Problem Based Learning Unit

FCJJ 37 - Renewable Energy Science Kit

Horizon Educational

HORIZON ENERGY CURRICULUM

Climate Change Activity

Climate Change Activity

Objective:

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

Background:

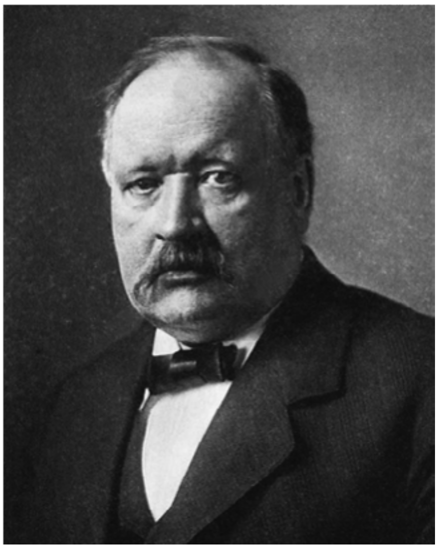
Is our planet getting warmer? Even if it is, does it matter? And how do we know that we're the ones responsible for it? It seems like everyone has an opinion about the idea of climate change, but what do we know for sure? During this activity, we'll be looking at many different sources of information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

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

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

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

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



Svante Arrhenius

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

Climate Change Activity

Carbon and Climate:

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

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

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

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

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

Climate Change Activity

Carbon Over Time:

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

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

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

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?

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

3. Many changes in the world have been blamed on changes in the climate. Use internet searches to estimate what the chances are that the following occurrences are caused by climate change and indicate your results in the table:

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

Climate Change Activity

4. 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?

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?

Action:

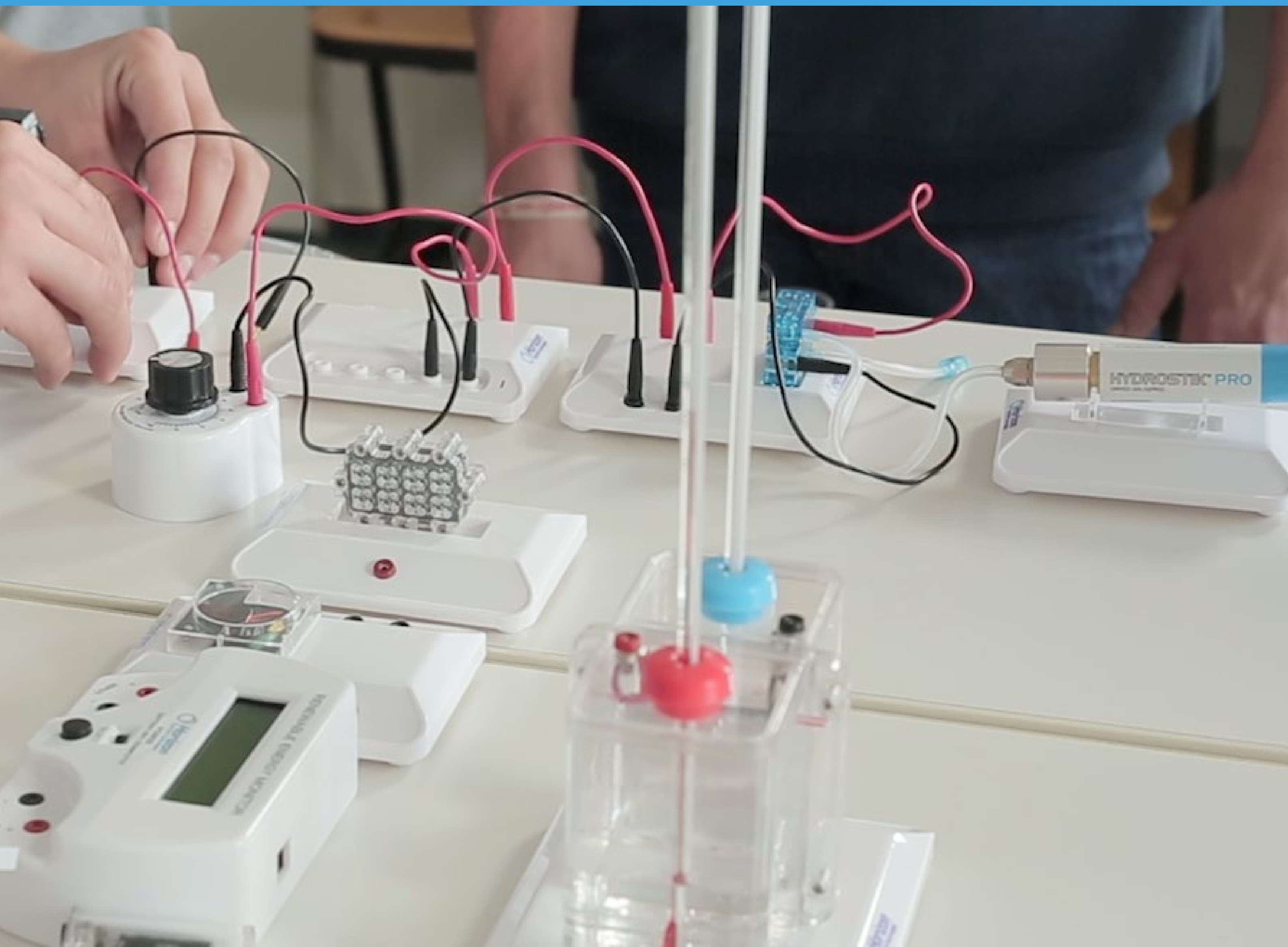
Discuss with your group and write your answers to these questions below.

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

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

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

Hardware Experiments



Electric Circuits

Goals

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

Background

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

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

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

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

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

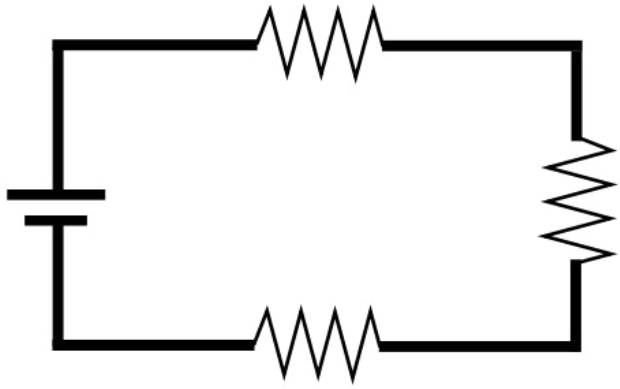


Fig. 1 Series circuit (with 3 resistors)

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

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

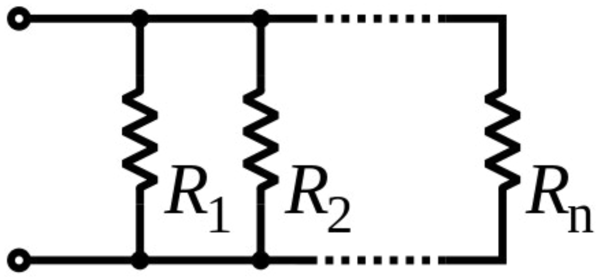


Fig. 2 Parallel circuit (of n resistors)

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

Electric Circuits

Procedure

1. Use your solar cell to power the small motor that controls the fan. You'll need to connect the solar cell to the fan using wires to carry the electricity. Why do you think you need two wires?
2. When you've connected the solar cell to the motor, you may have to give the fan a little push to get it started. The solar cell will work best in direct sunlight. What happens to the fan if you try the solar cell with other light sources?
3. You can use the electricity from the solar panel to generate hydrogen gas using the electrolyzer. The electrolyzer is the square with "H2" and "O2" printed on either side. What do you think will happen if you connect it to a source of electricity like the solar cell?
4. Your electrolyzer is also a hydrogen fuel cell that can generate electricity from hydrogen and oxygen. It has two small tubes attached to it. Is there anywhere else on the fuel cell that you could attach the longer tubes?
5. Look at the remaining pieces of your kit. If the fuel cell splits water into hydrogen and oxygen gases, what could you use to trap the gases so they don't float away?
6. Connect the tubes of your fuel cell so that you can trap the gases. To generate hydrogen, you'll need to supply an electric current. You can do this with the battery pack or the solar cell. Try both. Which is better at producing hydrogen? How do you know?
7. When you've produced hydrogen, you can use the fuel cell to power the motor just like you did with the solar cell. Plug the motor into the fuel cell and it should start turning. Note in your observations if you see any difference in how the motor works with the fuel cell instead of the solar cell.

Observations

Experimentation

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

Electric Circuits

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

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

Measurement

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

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

Current: ______________ A

Voltage: ____________ V

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

Current: ______________ A

Voltage: ____________ V

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

Resistance: _____________ Ω

Electric Circuits

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

Current: _____________ A

Voltage: ___________ V

Analysis

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

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

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

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

Electric Circuits

Conclusions

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

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

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

Green Power Grid

Goals

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

Background

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

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

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

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

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

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

Fuel Cell and Wind Procedure:

1. Look at the three different types of blades available (labeled A, B, and C). How are they similar? How are they different? Discuss with your group which type of blade you think would work best with your turbine and record your observations below.

2. Select the type and number of blades you want to test. Why do you want to test this type of blade first? Do you think it will be better or worse than the other types?

3. Check that the blades are in the same position using the three notches near the white bases of the blades. Rotate the individual blades if needed to get all the blades into the same position. Would your turbine still work if the blades were in different positions?

Green Power Grid

4. Insert the blades into the Rotor Base and put the Blade Holder and the Blade Assembly Lock, then attach the Blade Unit to the metal shaft of the turbine. Can your blades be positioned backwards? How do you know if there's a "right way" for a blade to be positioned?

5. Now you're ready to use the electricity from the wind turbine to generate hydrogen gas using the electrolyzer. The electrolyzer is the blue square with "H2" and "O2" printed on either side. What do you think will happen if you connect it to a source of electricity like the wind turbine?

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

7. Look at the remaining pieces of your kit. If the fuel cell splits water into hydrogen and oxygen gases, what could you use to trap the gases so they don't float away?

8. Connect the tubes of your fuel cell so that you can trap the gases. To generate hydrogen, you'll need to supply an electric current from the wind turbine.

9. Turn on the fan and position it in front of the turbine. It will work best if you keep the fan close to the turbine and line up the center of the fan with the center of the turbine. Why would changing the position of the fan affect the wind hitting the turbine?

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

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

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

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

Observations

Green Power Grid

Data Table:

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

Fuel Cell and Wind Experimentation:

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

Number of Each Type of Blade:	H2 gas? (Y/N):	Other Observations:

What combination worked best?

Green Power Grid

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

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

What arrangement worked best?

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

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

Green Power Grid

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

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

Fuel Cell and Solar Procedure:

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

Observations

Green Power Grid

Fuel Cell and Solar Experimentation:

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

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

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

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

Green Power Grid

Measurement

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

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

Current: ______________ A

Voltage: ____________ V

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

Current: ______________ A

Voltage: ____________ V

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

Green Power Grid

Analysis

1. Make a scientific claim about your electric generators.

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

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

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

Green Power Grid

Conclusions

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

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

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

Energy Conservation and Transformation

Goals

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

Background

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

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

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

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

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

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

Procedure

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

Energy Conservation and Transformation

Observations

Experimentation

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

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

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

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

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:

Current: ______________ A

Voltage: ____________ V

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

Resistance: _____________ Ω

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

Current: ______________ A

Voltage: ____________ V

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

Measurements of current and voltage should both be higher when splitting the water than when

Energy Conservation and Transformation

Analysis

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

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

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

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

Energy Conservation and Transformation

Conclusions

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

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

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

Redox Reactions

Goals

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

Background

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

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

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

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

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

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

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

Cathode (reduction):

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

Anode (oxidation):

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

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

Redox Reactions

Procedure

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

Observations

Experimentation

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

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

Redox Reactions

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

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

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

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

Redox Reactions

Measurement

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

1. Measure the current in Amps while generating hydrogen and oxygen. Time how long it takes to fill your hydrogen cylinder. Record your answers below:

Current: ____________ A

Time: ___________ sec

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

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

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

Redox Reactions

Analysis

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

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

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

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

Redox Reactions

Conclusions

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

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

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

Renewable Energy

Goals

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

Background

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

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

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

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

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

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

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

Wind Turbine Procedure:

1. Look at the three different types of blades available (labeled A, B, and C). How are they similar? How are they different? Discuss with your group which type of blade you think would work best with your turbine and record your observations below.

2. Select the type and number of blades you want to test. Why do you want to test this type of blade first? Do you think it will be better or worse than the other types?

3. Check that the blades are in the same position using the three notches near the white bases of the blades. Rotate the individual blades if needed to get all the blades into the same position. Would your turbine still

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work if the blades were in different positions?

4. Insert the blades into the Rotor Base and put the Blade Holder and the Blade Assembly Lock, then attach the Blade Unit to the metal shaft of the turbine. Can your blades be positioned backwards? How do you know if there's a "right way" for a blade to be positioned?
5. Connect the base of the turbine to the LED lights using the black and red wires. Why do you think the lights need two wires to work?
6. Turn on the fan and position it in front of the turbine. It will work best if you keep the fan close to the turbine and line up the center of the fan with the center of the turbine. Why would changing the position of the fan affect the wind hitting the turbine?
7. Record your observations in the Data Table below: Did the lights turn on? Were they dim or bright?
8. Discuss what you observed with your group and discuss what you want to change: the number of blades, the angle of the blades, the type of blades, or some combination of those.
9. Repeat steps 1-8 with as many changes as you can think of.

Observations

Data Table:

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

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Wind Turbine Experimentation:

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

Number of Each Type of Blade:	Observations:

What combination worked best?

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

Blade Order:	Observations:

What arrangement worked best?

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

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

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

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

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

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Solar Panel Procedure:

1. Use your solar cell to power the small motor that controls the fan. You'll need to connect the solar cell to the fan using wires to carry the electricity. Why do you think you need two wires?
2. When you've connected the solar cell to the motor, you may have to give the fan a little push to get it started. The solar cell will work best in direct sunlight. What happens to the fan if you try the solar cell with other light sources?
3. Now try using the solar cell to power the LEDs. Record your observations below.

Observations

Solar Panel Experimentation:

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

Light Color:	Observations:

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

Background Color:	Other Observations:

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

Fuel Cell Procedure

1. You can use the electricity from the battery pack to generate hydrogen gas using the electrolyzer. The electrolyzer is the square with "H2" and "O2" printed on either side. What do you think will happen if you connect it to a source of electricity like the battery pack?
2. Your electrolyzer is also a hydrogen fuel cell that can generate electricity from hydrogen and oxygen. It has two small tubes attached to it. Is there anywhere else on the fuel cell that you could attach the longer tubes?
3. Look at the remaining pieces of your kit. If the fuel cell splits water into hydrogen and oxygen gases, what could you use to trap the gases so they don't float away? Connect the tubes of your fuel cell so that you can trap the gases. To generate hydrogen, you'll need to supply an electric current. You can do this with the battery pack or the solar cell. Try both. Which is better at producing hydrogen? How do you know?
4. When you've produced hydrogen, you can use the fuel cell to power the motor just like you did with the solar cell. Plug the motor into the fuel cell and it should start turning. Note in your observations if you see any difference in how the motor works with the fuel cell instead of the solar cell.

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Observations

Fuel Cell Experimentation

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

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

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

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

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Measurement

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

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

Current: ______________ A

Voltage: ____________ V

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

Current: ______________ A

Voltage: ____________ V

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

Current: ______________ A

Voltage: ____________ V

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

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Analysis

1. Make a scientific claim about your electric generators.

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

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

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

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Conclusions

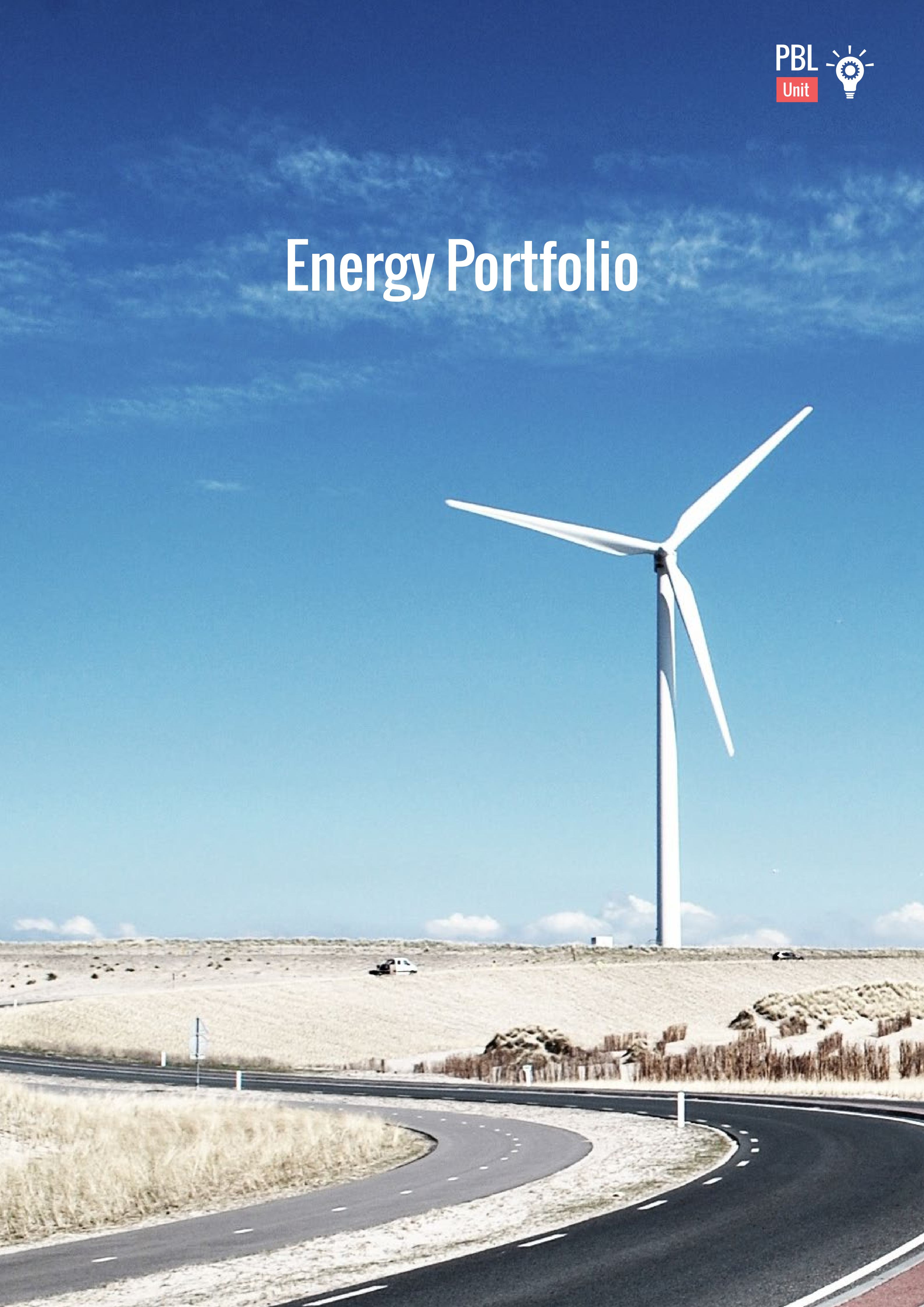
1. Do you think the fuel cell, wind turbine, or solar cell makes the best source of electric energy? Explain your reasoning.

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

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

PBL Unit

Energy Portfolio



Energy Portfolio

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

Video presentation:

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

Newspaper article:

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

Letter to mayor or city council:

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

Research paper:

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

PSA poster:

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

Scientific lecture:

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

Energy Portfolio

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

I, ____(student name) will complete a

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

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

Signed:____________________________________ Date:___________________