PHYSICAL SCIENCE JOURNAL FOR TEENS

How can hydrogen solve the problem of renewable energy storage?

LESSON

Introduction

This lesson plan has students explore hydrogen as a storage option for renewable energy resources, such as wind and solar.

Learning Objectives

After the lesson, the students should be able to:

- Describe the limitations of renewable energy.
- Explain how hydrogen is produced from water.
- Explain how hydrogen can be used to create electricity using a hydrogen fuel cell.

Key Terms

- electrolysis
- hydrogen fuel cell
- water splitting

Time Requirement

Minimum 4 class periods (could be on separate days).
With extensions: up to 5 class periods.

Grade Level

Grades 8-9

Teaching Standards

AP ENVIRONMENTAL SCIENCE:

- Unit 6 - Energy Resources and Consumption
- Topic 6.11 - Hydrogen Fuel Cells
- EK: ENG-3.P.1 - Hydrogen fuel cells are an alternative to nonrenewable fuel sources. They use hydrogen and oxygen in the air to form water and release energy (electricity) in the process. Water is the product (emission of a fuel cell).

- ENG-3.Q.1 - Hydrogen fuel cells have low environmental impact and produce no carbon dioxide when the hydrogen is produced from water. However, the technology is expensive and energy is still needed to create the hydrogen gas used in the fuel cell.

Refer to **Errata Sheet for AP Environmental Science** *as of September 2019*.

NEXT GENERATION SCIENCE STANDARDS:

- HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Materials

- Printed copies of Handout 1, "How Do We Store Electricity?"
- Printed copies of Handout 2, "Let's Make Hydrogen!"
- 9-volt battery
- Small plastic cups
- Thumb tacks
- Baking soda
- Lemon juice
- Tap water
- Distilled water
- Printed article and question handout **How Can We Turn Ocean Water into Renewable Energy?** from Science Journal for Kids and Teens (if reading in class)
- Optional: printed copies of Handout 3, "Hydrogen Fuel Cell Activity"
- Laptop and projector, smartboard, or printouts of images showing how hydrogen fuel cells can be used. (For ideas, see the SJK presentation **Hydrogen in the Real World.**)

Lesson Plan

1 GETTING STARTED

- **The Problem with Renewables Video (~3 minutes)**

  Show students a video that describes an important limitation of renewable energy sources: the difficulty of storing them. For example, **The Problem with Renewable Energy** from Tom Scott (from the beginning until 2:57)

- **Electricity Storage Ranking Activity (~15 minutes)**

  Divide students into pairs or groups. Give them each a copy of Handout 1, "How Do We Store Electricity?", which offers a description of how the common electricity storage options work. Students should discuss the options and rank them based on plausibility.

- **Electricity Storage Ranking Follow-up Discussion (~10 minutes)**

  Discuss the student rankings. Ask students if there is one storage option that can work for all parts of the country. What are the limitations that prevent some of these options from working? Focus students on the limitations of these storage methods. For example, batteries would have to be really large to store this amount of energy, and compressed air requires caves for storage, which are not available at all locations.

- **Meet Hydrogen! (~5 minutes)**

  Introduce students to the concept of hydrogen as a different way to store electricity. Show them a picture of how solar and wind energy can be transformed into hydrogen and then back into electricity and energy for cars.

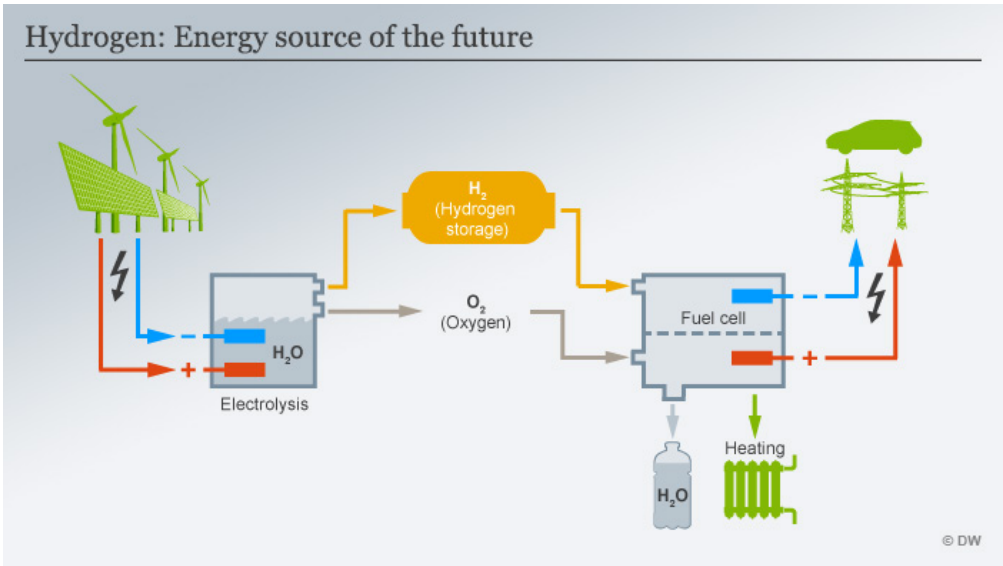


Image from DW:
"Hydrogen and wind: Allies for sustainable energy"
www.dw.com

Highlight the process of water splitting as a way to store the electricity from solar and wind. Transition into water splitting experiment.

Duration 35-40 min, depending on level

2 HANDS-ON ACTIVITY: WATER SPLITTING EXPERIMENT

Give students copies of Handout 2: "Let's Make Hydrogen!", which gives instructions for an experiment that splits water to form oxygen and hydrogen.

Procedure for Students

- Push the thumb tacks into the bottom of the plastic cup so that the points push up into the container. Space them so that they're the same distance apart as the two terminals of the 9V battery. Be careful not to prick yourself!
- Fill the cup with distilled water so that the points of the thumb tacks are completely submerged.
- Add a pinch of baking soda.
- Place the plastic cup on the terminals of the battery. The bottom of the thumb tacks need to touch both terminals.
- Record your observations in the chart.
- Discard the solution, and repeat the procedure three more times with the followings differences:

  - Add lemon juice instead of baking soda

  - Skip Step 3 (don't add anything)

  - Use tap water instead of distilled water

Extension Activity

If students have more time or if equipment is available:

- Run the experiment with different batteries (1.5 V, 6V, etc.)
- Run the experiment again with a solar cell instead of a battery.

Experiment Discussion

Students should share their findings. They can discuss which solution was best able to water split. Explain that a solution is needed to complete the circuit. Pure water doesn't conduct electricity, but if there is something in the water, like salt, the ions will conduct electricity. That is why you don't want to be out swimming during a thunderstorm!

Discuss the answers to the analysis questions. Focus on the requirements of water splitting. Ask students if they think that there is enough water in the world to create the hydrogen we need for energy storage. Use this discussion as a transition into the reading assignment.

Duration 35-45 min, depending on available equipment

3 READING ASSIGNMENT

- Individually or in groups, have students read the article **How Can We Turn Ocean Water into Renewable Energy?** published in *Science Journal for Kids and Teens*.
- Answer the assessment questions at the end of the article (teacher's key available on the same page)
- Discuss as a class. Why did the researchers create a device that couples osmosis with water splitting? How does this research impact the plausibility of hydrogen as a renewable energy storage option?

Duration 30-45 min

4 HYDROGEN FUEL CELL ACTIVITY

Introduce the activity to students: "Now that we know how we can use hydrogen to store energy, let's look at how we can take the hydrogen and turn it back into usable electricity."

Optionally, give out copies of Handout 3, "Hydrogen Fuel Cell Activity."

Directions

- Direct students to the SEPUP hydrogen fuel cell animation at **https://sepuplhs.org/high/hydrogen/fuelcell_sim5.html**. It shows how a hydrogen fuel cell uses hydrogen to provide energy to cars and houses.
- Students should write a story (individually or in groups) that describes what happens in a hydrogen fuel cell to create electricity.
- Ask students to swap stories with another student or group. They should read what was written and provide feedback. Is what is written accurate based on the simulation? Is what is written clear and concise?

Wrap-up Discussion

As a class, summarize the process of a hydrogen fuel cell. Have each group or student provide one step in the process until the story is completely told. Show students how this can be used on a house or in a car using pictures and/or videos. You can find some examples in the SJK presentation **Hydrogen in the Real World**

Duration 30-45 min

Writing Extensions

- Students can write a letter to a local politician persuading them to invest in hydrogen to make renewable energy a more viable option for their area.
- Students can make an advertisement to promote hydrogen as a fuel storage option. Their advertisement should include how hydrogen is made and how it can be used to power their homes or cars.

These assignments can be completed individually or in small groups. They can also be assigned for homework or completed during class time.

Duration 30 min or longer, depending on level of detail

Online Learning

Virtual Water Splitting Experiment:

Show students a video of a water splitting experiment. For example, **Making Hydrogen Gas at Home with a 9-Volt Battery** from Rhett Allain. After watching the video, students should create a diagram of water splitting either on paper or on a virtual whiteboard. They should label their drawing to indicate what is necessary to make hydrogen. Prompt them to determine which terminal creates the hydrogen gas and which creates the oxygen gas with an explanation of how they know.

Water Splitting animation:

Direct students to the **SEPUP electrolysis animation**. It shows how electricity can split water into hydrogen and oxygen gas. Students should answer questions to check understanding. For example, on which battery terminal does the hydrogen form? If you split four water molecules, how many hydrogen gas molecules do you get? How many oxygen molecules?

References

EPA: Energy Storage Options
https://www.epa.gov/energy/electricity-storage

SEPUP: Hydrogen Fuel Cell Simulation
https://sepuplhs.org/high/hydrogen/simulations.html

NAME: _____ **DATE:** _____

HOW DO WE STORE ELECTRICITY?

One of the concerns with renewable energy sources, such as wind and solar, is that they cannot easily be stored for a "rainy" day. Scientists have developed a number of storage options for this energy. In this activity, we are going to explore the current storage options to assess their usefulness.

Read the description of each storage option. Then rank the storage options from most useful (1) to least useful (5).

Storage Option	Description	Ranking
Pumped Hydroelectric	We use electricity to pump water up to a reservoir. When we release water from the reservoir, it flows down through a turbine to generate electricity.	
Compressed Air	We use electricity to compress air at up to 1,000 pounds per square inch and store it, often in underground caverns. When electricity demand is high, we release the pressurized air to generate electricity.	
Flywheels	We use electricity to accelerate a flywheel (a type of rotor). When people need the energy, the spinning force of the flywheel turns a generator. Scientists and engineers are exploring new designs to get larger rotational speeds to store more energy.	
Batteries	Similar to common rechargeable batteries, extremely large batteries can store electricity until people need it. Scientists and engineers are still exploring battery designs that can store grid-level electricity.	
Thermal energy storage	We use electricity to produce thermal energy, then store it until people need it. For example, we can use electricity to produce chilled water or ice during times of low demand and later use it for cooling during periods of peak electricity consumption.	

Source: **https://www.epa.gov/energy/electricity-storage**

→ **Explain your top choice: why do you think it's most useful?**

→ **Explain your last choice: what disadvantages does it have in comparison to other options?**

NAME: _____ **DATE:** _____

LET'S MAKE HYDROGEN!

Hydrogen is a storage option for the electricity produced by renewable energy sources, such as solar and wind. Using the process of electrolysis, electricity can be used to split water into hydrogen gas. This process is often referred to as water splitting, and it can be described by the following chemical reaction:

$$2H_2O \longrightarrow 2H_2 + O_2$$

The hydrogen produced by water splitting can then be stored and used later to power homes and cars when needed.

In this activity, we are going to split water to make hydrogen gas ourselves!

Procedure:

1. Push the thumb tacks into the bottom of the plastic cup so that the points push up into the container. Space them so that they're the same distance apart as the two terminals of the 9V battery. Be careful not to prick yourself!
2. Fill the cup with distilled water so that the points of the thumb tacks are completely submerged.
3. Add a pinch of baking soda.
4. Place the plastic cup on the terminals of the battery. The bottom of the thumb tacks need to touch both terminals.
5. Record your observations in the chart.
6. Discard the solution, and repeat the procedure three more times with the followings differences:
   - Add lemon juice instead of baking soda
   - Skip Step 3 (don't add anything)
   - Use tap water instead of distilled water

Analysis Questions:

How did water splitting change with the different solutions? Were some solutions better than others? Support your answer with observations from the experiment.

Which gas, hydrogen or oxygen, do you think was formed on the positive terminal of the battery? Explain your answer.

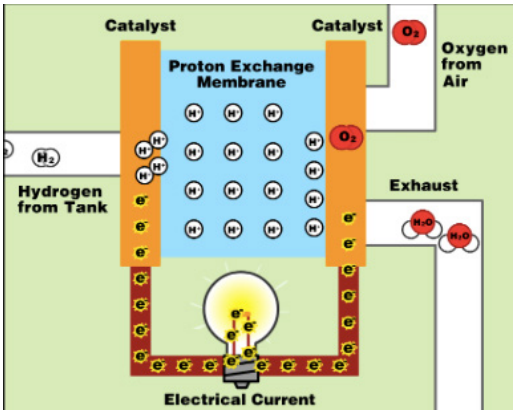
Based on this experiment, what do we need to make hydrogen?

NAME: _____ **DATE:** _____

HYDROGEN FUEL CELL ACTIVITY

Now that we know how we store energy made by solar and wind in hydrogen, let's explore how we can take that stored energy and turn it back into electricity that we can use to power our devices and our cars. In this activity, we are going to use an animation to explore how a hydrogen fuel cell can transform hydrogen back into usable electricity.

1. Navigate to the **SEPUP Hydrogen Fuel Cell** animation.
2. Explore the animation to figure out how a hydrogen fuel cell works.



3. Write a step-by-step description of what happens in the hydrogen fuel cell to make electricity. Begin with the hydrogen as it enters the cell. Consider: how does the chemical reaction in this fuel cell compare to the water splitting reaction?

Answer Key for Handout 2, "Let's Make Hydrogen!"

1. How did water splitting change with the different solutions? Were some solutions better than others? Support your answer with observations from the experiment.

The best results were with the baking soda and with the lemon juice. The reaction didn't work with only distilled water, because no bubbles were produced. It worked a bit better with tap water.

Supporting observations: The amount of bubbles on the thumb tacks indicates how much gas is produced.

Note to teacher: pure water does not conduct electricity. The process only works when there are ions in the water that can complete the circuit.

2.Which gas, hydrogen or oxygen, do you think was formed on the positive terminal of the battery? Explain your answer.

The negative terminal creates the hydrogen gas, while the oxygen gas is produced on the positive terminal. You can tell because there is a lot more gas produced by the negative terminal. Based on the chemical reaction of water splitting, more hydrogen gas is produced by the reaction, so the side of the battery with more gas must be the hydrogen side.

3. Based on this experiment, what do we need to make hydrogen?

We need water with something in it (ions), metal, and electricity.

Answer Key for Handout 3, "Hydrogen Fuel Cell Activity"

1. Hydrogen enters the fuel cell from the hydrogen storage tank.

2. Hydrogen reacts with the metal catalyst, releasing its electrons and becoming hydrogen ions.

3. The electrons move through the circuit wires. As they move, they are used to do electrical work, such as powering a light bulb or running an electric motor.

4. While the electrons move through the wires, the hydrogen ions move across the fuel cell membrane.

5. When these ions reach the other metal catalyst, they interact with oxygen that is brought in from the outside air and the electrons that are making their way through the wires. At this metal catalyst, all three join to make water molecules (which are released into the atmosphere).

6. The chemical reaction in this fuel cell is the opposite of the water splitting reaction.

$$2H_2O \longrightarrow 2H_2 + O_2$$