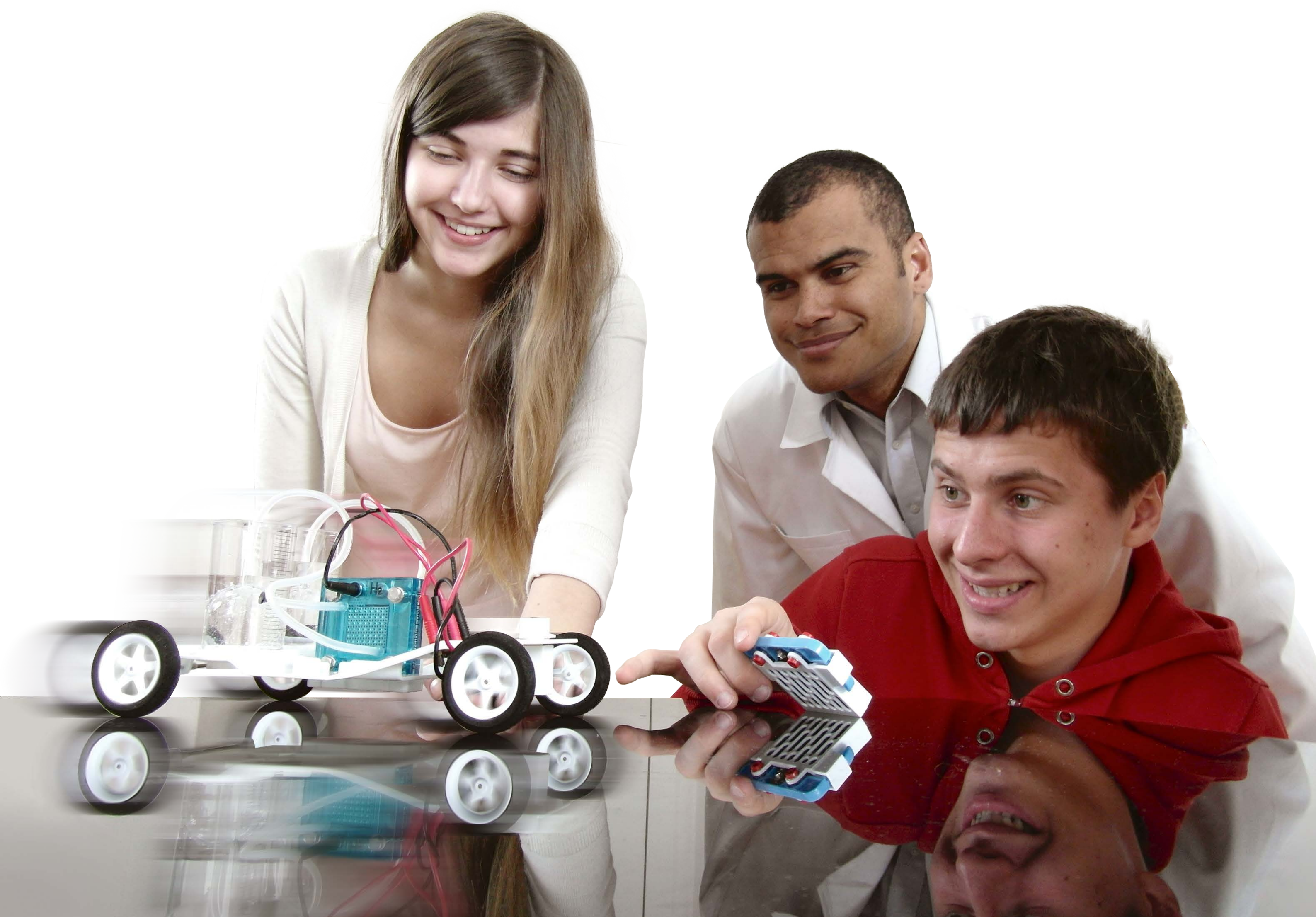
Problem Based Learning Unit

FCJJ-31 Multi Energy Car Science Kit



Horizon Educational

HORIZON ENERGY CURRICULUM

PBL Unit

Climate Change Activity

Objective:

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

Time required:

60 minutes

Materials required:

Laptops or tablets with internet connectivity

Overview:

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

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

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

Goals for Student Understanding:

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

Notes on This Activity:

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

Answer Key:

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

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

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

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

Answers will vary. Sample response:

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

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

Answers will vary. Sample response:

The article showed the data on what spectrum of radiation was absorbed and CO2 had the biggest peak on the graph by a long way. It also mentions that CO2 has been increasing in the atmosphere as the Earth's temperature has been rising.

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

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

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?

~400 ppm, happening right now.

2. If you look at the longest timescale and ignore the most modern data (the red and bright blue dots), what would the highest concentration of CO2 over the last 400,000 years be?

~300 ppm

Effects of Global Climate Change:

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

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

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

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

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

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

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

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

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

See above

Action:

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

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

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

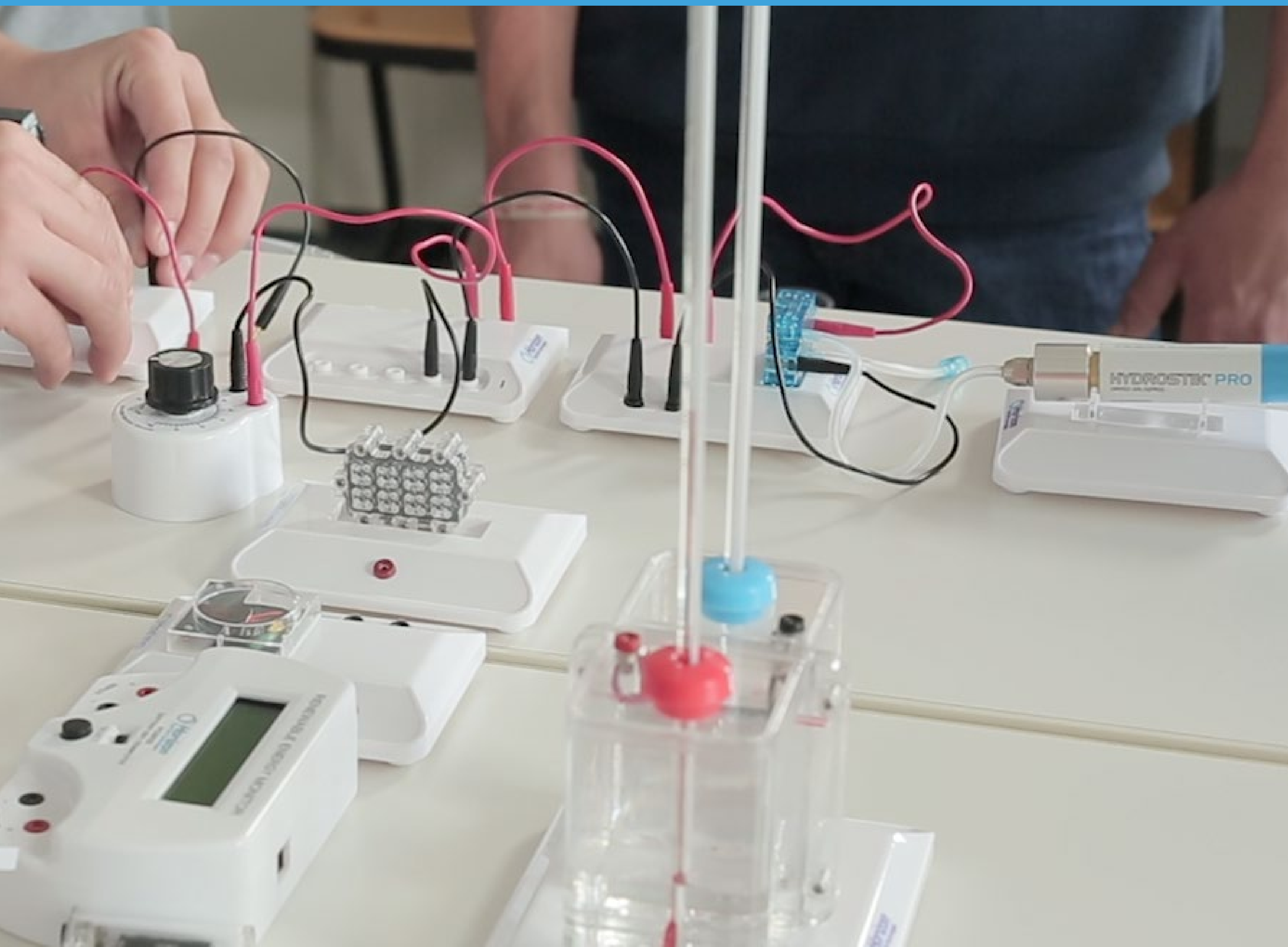
2. If you could encourage people to do one thing to combat global climate change, what would it be?

See above

3. What would travel and transportation look like in a world where non-polluting sources of fuel were used?

See above

Hardware Experiments



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.

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.

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.

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
- Make calculations based on data

Background

Energy is what allows all objects in the universe to move. The energy of atoms or molecules and the energy of stars or galaxies is all the same, just at different sizes. Though we talk about energy being consumed, lost, or used up, it can never be destroyed. It can also never be created. The only thing that energy can do is transform from one kind to another.

Using this fuel cell car, we can use the chemical potential energy of hydrogen to create electrical energy, which will be turned into kinetic energy to cause the car to move. But there are other ways that energy is transformed, even in this small car, which mean that not all the energy in each transformation remains in a useable form.

Thermal energy is an example of a type of energy that isn't always useful. Though we can use it for some applications, such as cooking food, the transformation of different kinds of energy into heat energy is usually a bad thing for most machines. In the case of a car, more heat energy means less kinetic energy, so a smaller percentage of the energy put into the car is used to actually run it.

Fuel cells are much more energy efficient than the internal combustion gasoline engines that power most cars today, but they still have their sources of inefficiency.

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? Try it and observe what happens.

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? Would you change the same thing or something different? Try it and observe what happens.

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. Why is there a difference between the current/voltage when producing hydrogen and the current/voltage when the car is running? Where has the energy gone?

Not all the energy has gone into the hydrogen during the electrolysis process, and not all the energy has gone into the car's motion while it's driving. Heat, friction, sound, and other sources of energy loss could be mentioned.

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: "A smoother surface allows the car to run for a longer time."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "On the tile floor, our car ran for 26 seconds. On the carpet, our car only ran for 14 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: "A smoother surface would reduce friction, a force that we learned opposes motion."

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. What kinds of energy did you observe while running your experiments with the fuel cell car?

Kinetic, Chemical, Potential, Sound, Electrical, and others may be acceptable answers.

2. Describe the ways that energy changed from one form to another during this activity.

Chemical energy in the battery became electrical energy in the wires, which became chemical energy in the hydrogen, which became electrical energy in the wires, which became kinetic energy in the motor, and others may be acceptable answers.

3. Describe three ways that energy was transformed that didn't help your car move faster or farther.

Motor made noise, friction of wheels on ground, friction of motor with axle/wheels, vibrations of motor, and others may be acceptable answers.

4. 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?

No, because that would only be possible in frictionless environment, violating law of conservation of energy.

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.

Renewable Energy Endurance Marathon

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. 10 min. per apparatus

Lesson Time

1 – 2 class periods, depending on number of types of car used

Assembly Requirements

- Small Phillips-head screwdriver
- Scissors
- Distilled water
- Salt
- Hot plate or other heating element

Materials (for each lab group):

- Horizon Electric Mobility Experiment Set
- Beaker or other container for holding salt water solution
- Stopwatch
- Meter stick

Renewable Energy Endurance Marathon

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.
- The lab involves students building cars powered by different energy sources and seeing how fast each of them can travel 5 meters. Feel free to alter the distance, types and number of cars they build, or even have different groups make different cars as needed.
- If building the salt water battery car, you’ll need a mixture of salt water (15mg salt per 25mL distilled H2O), heated to above 90°C (194°F). Each group will need 25mL of solution per activity.
- 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.

Safety

- Keep the fuel cells hydrated at all times. If the fuel cells dry out, they can become permanently damaged.
- Do not turn the hand crank generator counter-clockwise while connected to the supercapacitor: this can irreparably damage the supercapacitor.
- Safety goggles should be worn at all times.

Notes on the Electric Mobility Experiment Set:

- After use, be sure to clean out the salt water battery with distilled water. Dry before storing.
- Solar cell may not provide enough power for the car without direct sunlight.
- The hand-crank generator is sturdy, but not indestructible. Two revolutions per second is enough to charge the supercapacitor; more than that is just running the risk of breaking the generator.

Common Problems

- If your hydrogen fuel cell car stops moving while hydrogen is left in the tank, you may need to purge the gases by uncapping the tubes, then perform electrolysis for a few minutes to generate more hydrogen.
- If the salt water battery stops powering the car, the anode plate may need to be cleaned.

Renewable Energy Endurance Marathon

Goals

- Assemble multiple cars powered by renewable energy
- Alter the cars to increase their range
- Compare the pros and cons of different technologies

Background

One of the biggest challenges to building a car powered by renewable energy is the issue of range. People have always had to refuel their cars to keep them moving, but it's something that no one wants to have to do every day or every couple of hours on a long trip, so cars need to have the ability to travel for hundreds of miles at a time.

Also, no one wants to buy a car that takes forever to refuel. Electric cars especially have suffered from this drawback: it takes more than half an hour to fully charge their batteries on a high-speed charging system, and many hours to do so on a regular household electric current.

There are many different options for powering cars with renewable energy, but range will always be a factor in most people's decision on whether or not to buy a particular car. So whatever the fuel of the future might be, cars that run on it will have to be able to run for a long time.

Here are some examples of technologies that could be used to power cars and how they work:

- Solar panels – Change light to electricity to power an electric motor.
- Supercapacitors – Store electricity in a capacitor to power an electric motor.
- Fuel cells – Use hydrogen, split from oxygen in water, to generate an electric current and power a motor.
- Batteries – Store electricity chemically and use it to power an electric motor.
- Metal hydrides – Store hydrogen chemically and use it in a fuel cell to power an electric motor.

You may notice that many of these technologies seem very similar. At some point, they all have to turn a motor in order to get the car to move. However, the way in which they get the energy to do so is very different, and can result in a big difference in the amount of time that they can run.

During this activity, we will build cars powered by different technologies, modify them to try to increase their range, and determine which type of car can keep running for the longest time.

Note: For each trial, have one member of your group stand at either end of the race track. Release the car from one end and have the person at the other end pick up the car and turn it around once it reaches them. Continue to do this until the car stops running and record your time and distance.

Solar Car Procedure

1. You'll need the car frame, red and black wires, the solar panel, and the solar panel support to assemble the solar car.
2. 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.

Renewable Energy Endurance Marathon

3. Place the solar panel on top of the support.
4. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame.
5. Use the other red and black wires to connect the solar panel to the other plugs on the front of the frame.
6. Make sure the car is in direct sunlight, and it should start to run.
7. Use the stopwatch to time how long your car travels. Calculate distance by counting laps and multiplying by 5, then add on however many more meters your car traveled on its final lap. Repeat and record your results in the table below.

Trial	Time (sec):	Laps:	Distance (m):	Observations:
1				
2				
3				

Fuel Cell Procedure

1. You'll need 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.
2. Insert the cylinders into the frame of the car. Fill them with about 40 mL of distilled water.
3. Uncap the tube on the O2 side of the fuel cell.
4. Fill the syringe with distilled water and fill the fuel cell using the syringe.
5. Replace the cap on the O2 tube.
6. 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.
7. 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.
8. Once you see bubbles start to escape the H2 cylinder, turn off and disconnect the battery pack.
9. Connect the loose red and black wires to the fan or LEDs to start generating electricity.
10. Use the stopwatch to time how long your car travels. Calculate distance by counting laps and multiplying by 5, then add on however many more meters your car traveled on its final lap. Repeat and record your results in the table below.

Renewable Energy Endurance Marathon

Trial	Time (sec):	Observations:
1		
2		
3		

Salt Water Battery Procedure

1. You'll need red and black wires, the salt water battery (white bottom and blue top), syringe, and a graduated cylinder to assemble the salt water battery.

2. 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!

3. Using the syringe, transfer 15mL of the salt water solution into the bottom of your battery.

4. Snap the blue top of the battery onto the white bottom.

5. Attach one red wire to two red plugs on the left and right sides of the battery at the back.

6. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame.

7. Connect the loose wires from the battery to the other plugs on the front of the frame.

8. Use the stopwatch to time how long your car travels. Calculate distance by counting laps and multiplying by 5, then add on however many more meters your car traveled on its final lap. Repeat and record your results in the table below.

9. When you're finished with the salt water battery, rinse the top and bottom with distilled water.

Trial	Time (sec):	Observations:
1		
2		
3		

Supercapacitor Procedure

1. You'll need red and black wires, the capacitor, and the hand-crank generator to use the supercapacitor.
2. Connect the capacitor to the hand-crank generator using the set of red and black wires.
3. Gently turn the hand-crank clockwise to generate current and charge the capacitor. Charge the capacitor for at least 60 seconds.
4. Disconnect the hand-crank generator from the capacitor and connect the capacitor to the plugs on the

Renewable Energy Endurance Marathon

front of the frame. Secure the capacitor in the middle of the frame.

5. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame.
6. Use the stopwatch to time how long your car travels. Calculate distance by counting laps and multiplying by 5, then add on however many more meters your car traveled on its final lap. Repeat and record your results in the table below.

Trial	Time (sec):	Observations:
1		
2		
3		

Renewable Energy Endurance Marathon

Experimentation

1. Choose two or three technologies that traveled the farthest. Discuss with your group ways you could improve the car to make each of them go even farther. Write down your best ideas here:

Light Color:	Observations:
	1. 2. 3.
	1. 2. 3.
	1. 2. 3.

2. Now build your car using each technology and try the ideas you thought of to see what happens to the car's speed. Record what you changed, how you changed it, and the results below:

Technology:	Changed What?:	Changed How?:	Time (sec):	Distance (m):

Renewable Energy Endurance Marathon

Analysis

1. Make a scientific claim about what you observed while racing your cars.

Claim should reference the car's performance and its source of power.
Example: "The salt water battery provides the best range for the car."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "Our longest time for running the car was 18 minutes 35 seconds, when we changed the concentration of salt in the salt water battery during our experiments."

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

Reasoning can draw from Background section and/or other materials used in class.
Example: "When the car is running for a longer time, it has a farther range."

4. Design an experiment that would test whether the surface the car runs on affects its range. Describe your experiment below:

There are many possible answers, but students should describe what they would change about the surface, explain how they think it could change the car's range, and have clear control and experimental groups in their description.

Renewable Energy Endurance Marathon

Conclusions

1. What would be the biggest drawback to using the technology that ran for the longest time in a full-sized car? What makes this problem the biggest drawback?

There are numerous possible acceptable answers depending on the technology chosen: size, slow speeds, lack of resources, and more. Regardless of what they choose, students should be able to explain why the drawback they chose is such a major issue.

2. What is a possible way that you could overcome this drawback?

Again, there are many acceptable answers, which will depend upon the technology chosen and the particular drawback described above. Students should be able to weigh the possibilities of overcoming it and suggest a plausible solution, though it need not be one known to work in real life.

3. Do you think the technology that ran for the longest time would be the most practical solution for a renewable energy source to power a full-sized car? Why or why not?

Students could answer "Yes" or "No" so long as they can back up their response with data from their experiments or information they know about the way that this technology and/or the other technologies they experimented with would work on a full-sized car.

4. Could a combination of these technologies perform with even better range? Describe a possible combination below that you think might work.

Any combination is acceptable as long as students are able to describe what aspects of that combination make it likely to perform better than either tech on its own.

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
- ☑ 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
- 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.

Solution Concentrations

Next Generation Science Standards

NGSS Science and Engineering Practices:

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

NGSS Cross-cutting Concepts:

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

NGSS Disciplinary Core Ideas:

- ☑ PS1.A: Structure and Properties of Matter
- ☑ PS3.A: Definitions of Energy

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)

Solution Concentrations

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.

Solution Concentrations

Goals

- Create solutions of different concentrations
- Use solutions to run a salt water battery
- Make calculations based on solution data

Background

Combining two substances doesn't have to result in a chemical reaction. It's possible to mix substances and have them form a mixture instead of a compound. Mixtures are classified based on how the substances interact when mixed together.

Heterogeneous mixtures still have different parts visible (like if you shake up oil and vinegar salad dressing) while homogeneous mixtures appear to be the same throughout (like air, which is a mixture of nitrogen, oxygen, carbon dioxide, and trace gases).

Solutions are a special type of homogeneous mixture where the particles of the substance being dissolved are so small that they can't be separated from the mixture by straining or centrifuging. Salt in water is a perfect example: once the salt has dissolved in the water, it can't be removed unless the water is evaporated.

Dissolved salt splits into sodium ($Na+$) and chloride ($Cl-$) ions. The presence of these ions in the water makes it easier for an electric current to flow. This allows us to generate electricity by pumping electrons from the magnesium anode to the cathode (which is actually the air) through the wires, just like a battery. If you don't remember what anodes and cathodes are, read more about electrodes in Introduction to Batteries.

The concentration of a solution can be expressed as a percentage ratio (mass of solute/volume of solvent) or as a molar ratio such as molarity (moles of solute/volume of solvent) or molality (moles of solute/mass of solvent).

During this activity, you will use a solution of salt in water to run a battery and generate an 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.

Solution Concentrations

Observations

Data Table

Trial	Time (sec):	Observations:
1		
2		
3		

Experimentation

1. Prepare solutions of salt water according to the following concentrations. Record how much salt you used in each concentration below:

Concentration:	g NaCL:	mL H2O:
4%	1	25mL
8%	2	25mL
12%	3	25mL
16%	4	25mL
20%	5	25mL

Solution Concentrations

2. Using the different concentrations of salt water solution, use the battery to power the motor as in the Procedure section. Observe what happens each time and record your results below. Be sure to rinse out the salt water from the battery after each trial.

Concentration:	Time (sec):	Observations:
4%		
8%		
12%		
16%		
20%		

3. Using salt water of different temperature, run the battery like you did in the Procedure section, using the same concentration each time. Write your observations below.

Temperature (°C):	Time (sec):	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 running the battery at different concentrations of salt. Record your answers below:

Solution Concentrations

Concentration:	Current (A):	Voltage (V):
4%		
8%		
12%		
16%		
20%		

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. Measure the current in Amps and the voltage in Volts while running the battery with different temperatures of salt water. Record your answers below:

Temperature (°C):	Time (sec):	Observations:

4. Construct an explanation of what you observed as you tested salt water solutions of different temperatures.

Solution Concentrations

Analysis

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

Claim should reference the data from the concentration or temperature experiment.
Example: "The best concentration of the salt water solution is between 16 and 20%."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The current we measured for 20% was 0.195 Amps, while the current at 16% was 0.196 Amps and the current at 12% was 0.174 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: "The highest current output must occur when the battery is running most efficiently."

4. Design an experiment that would determine the volume of salt water solution that would produce the most electric current. Describe your experiment below:

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

Solution Concentrations

Conclusions

1. Express the concentrations of salt water solution you measured as molar and molal solutions:

Concentration:	Molarity (mol/L):	Molality (mol/kg):
4%		
8%		
12%		
16%		
20%		

Since 1L H2O has a mass of 1kg, molarity and molality should be the same.

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

Students should note that there is a point at which added salt does nothing to affect the generation of electricity and speculate as to why that might be.

3. Based on your observations, what is the relationship between the temperature 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.

Renewable Energy Sprint

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. 10 min. per apparatus

Lesson Time

1 – 2 class periods, depending on number of types of car used

Assembly Requirements

- Small Phillips-head screwdriver
- Scissors
- Distilled water
- Salt
- Hot plate or other heating element

Materials (for each lab group):

- Horizon Electric Mobility Experiment Set
- Beaker or other container for holding salt water solution
- Stopwatch

Renewable Energy Sprint

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.
- The lab involves students building cars powered by different energy sources and seeing how fast each of them can travel 5 meters. Feel free to alter the distance, types and number of cars they build, or even have different groups make different cars as needed.
- If building the salt water battery car, you'll need a mixture of salt water (15mg salt per 25mL distilled H2O), heated to above 90°C (194°F). Each group will need 25mL of solution per activity.
- The Hydrostik car requires the use of the Hydrofill Pro (sold separately). If you're building the Hydrostik car, assemble the mini fuel cell as described in step c of the "Fuel cell and hydrogen storage" assembly instructions.
- 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.

Safety

- Keep the fuel cells hydrated at all times. If the fuel cells dry out, they can become permanently damaged.
- Do not turn the hand crank generator counter-clockwise while connected to the supercapacitor: this can irreparably damage the supercapacitor.
- Safety goggles should be worn at all times.

Notes on the Electric Mobility Experiment Set:

- After use, be sure to clean out the salt water battery with distilled water. Dry before storing.
- Solar cell may not provide enough power for the car without direct sunlight.
- The hand-crank generator is sturdy, but not indestructible. Two revolutions per second is enough to charge the supercapacitor; more than that is just running the risk of breaking the generator.

Common Problems

- If your hydrogen fuel cell car stops moving while hydrogen is left in the tank, you may need to purge the gases by uncapping the tubes, then perform electrolysis for a few minutes to generate more hydrogen.
- If the salt water battery stops powering the car, the anode plate may need to be cleaned.

Renewable Energy Sprint

Goals

- Assemble multiple cars powered by renewable energy
- Alter the cars to increase their speed
- Compare the pros and cons of different technologies

Background

What makes a car move? Most cars today are powered by gasoline, but that wasn't always the case. Early cars were powered by kerosene, ethanol, electricity, even steam. In fact, until the electric starter motor became common in 1920, steam cars outsold gasoline cars!

Without a starter, gasoline cars had to be hand-cranked to start, which occasionally caused backfires that suddenly swung the crank backwards, often resulting in a broken arm for the poor person operating it. It's easy to see why steam was more popular!

Steam engine in a 1924 Stanley Steamer

Today, there probably aren't many people who'd favor a return to steam-powered cars. However, there are many other power sources that are receiving attention as the world looks for alternatives to traditional gasoline power in the face of global climate change.

Different technologies have advantages and disadvantages. Some of them (like the possibility of breaking your arm with a hand crank) can be solved with new inventions, while others (like the carbon dioxide in engine exhaust) are too closely tied to how the technology works to be eliminated.

Here are some examples of technologies that could be used to power cars and how they work:

- Solar panels – Change light to electricity to power an electric motor.
- Supercapacitors – Store electricity in a capacitor to power an electric motor.
- Fuel cells – Use hydrogen, split from oxygen in water, to generate an electric current and power a motor.
- Batteries – Store electricity chemically and use it to power an electric motor.
- Metal hydrides – Store hydrogen chemically and use it in a fuel cell to power an electric motor.

You may notice that many of these technologies seem very similar. At some point, they all have to turn a motor in order to get the car to move. But how they get the energy to do that is very different, and that will affect how the car performs when powered by each of them. Whatever technology they run on, we want cars to do many different things: they should accelerate quickly, operate reliably, and be able to be refueled easily. Today we will test just one aspect of the job that a car is supposed to do: provide energy quickly.

During this activity, we will build cars powered by different technologies, modify them to try to increase their power output, and determine which type of car can complete a 5-meter drag race in the fastest time.

Renewable Energy Sprint

Solar Car Procedure

1. You'll need the car frame, red and black wires, the solar panel, and the solar panel support to assemble the solar car.
2. 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.
3. Place the solar panel on top of the support.
4. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame.
5. Use the other red and black wires to connect the solar panel to the other plugs on the front of the frame.
6. Make sure the car is in direct sunlight, and it should start to run.
7. Use the stopwatch to time how long it takes for your car to go 5 meters. Repeat and record your results in the table below.

Trial	Time (sec):	Laps:	Distance (m):	Observations:
1				
2				
3				

Fuel Cell Procedure

1. You'll need 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.
2. Insert the cylinders into the frame of the car. Fill them with about 40 mL of distilled water.
3. Uncap the tube on the O2 side of the fuel cell.
4. Fill the syringe with distilled water and fill the fuel cell using the syringe.
5. Replace the cap on the O2 tube.
6. 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.
7. 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.
8. Once you see bubbles start to escape the H2 cylinder, turn off and disconnect the battery pack.
9. Connect the loose red and black wires to the fan or LEDs to start generating electricity.

Renewable Energy Sprint

10. Use the stopwatch to time how long the fuel cell car takes to complete the race. Record your results below.

Trial	Time (sec):	Observations:
1		
2		
3		

Salt Water Battery Procedure

1. You'll need red and black wires, the salt water battery (white bottom and blue top), syringe, and a graduated cylinder to assemble the salt water battery.

2. 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!

3. Using the syringe, transfer 15mL of the salt water solution into the bottom of your battery.

4. Snap the blue top of the battery onto the white bottom.

5. Attach one red wire to two red plugs on the left and right sides of the battery at the back.

6. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame.

7. Connect the loose wires from the battery to the other plugs on the front of the frame.

8. Use a stopwatch to time how fast the battery can make the car complete the race. Record your results below.

9. When you're finished with the salt water battery, rinse the top and bottom with distilled water.

Trial	Time (sec):	Observations:
1		
2		
3		

Supercapacitor Procedure

1. You'll need red and black wires, the capacitor, and the hand-crank generator to use the supercapacitor.
2. Connect the capacitor to the hand-crank generator using the set of red and black wires.
3. Gently turn the hand-crank clockwise to generate current and charge the capacitor. Charge the capacitor for at least 60 seconds.

Renewable Energy Sprint

4. 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.
5. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame.
6. Use a stopwatch to time how fast the capacitor can make the car complete the race. Record your results below.

Trial	Time (sec):	Observations:
1		
2		
3		

Metal Hydride Procedure

1. You'll need red and black wires, the mini fuel cell, purge valve, silicon tubing, clamp, hydrostik, and the pressure regulator to assemble the hydrostik generator.
2. Push the silicon tubing through the clamp until the clamp is about halfway along the tubing.
3. Attach one end of the tube to the pressure regulator by unscrewing the cap, threading the tubing through the cap, pushing the tubing onto the regulator, and screwing the cap back on.
4. Screw in the pressure regulator to the top of the hydrostik.
5. Attach the other end of the tube to the nozzle of the mini fuel cell.
6. Place the fuel cell in the frame of the car with the nozzles facing forward.
7. Use the loose red and black wires to connect the red and black plugs on the fuel cell to the other red and black plugs on the front of the frame.
8. Open the clamp and press the purge valve for two seconds on the fuel cell. This will allow hydrogen to enter the fuel cell and cause the car to start running.
9. Use a stopwatch to time how fast the fuel cell can make the car complete the race. Record your results below.
10. When the hydrostik is empty, use the Hydrofill Pro to refill it.

Trial	Time (sec):	Observations:
1		
2		
3		

Renewable Energy Sprint

Experimentation

1. Choose two or three technologies that were the fastest to complete the track. Discuss with your group ways you could improve the car to make each of them go faster. Write down your best ideas here:

Light Color:	Observations:
	1. 2. 3.
	1. 2. 3.
	1. 2. 3.

2. Now build your car using each technology and try the ideas you thought of to see what happens to the car's speed. Record what you changed, how you changed it, and the results below:

Technology:	Changed What?:	Changed How?:	Time (sec):	Distance (m):

Renewable Energy Sprint

Analysis

1. Make a scientific claim about what you observed while racing your cars.

Claim should reference the car's performance and its source of power.
Example: "The supercapacitor provided the most electrical energy to the car."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "Our fastest time for completing the track was 8.6 seconds, when we charged the capacitor for twice as long during our experiments."

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

Reasoning can draw from Background section and/or other materials used in class.
Example: "When the car is moving faster, it must have more energy than when it was moving slower."

4. Design an experiment that would test how a particular technology you used today could be improved to increase the amount of energy it produced. Describe your experiment below:

There are many possible answers, but students should describe the particular characteristic of the technology they want to change, explain how they think it could improve the amount of energy produced, and have clear control and experimental groups in their description.

Renewable Energy Sprint

Conclusions

1. What would be the biggest drawback to using the technology that completed the race the fastest in a full-sized car? What makes this problem the biggest drawback?

There are numerous possible acceptable answers depending on the technology chosen: availability of fuel, recharging time, weight, cloudy days, and more. Regardless of what they choose, students should be able to explain why the drawback they chose is such a major issue.

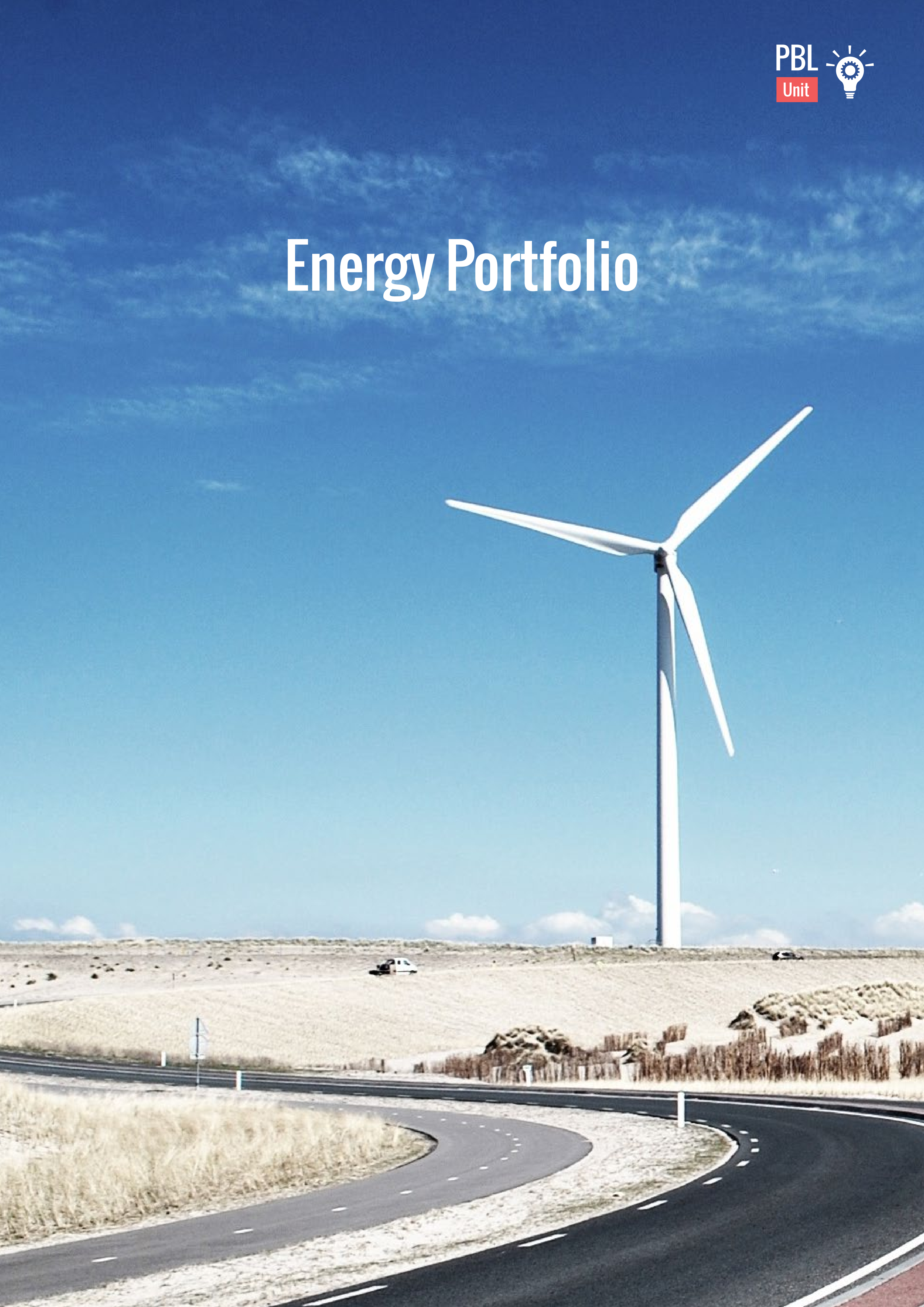
2. What is a possible way that you could overcome this drawback?

Again, there are many acceptable answers, which will depend upon the technology chosen and the particular drawback described above. Students should be able to weigh the possibilities of overcoming it and suggest a plausible solution, though it need not be one known to work in real life.

3. Do you think the technology that ran the race the fastest would be the most practical solution for a renewable energy source to power a full-sized car? Why or why not?

Students could answer “Yes” or “No” so long as they can back up their response with data from their experiments or information they know about the way that this technology and/or the other technologies they experimented with would work on a full-sized car.

Energy Portfolio



Energy Portfolio

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

Video presentation:

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

Newspaper article:

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

Letter to mayor or city council:

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

Research paper:

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

PSA poster:

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

Scientific lecture:

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

Energy Portfolio

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

I, ____(student name) will complete a

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

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

Signed:____________________________________ Date:___________________