps."

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 larger current indicates that the battery is operating more efficiently."

Electrochemistry

4. Design an experiment that would determine the effect of the size of the anode on the performance of the battery. Describe your experiment below:

Many answers are acceptable, but students should describe how they would change the size of the anode and measure the resulting current. There should be clear control and experimental groups in the description.

Conclusions

1. Based on your observations, what is the relationship between the volume of the salt water solution and the amount of electricity generated by the battery?

Students should note the direct relationship between the temperature and the current generated.

2. What other factors did you identify that affected the output of the battery?

Answers will vary based on students' choices in the Experimentation section.

3. Based on your experiments, what would be the best possible conditions for maximizing the electrical output of the battery?

Answers will vary based on students' choices in the Experimentation section.

Light

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 min. per apparatus

Lesson Time

1 – 2 class periods, depending on experiments completed

Assembly Requirements

- None

Materials (for each lab group):

- Horizon Electric Mobility Experiment Set
- Stopwatch
- Colored construction paper
- Various colored light filters
- Heat lamp and/or UV lamp (optional)
- Horizon Renewable Energy Monitor or multimeter (optional)

Light

Lab Setup

- Your students will need the car frame, red and black wires, the solar panel, and the solar panel support to assemble the solar car.
- 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.
- A heat lamp or UV lamp may be used during experiment #2, if available.
- If you don't have access to a multimeter or Horizon Renewable Energy Monitor, omit the Measurements section of this activity.

Safety

- Students should use protective gloves if changing recently-used bulbs as certain types can become quite hot.

Notes on the Solar Panel:

- 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.

Common Problems

- Check your electrical connections if the car fails to operate properly.

Light

Goals

- ✓ Use a solar panel to generate electricity from light
- ✓ Run a motor with the electricity generated
- ✓ Use the speed of the motor to measure light energy

Background

Light is a strange phenomenon. You've probably been using two highly sensitive light detectors since the day you were born, and they're helping you to read these words right now. But what we see as light is just part of a diverse type of energy that exists all over the universe and has many uses here on our own planet as well.

Light is just a small part of something known as the electromagnetic spectrum, a form of energy that travels through space as waves. You can see only part of that spectrum with your eyes, which your brain interprets as colors. Difference in wavelength (the distance between the peaks of the waves) result in different colors. The colors you can see range from red at the long end of the spectrum to violet at the short end.

But there are many more "colors" beyond those that you can't see, although you may have heard of their names. We call the colors with wavelengths too short to see "ultraviolet" and those with wavelengths too long to see "infrared." Other types of electromagnetic waves, like X-rays and gamma rays, have even shorter wavelengths than ultraviolet. Radio waves and microwaves have even longer wavelengths than infrared.

Solar power is a way of generating electricity that uses the energy contained in these waves to create an electric current. During this activity, you'll use a solar panel to generate an electric current and describe how it works.

Procedure

1. Look at the top of the car frame to see where you should attach the solar panel support. Make sure the solar panel support fits securely onto the top of the frame.
2. Place the solar panel on top of the support.
3. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame.
4. Use the other red and black wires to connect the solar panel to the other plugs on the front of the frame.
5. Make sure the car is in direct sunlight, and it should start to run.
6. Use the stopwatch to time how long it takes your car to complete the track.

Light

Observations

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 car while the panel is hit with different wavelengths of light and record your observations below:

Light Color:	Time to fill H2:	Observations:

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 car while the panel is in front of different colored backgrounds and record your observations below:

Light Color:	Time to fill H2:	Observations:

Light

3. Raise the front wheels off the ground 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.

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. Raise the front wheels off the ground. Measure the current in Amps and the voltage in Volts while shading the solar panel to find the minimum values for each that will still run 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. Voltage is equal to the current multiplied by the resistance (V = IR), so according to your data what is the resistance of the motor?

Resistance: ___________ Ω

3. Use different colors of light with your solar panel as before. Measure the current in Amps and the voltage in Volts while running the motor. What color gave the highest values? Record your answers below:

Color: _____________

Current: ____________ A

Voltage: ___________ V

Light

Analysis

1. Make a scientific claim about what you observed while running the solar car.

Claim should reference the limits of the solar cell's capabilities, in terms of wavelengths of light, amount of light, or absorption of its surrounding.
Example: "The solar panel works best with visible wavelengths of light."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The car completed the track in 15 seconds when the solar panel was under visible light. Infrared took 26 seconds and ultraviolet took 24 seconds."

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 solar panel must have been producing less current if it took longer for the car to run the same distance."

4. Design an experiment that could test the relationship between the energy of light and its wavelength.

There are many possible answers, but there should be a mention of a way to measure both the wavelength and energy of the light, and clear control and experimental groups in the experiment.

Light

Conclusions

1. Based on your observations, do you think a solar panel would be useful for generating electric energy from any type of light? Explain your reasoning.

"Yes" or "no" are both acceptable answers, so long as students are able to point to specific data from their experiments to back up their assertion.

2. What would you say is the most important factor in determining how much electric energy a solar panel produces?

Student answers should reference data collected in all experiments.

3. Based on your observations, what color of light emits the most energy?

Answers will depend on the variety of colors used.

4. Based on your observations, what color of background absorbs the most energy?

Answers will depend on the variety of colors used.

Semiconductors

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
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- ☑ 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 min. per apparatus

Lesson Time

1 – 2 class periods, depending on experiments completed

Assembly Requirements

- None

Materials (for each lab group):

- Horizon Electric Mobility Experiment Set
- Protractor
- Stopwatch
- Colored construction paper
- Various colored light filters
- Heat lamp and/or UV lamp (optional)
- Horizon Renewable Energy Monitor or multimeter (optional)

Semiconductors

Lab Setup

- Your students will need the car frame, red and black wires, the solar panel, and the solar panel support to assemble the solar car.
- 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.
- A heat lamp or UV lamp may be used during experiment #2, if available.
- If you don't have access to a multimeter or Horizon Renewable Energy Monitor, omit the Measurements section of this activity.

Safety

- Students should use protective gloves if changing recently-used bulbs as certain types can become quite hot.

Notes on the Solar Panel:

- 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.

Common Problems

- Check your electrical connections if the car fails to operate properly.

Semiconductors

Goals

- ✓ Use a solar panel to generate electricity from light
- ✓ Understand how semiconductors in the solar panel change light to electricity

Background

Metalloids are strange elements. They exhibit characteristics of both metals and nonmetals, defying categorization in either category. Silicon and germanium, the metalloids in Group 14, have become some of the most important elements to our modern world: they're the most commonly used semiconductors.

A semiconductor is a material that conducts electricity weakly due to high resistance. However, unlike metals, their resistance decreases when heated. From the first experiments with semiconductors in the 1830s by Michael Faraday, it was obvious that they behaved differently. They quickly became vital materials for radios and telephones. Since the late 20th century, they've enabled the mass production of computers and solar panels.

In a solar panel, silicon semiconductors use the photovoltaic effect to convert sunlight to electricity. Photons of light strike valence electrons in the semiconductor, causing them to travel through the material and generating an electric current that can be collected and used as a power source for all kinds of applications, from satellites and spaceships to pocket calculators.

During this activity, we will use the semiconductors in a solar panel to generate an electric current and use that current to power a small motor and determine how the semiconductors work.

Procedure

1. Look at the top of the car frame to see where you should attach the solar panel support. Make sure the solar panel support fits securely onto the top of the frame.
2. Place the solar panel on top of the support.
3. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame.
4. Use the other red and black wires to connect the solar panel to the other plugs on the front of the frame.
5. Make sure the car is in direct sunlight, and it should start to run.
6. Use the stopwatch to time how long it takes your car to complete the track.

Semiconductors

Observations

Experimentation

1. With the front wheels lifted, 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.

2. 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 motor while the panel is hit with different wavelengths of light and record your observations below:

Light Color:	Time to fill H2:	Observations:

Semiconductors

3. Raise the front wheels off the ground and use a piece of paper or other method to shade parts of the panel. Using a ruler, measure the farthest distance in from the edge of the solar panel that you can move the covering before the motor stops running.

Side:	Distance:	Observations:

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. Raise the front wheels off the ground and measure the current in Amps and the voltage in Volts while tilting the panel to get the highest values. Record your measurements 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 shading the solar panel. What is the lowest current and voltage that will still run the motor?

Current: _____________ A

Voltage: ___________ V

Semiconductors

3. Use different colors of light with your solar panel as before. Measure the current in Amps and the voltage in Volts while running the motor. What color gave the highest values? Record your answers below:

Color: ______________

Current: _____________ A

Voltage: ___________ V

Analysis

1. Make a scientific claim about silicon semiconductors based on what you observed while running the solar car.

Claim should reference physical or chemical characteristics of silicon semiconductors.
Example: "Silicon solar cells are best at conducting electrons with a visible light wavelength."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The car completed the track in 15 seconds when the solar panel was under visible light. Infrared took 26 seconds and ultraviolet took 24 seconds."

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

Reasoning can draw from Background section and/or other materials used in class.
Example: "Longer times mean the semiconductors didn't conduct electrons as well."

4. Design an experiment that could test the effects of temperature extremes on the silicon in the solar cell. Describe your experiment below:

Many answers are possible, but students should include ways of changing/measuring the temperature and monitoring the solar cell electrical output. There should be clear control and experimental groups in the description.

Semiconductors

Conclusions

1. Based on your observations, do you think a solar panel would be useful for generating electric energy from any type of light? Explain your reasoning.

“Yes” or “no” are both acceptable answers, so long as students are able to point to specific data from their experiments to back up their assertion.

2. What would you say is the most important factor in determining how much electric energy a solar panel produces?

Student answers should reference data collected in all experiments.

3. Based on your observations, what color of light is absorbed most easily by the solar panel?

Answers will depend on the variety of colors used.

Renewable Energy

Goals

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

Background

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

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

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

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

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

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

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

Renewable Energy

Fuel Cell Procedure

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

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

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

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

Observations

Fuel Cell Experimentation

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

Ideas for variables to change:

Renewable Energy

Trial:	Changed Variable:	Voltage (V):	Current (A):	Power (W):
Control	Nothing			
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

At your best configuration, what is the longest time you can get your generator to run?

Solar Procedure

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

Renewable Energy

Observations

Solar Experimentation

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

Ideas for variables to change:

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

Renewable Energy

Wind Procedure

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

Observations

Wind Data Table

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

Renewable Energy

Wind Experimentation

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

Ideas for variables to change:

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

Renewable Energy

Salt Water Battery Procedure

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

Observations

Renewable Energy

Salt Water Battery Experimentation

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

Ideas for variables to change:

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

Renewable Energy

Capacitor Procedure

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

Observations

Renewable Energy

Capacitor Experimentation

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

Ideas for variables to change:

Trial:	Changed Variable:	Voltage (V):	Current (A):	Power (W):
Control	Nothing			
1				
2				
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At your best configuration, what is the longest time you can get your generator to run?

Renewable Energy

Thermoelectric Assembly

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

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

Thermoelectric Procedure

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

Observations

Renewable Energy

Thermoelectric Experimentation

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

Ideas for variables to change:

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

Renewable Energy

Ethanol Procedure:

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

Observations:

Renewable Energy

Ethanol Experimentation:

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

Ideas for variables to change:

Trial:	Changed Variable:	Voltage (V):	Current (A):	Power (W):
Control	Nothing			
1				
2				
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At your best configuration, what is the longest time you can get your generator to run?

Renewable Energy

Data Summary:

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

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

Highest recorded voltage: __________V generated by the _________________.

Highest recorded power: ___________W generated by the ________________.

Longest running time: ____________sec generated by the _________________.

Analysis

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

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

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

Renewable Energy

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

Conclusions

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

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

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

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 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.

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.

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:

- ☑ PS2.A: Forces and Motion
- ☑ PS3.B: Conservation of Energy and Energy Transfer

Initial Prep Time

Approx. 5 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 Electric Mobility Experiment Set
- Distilled water
- AA batteries
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

Energy Conservation and Transformation

Lab Setup

- Before the lab starts, you should cut the silicon tubing and prepare the fuel cell as indicated in steps a- c of the "Hydrogen powered car" assembly instructions. This should take no more than a few minutes for each kit.
- Your students will only need the red and black wires, the fuel cell, battery pack, H2 and O2 cylinders, two lengths of tubing, and a syringe to assemble the fuel cell.
- 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 Fuel Cell Cars:

- Be sure the fuel cell and cylinders are securely attached to the car chassis before running it.
- The steering can be adjusted with the knob on the front of the chassis if the car drifts to one side or the other.

Common Problems

- If performance decreases, purge your fuel cells by opening up the tube caps to allow trapped air to escape.
- 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 energy can change
- Observe the transformation of energy
- Compare the efficiencies of processes

Background

We can't create or destroy energy, only transform it from one form to another. But why do we talk about energy being used up, wasted, or lost? When energy transforms into a form that we can't use effectively, it can be said to be wasted. Our goal then is to minimize the amount of energy that is wasted in any energy transformation by trying to get as much of the energy as possible to convert into the form we want.

Gasoline-powered cars face this problem every day. The ideal energy transformation is from the chemical potential energy within the fuel to kinetic energy of motion, which causes the car to move. However, most internal combustion engines, which release the stored energy of the fuel by burning it, have terrible efficiency, averaging around 20%.

Efficiency is just the ratio of the output (or useful) energy of a process to its input energy. Efficiency is always a dimensionless number from 0 to 1.0, and is usually written as a percentage from 0% to 100%.

Internal combustion engines, which run on gasoline, have an upper limit of around 40% efficiency. So a majority of the energy transformation of an internal combustion engine does not go into its primary use: motion. Instead, the potential energy of the gasoline is turned into sound, vibration, and a large amount of heat.

Fuel cells, in comparison, regularly achieve 60% efficiency in stacks, and have upper limits approaching 85%. With no moving parts, there's much less energy loss to heat and friction.

How well does a miniature fuel cell approach the efficiencies of its larger cousins? We will run a series of experiments to find out.

Procedure

1. Insert the cylinders into the frame of the car. Fill them with about 40 mL of distilled water.
2. Uncap the tube on the O2 side of the fuel cell.
3. Fill the syringe with distilled water and fill the fuel cell using the syringe.
4. Replace the cap on the O2 tube.
5. Insert the fuel cell into the frame of the car in front of the cylinders. Attach the H2 and O2 sides of the fuel cell to the H2 and O2 cylinders with the longer tubes, which will prevent the hydrogen and oxygen gases from escaping.
6. Connect the battery pack to the fuel cell using the red and black plugs, then turn on the battery pack. You should see the fuel cell start to generate hydrogen and oxygen gas.
7. Once you see bubbles start to escape the H2 cylinder, turn off and disconnect the battery pack.
8. Connect the red and black wires to the car chassis to start the car.

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 motor begins to run and can make note of any particular aspect of the car's performance: sound of the motor, whether it goes in a straight line or not, how long it runs, etc.

2. What could you change about your car that might make the car run faster? Design an experiment to try to make the car run faster. Describe it and record your results below.

Using less water in the cylinders to decrease weight, running the car on a different surface, decreasing friction, and others may be acceptable answers.

3. What if you wanted to make your car run for a longer time? How would you alter your car to achieve that? Design an experiment you could run and describe it below.

Answers may differ from the previous question, but some may be similar. However, it should be noted that to make the car run longer it could also have bigger fuel tanks, generate more hydrogen, or be picked up so that the wheels spin freely.

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. Lift the front wheels to keep the car in one place and measure the current in Amps and the voltage in Volts while the car is running. Record your answers below:

Current: ____________ A

Voltage: __________ V

4. P = I • V, where P is power, I is current, and V is voltage. Calculate the power required to split water and the power to run the car and record your answers below:

Power (generating): ____________ W

Power (running): ____________ W

5. How do you explain the results you just calculated in terms of the efficiency of the fuel cell?

Energy Conservation and Transformation

Analysis

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

Claim should reference energy use, transformation, and/or conservation in the running car.
Example: "The most effective way to increase the car's running time is to reduce friction."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The car ran for 18 seconds unmodified. Reducing weight made it run for 2 seconds more. Running it on a smoother surface made it run for 8 seconds more."

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 read about reducing friction as a way to increase efficiency."

4. Use your observations to design an experiment you could run to try to increase the energy efficiency of the fuel cell. Describe your experiment below.

Change pressure/temperature of the water/gases, construct it with different materials, decrease the weight of the car, reduce friction, 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. Would it ever be possible to use 100% of the electric energy produced by the fuel cell to move the car? Why or why not?

Answers should cite the Law of Conservation of Energy and mention the ways in which energy is converted that do not result in kinetic energy.

2. Do you think your fuel cell achieved the levels of efficiency of the fuel cell stacks described in the Background section? Why or why not?

Comparing the energy required to split the water with the energy produced by recombining it yields much less than the efficiencies described in the Background. The reasons are that the fuel cell is much smaller and not a stack as described. Students may also cite their calculations to back up their assertion.

3. Why is it important for machines to have high efficiency?

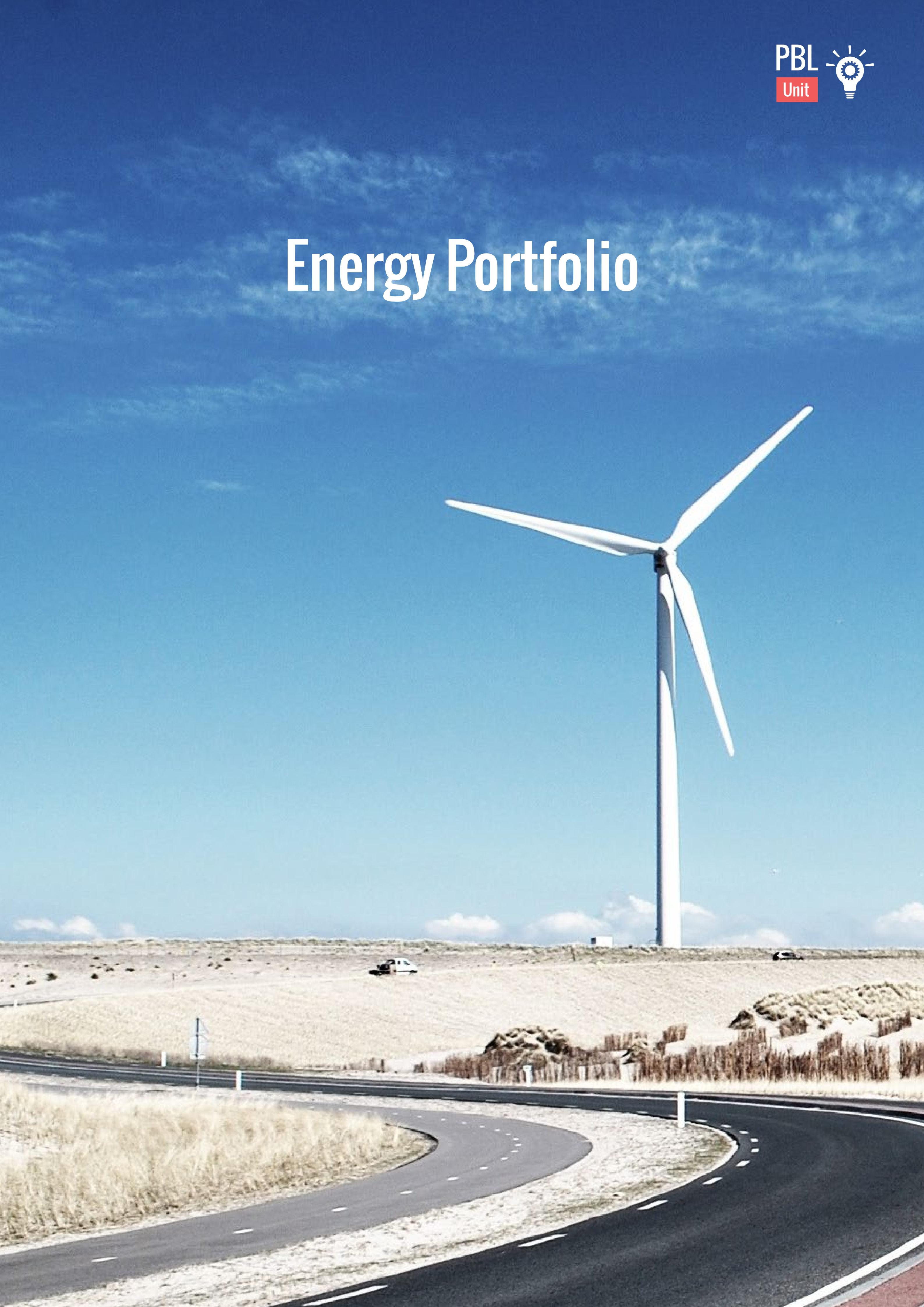
Wasted energy means that more materials, fuels, and resources are needed to achieve the desired result. At the very least, this means it costs more. At worst, this also contributes to the eventual heat death of the universe.

4. Based on your results, do you think fuel cells are a good energy source for cars?

Students may take either position on this question, provided they are able to cite information from their experiments to back up their stance.

PBL Unit

Energy Portfolio



Energy Portfolio

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.

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:___________________