	Physics	High School	5 hours

Unit Plan - Description

During this activity, students will learn about renewable energy, the law of conservation of energy, and basic chemical reactions. The primary content includes the definition, transfer, and conservation of energy, and types of interactions.

Focus

Students will engage with multiple resources to understand how biofuels are used to generate electricity.

Behaviors

SWBAT run an ethanol fuel cell and explain how it works.

SWBAT construct an explanation of the results of an experiment.

SWBAT understand how other forms of energy can be used to generate electrical energy.

NGSS Science and Engineering Practices

- Asking Questions and Defining Problems
- 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 Crosscutting Concepts

- Patterns
- Cause and Effect
- Scale, Proportion, and Quantity
- Energy and Matter
- Structure and Function
- Stability and Change

NGSS DCIs

HS-PS2.A, HS-PS2.B, HS-PS3.B

Energy Literacy Framework

1.1, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 4.1, 4.2, 4.6, 4.7, 6.1, 6.4, 6.5, 6.8

Common Core ELA and Math

RST.6-8.1, RST.6-8.3, WHST.6-8.7, MP.2, 6.RP.A.2, 6.RP.A.3, 6.SP.B.5

Classroom and Homework Activities

1. Lab Activity Sheet
2. Intro. to Ethanol Reactions
3. Stating a Scientific Claim
4. Measuring Current in a Circuit

Electronic and Online Activities

Procedure

Over the course of multiple lessons, students will engage with a variety of resources dealing with ethanol and renewable energy resources. Electronic and online resources will be available to supplement in-class resources as well as instructor-led small- and whole-group discussions. Formative assessment will be conducted with oral questions during activities and students will complete a final written assessment at the close of the activity.

Lab Setup

- Before the lab starts, you should assemble the fan motor, and complete steps 1-3 of the assembly guide. This should take no more than a few minutes for each kit.
- Multiple experiments are included so you can choose which ones to perform with your students.
- If you want to perform the Concentration of Ethanol experiment, you'll have to prepare solutions for your students beforehand. It's easiest to fill a graduated cylinder with a certain amount of pure ethanol and then fill it to 60mL with distilled water. Here is the amount of pure ethanol you should use for each concentration: 5%: 3mL 7%: 4.2mL 10%: 6mL 12%: 7.2mL 15%: 9mL
- If you want to perform the Temperature experiment, you'll need multiple adjustable hot plates or similar devices to choose specific temperatures (see safety note below).
- If you're using the Measurement section, you'll need a stopwatch as well as a multimeter.
- 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

- Do not use greater than 15% ethanol mixtures in the fuel cell or it will be irreparably damaged.
- Do not mix pure ethanol with water inside the fuel tank. Use the container with the milliliter markings or a graduated cylinder first and then transfer the mixture to the fuel tank.
- Ethanol is volatile and the mixtures should never be heated to more than 60ºC (140ºF).
- Safety goggles should be worn at all times.

Notes on Using This Kit

- It's recommended that you mix your ethanol beforehand in a large batch, to prevent you from having to continue mixing ethanol throughout the activity. As a guide for how much to make, please note that students will go through about 60mL per experiment per group.

Common Problems

- If no electricity is flowing, check that all connections are properly wired and try again.
- The fan motor sometimes needs a quick tap or flick to get it to start spinning.
- If the fuel level in the tank drops too low, ethanol will not flow into the fuel cell. Keep the level of ethanol higher than the fuel cell's inlet nozzle.
- If the fan slows, purge the fuel cell with distilled water and air as described in the **Procedure** section then wait 5-10 minutes before attaching the fan again.

Using the Comprehension Questions Formative Assessment Tool

- As your students are working on their activities and you circulate from group to group, use the grid system to keep track of how well individual students are understanding the material.
- You can use a code to quickly assess each individual's level of mastery after talking with them, for example: (B)elow Grade Level, (A)t Grade Level, (E)xceeds Grade Level.
- Feel free to adopt your own code, and be sure to write them in pencil so you can adjust them as your students improve over time. Use this tool to take stock of your students' progress at a glance and provide resources to those who need it.
- You can even add your own questions to gauge your students' knowledge of other areas of your curriculum.

Resource Availability

- The electronic and print resources included in this mini-unit are designed to be accessible by students at all levels of achievement. We suggest that you make as many resources as possible available to your students as they engage with the new content so they have multiple opportunities to familiarize themselves with the information.
- If you have additional resources or feel that some of our resources cover material outside the scope of your class, feel free to customize as needed.

Creating New Materials

- We include all our instructional files as modifiable files so that you can customize them to your own class. We've aligned our activities with the Next Generation Science Standards and the US Department of Energy's Energy Literacy Framework. If you need to add content to comply with a specific state standard or the scope and sequence of your course, feel free to do so.
- In fact, if you develop a great new experiment or additional student resource, let us know! We regularly select the best teacher-submitted lessons, labs, and activities and share them with other educators all over the world. Winners are all listed on our website and receive free Horizon Educational Kits for their classrooms.

Analysis

Make a *scientific claim* about your ethanol fuel cell. What are the conditions that would generate the most electricity from this fuel cell? To help you write a claim statement, see "Stating a scientific claim"

Level 1 example answer: "The fuel cell works better when it has more fuel."
Level 2 example answer: "The ethanol fuel cell makes the most electricity when it's hotter and when the ethanol has a concentration of 15%."
Level 3 example answer: "A fuel cell makes more electricity at a temperature of at least 50ºC and at a concentration of at least 15%."

What *evidence* can you use from your **observations** and your **experimentation** to back up your claim?

Level 1 example answer: "The fan stopped spinning when it ran out of fuel."
Level 2 example answer: "We saw the fan spinning fastest at higher temperatures and higher concentration."
Level 3 example answer: "Our fan was spinning really fast when the temperature was 50ºC and also when the concentration was 15%."

State the *reasoning* you used to make your claim.

Level 1 example answer: "Since the fuel was running out, the fuel cell must have been working less."
Level 2 example answer: "Changing the temperature and concentration must have affected the electricity because the fan changed speeds."
Level 3 example answer: "Higher concentrations and temperatures must have caused higher electricity, but we didn't test higher than that so it might be even better with higher numbers."

Use the data you collected to *design an experiment* that you could run to test the effect of air temperature on the fuel cell. Explain the steps of your experiment here:

Level 1 example answer: "We could heat up the air around the fuel cell."
Level 2 example answer: "We could bring the fuel cell into a warm room and see if it made the fan spin faster than when it was in a cold room."
Level 3 example answer: "We could measure the temperature of the air and use a fan or a heater to change the temperature. Then we could see what happened to the fan when we were at a hotter or colder temperature."

Does it matter if the fuel cell is attached to something other than the fan? *Design an experiment* that would test what happens when other electric machines are powered by the ethanol fuel cell. Explain the

steps of your experiment here:

Level 1 example answer: "We could use the fuel cell to give electricity to a lightbulb."
Level 2 example answer: "We could measure how much electricity the fuel cell makes when we attach it to different motors or maybe lights."
Level 3 example answer: "If we had a way to measure how much electricity it made, we could hook it up to different things like lights or motors and measure how much electricity it made for each of them."

Conclusion

1. What happens if you attach the wires to the fan backwards (red to black and black to red)? *Construct an explanation* of what you observe.

Level 1 example answer: "It's going backwards because we hooked it up backwards."
Level 2 example answer: "The electricity must be moving backwards so the fan goes backwards too."
Level 3 example answer: "If the electricity is moving in the opposite direction, then that must make the motor turn in the opposite direction, so our fan spins backwards."

2. Could you use an ethanol fuel cell to provide power to your house? *Develop an argument* to support your position using evidence you observed during this activity and defend your argument if there are different points of view in your group.

Level 1 example answer: "Yes because houses use electricity too."
Level 2 example answer: "No because the fuel cell doesn't make enough electricity. It would have to make a lot more."
Level 3 example answer: "Yes, but only if there was a really big fuel cell or there were lots of little ones working together because one small one like we have doesn't make enough electricity."

3. Was energy made or used up during this activity? *Construct an explanation* of what happened to the energy and why.

Level 1 example answer: "Energy was used up by the fan but made by the fuel cell."
Level 2 example answer: "You can't make new energy or use it up, but you can make it change from one kind to another. The fuel cell took energy from the ethanol and made it into electricity, which the fan turned into moving energy."
Level 3 example answer: "There was chemical energy in the ethanol, which the fuel cell turned into electric energy. The fan took that electricity and turned it into motion. There was also friction, so some of the energy turned into heat."

4. What would you do to improve the electricity production of your ethanol fuel cell? *Design a solution* that would increase the amount of electricity you would get from your fuel cell.

Level 1 example answer: "You could make the fuel cell bigger so it fits more ethanol."
Level 2 example answer: "It ran better when it was warmer, so maybe you could keep the fuel cell hotter with a heater attached to it."
Level 3 example answer: "You have to keep the concentration near the amount that we found out made the fan go faster, and then also keep the temperature near 50º for the same reason. You could also maybe find out if there are different things you could run with the electricity."

Measurement

How much electricity is running through our circuit? To find out, we'll need to use an ammeter like the Horizon Renewable Energy Monitor to measure the amount of electric current being produced by the generator. Read "Measuring Current in a Circuit" for more information on how to set this up.

When your ammeter is connected to your circuit, run the ethanol fuel cell to power the fan. Use a stopwatch and measure the amount of current in the circuit at different times. If you have the Horizon Renewable Energy Monitor, you can also measure the volts. Record your data below:

Time (min)	***Amps (A)***	***Volts (V)***
0		
2		
4		
6		
8		
10		

Does the amount of electricity produced by the fuel cell change? *Construct an explanation* of what you observed.