Earth Sciences | High School | 5 hours

## Unit Plan - Description

For this activity, students will learn about hydrogen fuel cells and what makes them a sustainable energy resource. They will explore the different components of a hydrogen fuel cell car, assemble it, and conduct experiments to see how it works. The primary content includes basic chemical reactions, transfer and conservation of energy, and designing and constructing engineering solutions.

## Focus

Students will engage with multiple resources to understand how energy is transformed during chemical reactions and the relationship between chemical and electrical energy.

## Behaviors

SWBAT construct a functioning electrolytic cell and explain its chemical reaction.

SWBAT explain how machines conserve energy.

SWBAT understand the difference between renewable and nonrenewable sources of 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-ETS1.B, HS-ESS2.A, HS-ESS2.D, HS-ESS3.A, HS-ESS3.C, HS-ESS3.D

## 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 Electrodes
3. Stating a Scientific Claim
4. Measuring Current in a Circuit

## Electronic and Online Activities

1. Electrolysis video
2. Hydrogen Fuel Cell video
3. Department of Energy website
4. Energy Conservation game

## Procedure

Over the course of multiple lessons, students will engage with a variety of resources dealing with fuel cells 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

- For this activity, you have the option of assembling the cars beforehand or allowing your students to assemble them by following the guiding questions in the "Assembly" section.
- If you choose to let your students assemble the cars themselves, it is recommended that you complete steps 1 through 3 of the "*Hydrocar Assembly Guide*" in advance so that your students don't need to use screwdrivers or cut lengths of tubing.
- If you choose to assemble the cars beforehand, be sure to allow time before class to assemble each car. You'll need AA batteries, scissors, a ruler, a small Philips-head screwdriver, and plenty of distilled

water to assemble them. See the "*Hydrocar Assembly Guide*" for complete assembly instructions.

- 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.

## ⚠ 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 Using This Kit

- Though the car can detect and steer around objects that it bumps into, it won't detect the edge of a table. It may be best to put them on the floor when it's time to have them run.
- There is an on-off switch on the body of the car. Check that students have it set in the "on" position if they can't get their car to run.

## Common Problems

- The solar cell works best with direct sunlight, and could take up to 20 minutes to fill the hydrogen container on the car. If pressed for time, use the battery pack instead.
- 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.

## 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 car: what affected how far or how fast it could go? To help you write a claim statement, see "Stating a scientific claim"

***• Level 1 example answer: "Our car ran for 47 seconds."***
***• Level 2 example answer: "Friction affected how far our car went."***
***• Level 3 example answer: "When we reduced friction our car ran for longer."***

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

***• Level 1 example answer: "First the car ran for a long time, then it ran for a shorter time."***
***• Level 2 example answer: "The car ran for 36 seconds during the first test, and for 22 seconds during the second test."***
***• Level 3 example answer: "The car ran for 49 seconds when it ran in a straight line, but for only 26 seconds and moved slower when it ran into objects."***

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

***• Level 1 example answer: "The table is a smoother surface than the carpet, so the car was faster."***
***• Level 2 example answer: "Friction stops the car from moving."***
***• Level 3 example answer: "A lower mass requires less force to move it, so if the car produces the same amount of energy every time, it should move a lighter mass for a longer time."***

Now that you've seen the hydrogen fuel cell car working, *design an experiment* that could determine the best surface for the car to run on. Explain the steps of your experiment here:

***• Level 1 example answer: "Run the car on the table and on the floor and compare them."***
***• Level 2 example answer: "Time how long the car runs on a smooth surface and time how long the car runs on a rough surface."***
***• Level 3 example answer: "Test the car by running it on many different surfaces: wood, cement, tile, carpet, desktop, asphalt, and more. Charge it the same amount each time and make sure it doesn't run into anything. Compare the running time of each test to find the surface that records the longest running time."***

Use your knowledge of global climate change, *design an experiment* that would compare the environmental impact of a hydrogen fuel cell car to that of a gasoline-powered car. Explain the steps of your experiment here:

***• Level 1 example answer: "Run a gasoline car and a hydrogen car and compare the emissions of both."***
***• Level 2 example answer: "Run the cars for the same amount of time and at the same speed and measure how much exhaust they each produce."***
***• Level 3 example answer: "Measure the amount and type of emissions produced by a gasoline and hydrogen powered cars over a set amount of time and at a set speed and then research the environmental impact of each."***

## Conclusion

1. What would be the advantages and disadvantages of using hydrogen fuel cells in a full-sized car? *Develop an argument* for or against hydrogen fuel cell cars 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: "Hydrogen fuel cells produce electricity but hydrogen can catch fire easily."
Level 2 example answer: "I think hydrogen fuel cells would make a good fuel source because it can power a car without creating pollution."
Level 3 example answer: "I think hydrogen would not make a good fuel source because it is too hard to get enough energy to power a car for a long time and there aren't many places to fill up a hydrogen car. Even though it doesn't pollute and it's easy to get it from water, I think that there are more disadvantages than advantages."

2. What other renewable energy sources could be used to power cars of the future? Compare hydrogen fuel cells to other energy sources and *develop an argument* supporting the fuel source you think is the best.

Level 1 example answer: "Cars could run on biofuels."
Level 2 example answer: "A car could have a battery that was charged by solar or wind power and then it wouldn't produce any pollution."
Level 3 example answer: "If a car combined a fuel cell with solar power, it could make new hydrogen without making pollution. This would work better than wind power because it could be used on the car while it was driving or standing still."

3. Was energy created or used up during this experiment? *Construct an explanation* of where energy was moving during this activity and how you know if it was created or used up.

**Level 1 example answer: "Energy wasn't created or used up during this experiment."**
**Level 2 example answer: "Energy was created from hydrogen when the fuel cell made electricity and was used up when the car was moving, but it was the same amount of energy."**
**Level 3 example answer: "Energy is never created or destroyed, but it changes from one form to another. Energy moved from the battery to the fuel cell and then to the car motor, where it became heat and motion."**

## Measurement

Read "Measuring Current in a Circuit" for more information on how to use the Horizon Renewable Energy Monitor or a multimeter with your fuel cell car.

With an ammeter connected to the car, connect the circuit to the fuel cell and start the car. What is the amperage produced?

Car running produces _____ amps. (**Student answers should be in the milliamp range**)

Using the renewable energy monitor, you can also measure the voltage in volts and the power produced by the car, measured in watts. What is the power output of the hydrogen fuel cell?

Voltage: _____ volts Power output: _____ watts

(**Student answers should be in millivolt and milliwatt ranges**)

We know that power in watts is the current in amps multiplied by the voltage in volts, or $P_{(W)} = I_{(A)}V_{(V)}$. Is this true based on the data you gathered? *Construct an explanation* of the possible sources of error in your measurements.

**Level 1 example answer: Student calculates P=IV.**
**Level 2 example answer: Student calculates P=IV and compares it to measured power in watts.**
**Level 3 example answer: Student calculates P=IV, compares calculated answer to measured answer, and identifies at least one source of error in measurements.**

What if your car didn't carry water to produce hydrogen and instead just carried hydrogen gas? What changes would have to be made to your car? In the space below, sketch what that car might look like and write an explanation of how it would work.

**Level 1 example answer: A sketch of a car with a hydrogen tank.**
**Level 2 example answer: A sketch of a car with a hydrogen tank and fuel cell, both labeled.**
**Level 3 example answer: A sketch of a car with a hydrogen tank, fuel cell, engine, and an explanation of the flow of fuel, waste, and electrical energy.**