



A COMPREHENSIVE CURRICULUM EXAMINING:

- Energy use today and tomorrow
- The potential of hydrogen as a primary energy source
- Revolutionary fuel cell technology



HYDROGEN: TOMORROW'S ENERGY SOURCE

Message to Educators

The U.S. Department of Energy has said that hydrogen is the “man on the moon” for this generation. As the most abundant and nonpolluting element on earth, hydrogen holds tremendous promise for our country and the world as a primary energy source.

To help your students better understand and appreciate this new energy source and technology that will certainly be fundamental in their future, General Motors and Weekly Reader Corporation Custom Publishing have collaborated to bring you this free educational program, *Hydrogen: Tomorrow's Energy Source*. Created for grades 5 through 8, it is designed to help students:

- explore the energy systems in place today;
- understand the current challenges and increasing energy demands;
- learn about hydrogen and the benefits of using it for our future energy needs;
- discover the possibilities of fuel cell technology and how it works; and
- cultivate an awareness of the hydrogen economy and what it will take to encourage the use of hydrogen as a primary source of energy.

We hope that you find these materials helpful in teaching your students about one of the most relevant economic, environmental and societal topics of our time.

Please share your opinion of these materials by returning the enclosed educator survey and reply card so that we can create future materials that best suit the needs of you and your students.

Target Audience

Students in grades 5 through 8

National Education Standards Links

Science

- Structure and properties of matter
- Sources and properties of energy

Technology

- Relationships among science, technology, society and the individual
- Nature and uses of different forms of technology

Geography

- How human actions modify the physical environment
- How physical systems affect human systems
- Changes that occur in the meaning, use, distribution and importance of resources
- Global development and environmental issues

Mathematics

- Strategies in the problem-solving process
- Properties of the concepts of numbers
- Procedures while performing the processes of computation

Program Components

- This teacher's guide, which includes support information to accompany the student booklet, and four reproducible student activities to be used as introductory and follow-up lessons
- A “Fuel Cells: Driving the Future” classroom DVD
- Fifty (50) 12-page student booklets
- A 22" x 32" wall poster
- An educator survey
- An educator reply card



Using the Poster

Please display the wall poster in your classroom as an introduction to these lessons or to culminate the unit. The poster highlights the benefits of hydrogen and includes a timeline of energy use in the U.S. Also featured are three fuel cell vehicles developed by GM that illustrate the advances made in transitioning to the coming hydrogen economy. Students can learn about these vehicles at gmability.com/education.

“Fuel Cells: Driving the Future” DVD

Total Running Time: 13:30

Use this classroom DVD to begin a discussion with your students on energy use today and tomorrow. The DVD provides an animated look at how fuel cells work, and highlights the technology and vehicles being developed to run on hydrogen.

You may want to pause the DVD and discuss the following questions with your class while viewing:

1. **What are some of the things we use energy for?** (powering vehicles and electronics, heating and cooling homes, running factories)
2. **Where do we get most of the energy we use today?** (from fossil fuels, like petroleum, natural gas and coal)
3. **What is the difference between nonrenewable and renewable energy resources?** (Nonrenewable resources can't be replaced in a short amount of time; their supply is limited. Renewable resources are those that can be replenished in a short period of time.)
4. **How and where can hydrogen be produced in the United States?** (Hydrogen cannot be extracted from the ground like fossil fuels, but can be derived from a variety of sources all over the country using many different kinds of power. Some examples are wind in the Midwest, solar energy in California and the Southwest, hydroelectric power in the Northwest, coal in the Northeast, natural gas in the Rocky Mountains or oil in the Gulf States.)
5. **What could fuel cells be used for in the future?** (to power homes, businesses, factories, vehicles, and electronics like cell phones, laptops or portable video games)
6. **What two elements does a fuel cell combine?** (hydrogen and oxygen)
7. **What emission is produced from vehicles powered by fuel cells?** (water vapor)
8. **Why are people looking at hydrogen fuel cells as a possible energy source for the future?** (Demand for personal transportation is expected to grow in the next 20 years, creating environmental and energy concerns. Hydrogen fuel cells have environmental advantages over fossil fuels being used today; stationary fuel cells could potentially generate electricity for developing countries; a fuel cell power supply has the potential to output electrical power as long as there is a continuous supply of hydrogen.)
9. **What is meant by the phrase “the hydrogen economy”?** (It's an energy system in which hydrogen is produced cleanly and domestically from a variety of sources; and is distributed and stored on a routine basis. It's also a system in which hydrogen-powered fuel cells are as accepted and utilized as gasoline engines are today.)



Student Booklet Discussion Guide

Distribute the booklets to students and use the points below to generate classroom discussion.

Page One - Ask your students what they know about hydrogen. Then, see what students have already heard about the current energy situation and the focus on hydrogen as a solution to solving our growing demand for energy in the future.

Page Two - Discuss the terms under the window on this page. Ask students: *What fuel do we currently use as the primary source (40%) of our energy needs?* (petroleum) *Does using petroleum for energy cause environmental concerns?* (Yes, burning fossil fuels such as petroleum releases carbon dioxide, a greenhouse gas that may contribute to global warming.) *How can increased reliance on hydrogen and other renewable fuels make our economy less vulnerable to petroleum supply disruptions?* Flexibility is the key to withstanding petroleum supply disruptions and these alternative fuels allow our economy to quickly switch out of petroleum when the world supply is disrupted by domestic events such as petroleum refinery explosions or international events such as petroleum embargoes.

Page Three - Talk to your students about energy and ways they depend on energy (traveling to school, lighting classrooms, powering computers, etc.). Also review terms like fossil fuels, greenhouse gases and critical pollutants.

Page Four - Tell students that by the year 2030, the world's economy — the amount of goods and services that it produces — will more than double and the population will increase by two billion people. Discuss the impact that will have on energy demands and transportation use.

Page Five - Discuss renewable energy resources with your class, and the benefits they have over nonrenewable resources. Ask students to consider how their lives would be different today if we were still using wood as our primary energy source, as people did prior to 1885.

Page Six - Explain to students that the word *hydrogen* comes from the Greek words *hydro* meaning *water*, and *genes* meaning *generator*. That's because when two hydrogen atoms combine with oxygen, they form water (H₂O). Also share with students that NASA has used hydrogen for fuel in the space program for years. The astronauts even drink the water that it generates.

Page Seven - Discuss the meaning of technology. (Technology is the science of applying knowledge to make, use or improve something. It has shaped the world in which we live, play, work, communicate and travel.) Ask your students what they think are the most important technological advancements we use in our world today. List them on the chalkboard. Then challenge students to rank the top five in order of importance.

Pages Eight and Nine - Review chemistry terms with students, including elements, anode, cathode, protons, electrons and compounds. For a fuel cell glossary and an interactive tour on how fuel cells work, have students visit gmability.com/education. There's also an online fuel cell crossword puzzle to test students' comprehension.

Page Ten - Tell students that micro-fuel cells have the potential to last more than three times as long as batteries between refueling. Ask students to think of other uses for fuel cells. What are the benefits of this technology?

Page Eleven - Have students imagine a vehicle providing power for a house. What do they think such a vehicle would look like? Explain to your class that the fuel cell stack used to provide power to a vehicle is only about the size of a suitcase. It fits into an 11-inch-thick chassis that looks like a skateboard.

Page Twelve - Tell students that GM has partnered with Shell Hydrogen LLC so that while GM produces hydrogen fuel cell-powered vehicles, Shell can provide the hydrogen fueling stations necessary to refuel them. What other types of partnerships do students think would be needed to bring about the hydrogen economy?

Activity One – H is for Hydrogen

This activity strengthens and reviews basic chemistry vocabulary, while introducing students to the element hydrogen. Photocopy and distribute the activity to students, and allow time for them to complete it independently before reviewing the answers as a class.

Answers

1. hydrogen 2. sun 3. proton 4. first, or inner, shell of an atom 5. oxygen 6. atomic number 7. electron

Share with students the fact that hydrogen atoms can only join together to form helium atoms at temperatures close to 100,000,000°C!

As an extension, challenge students to write five riddles of their own related to various elements and chemical terms. Combine all riddles to play a game in class with teams of students.

Activity Two – Why Hydrogen?

This activity teaches students the difference between fossil fuels and hydrogen-powered fuel cells. It will help students understand the positive impact that fuel cells have on the environment. Begin by explaining the following to students:

- We currently get most of our energy from fossil fuels — petroleum, natural gas and coal.

These are essential sources of energy that are important to America's industry and economy.

- There is a finite amount of fossil fuels in the world. These are nonrenewable energy resources.
- Renewable energy resources are those that can be replenished in a short period of time. Many alternative fuels are renewable sources of energy and can help meet future energy demands.
- Hydrogen can be produced from the decomposition of water, and becomes water again when it combines with oxygen in a fuel cell.

Photocopy and distribute the activity sheet to students. After they study the diagrams and answer the questions, discuss the answers as a class.

Answers

1. Fossil fuels, such as petroleum, natural gas and coal, are energy sources thought to be formed over millions of years from the remains of dead plants and animals.
2. Nonrenewable resources are thought to be formed over millions of years and cannot be replaced in a short period of time. Renewable resources are those that can be replenished in a short period of time.
3. Water, the air we breathe (the atmosphere), fossil fuels
4. Solar, wind, biomass, geothermal, hydropower

5. Electricity

6. Water vapor and heat

7. Gasoline is made from petroleum, or crude oil, which is pumped from the ground.

8. Greenhouse gases work like glass in a greenhouse wall. They allow sunlight to come in to the earth's atmosphere, but prevent some heat from escaping.

9. Global warming results in additional heating of the earth's atmosphere.

Activity Three – How Does Your Energy Measure Up?

In this activity, students look at how hydrogen compares to other energy carriers in use today, including gasoline, natural gas, heating oil and electricity. Photocopy and distribute the activity to students. Allow students to use a calculator when solving the problems, but ask that they show the steps outlining how they reached their answers on a separate piece of paper.

Depending on the ability levels of your group, you may want to read the word problems aloud as a class and discuss the steps necessary to finding the answers. Or, you may have students work in pairs to complete the activity. Discuss the answers as a class.

Answers

1. Gasoline-powered vehicle: \$36.94; Hydrogen fuel cell vehicle: \$19.82; cheaper by \$17.12
2. Gasoline-powered vehicle: week - \$21.48; month - \$85.92; Hydrogen fuel cell vehicle: week - \$11.52; month - \$46.08
3. Gasoline-powered vehicle: \$1,030.91; Hydrogen fuel cell vehicle: \$553.17; cheaper by \$477.74; five-year savings: \$2,388.70
4. 85,068,000 Btu; 633.89 kg of hydrogen
5. 3,940,860 Btu; 29.37 kg of hydrogen
6. 93,113.48 cubic feet of natural gas; 715.35 kg of hydrogen

As an extension, have each student poll at least two adults on the number of miles they drive each week. Using the fuel price rate and miles per kilogram/gallon in the activity, students should create a chart comparing savings over a month and year's time if the adults were driving hydrogen fuel cell vehicles.

Activity Four – Coming Together for a Hydrogen Economy

This activity focuses on the hydrogen economy and the various partnerships necessary for the transition to it. Photocopy and distribute the activity to students. Headlines about various types of agreements are featured to convey that one company can have many partners in furthering the hydrogen economy, and

those partners, in turn, can work with additional collaborators. In creating a graphic organizer, students should place each partner/country's name in a circle and connect them appropriately, revealing a web of associations working together to transition to a hydrogen economy.

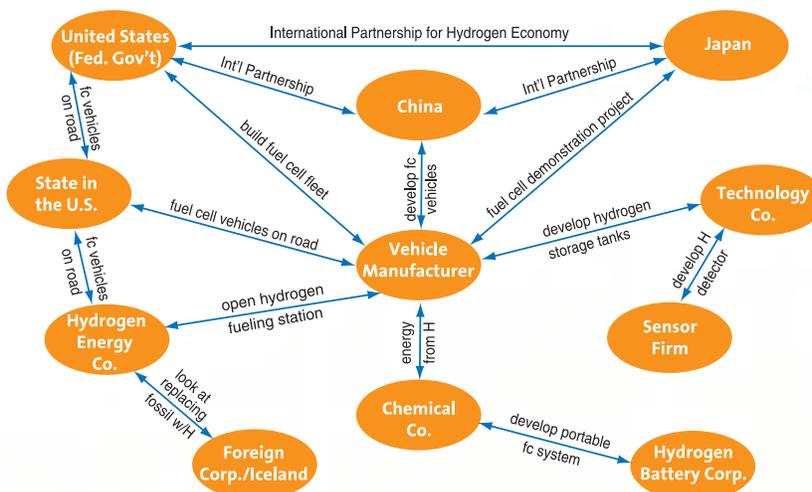
Although individual student webs will vary, one possible answer is shown below.

After students complete their organizers, brainstorm as a class why each of the entities included is important to the process and what role they play in promoting the hydrogen economy.

Explain to students that there are challenges that need to be overcome before we fully transition to the hydrogen economy, including: hydrogen storage, affordable cost, durability of the fuel cell stack, infrastructure development and public acceptance, among

others. Mention one of these challenges to your students and have them brainstorm solutions: how does the challenge affect the process, what has to happen to overcome it, and which groups or types of companies could help?

As an extension, ask students to collect current news stories of countries and businesses working together to further the hydrogen economy. These can be formed into another graphic organizer similar to the one created in this activity. After students acquire an understanding of where the world stands in this transition, have them predict milestones in the hydrogen economy, such as stationary fuel cells being sold for single home use and the first fuel cell vehicle being sold at a price competitive to gasoline-powered vehicles.



Extension Activities

- Ask students to pretend that fuel cell vehicles are available to the public, and they are being sold at prices competitive to other vehicles. Have them write newspaper articles urging the public to trade in their old vehicles and buy new fuel cell vehicles, as opposed to ones that use gasoline.
- Invite students to create advertisements for products that run on hydrogen for power. It can be an already existing product, or one they develop.
- Have students research existing partnerships that have been formed to help transition to the hydrogen economy. Also, encourage students to research state and other localized initiatives on fuel cell development and the hydrogen economy.
- Ask students to investigate different types of fuel cells (PEM, phosphoric acid, etc.) and how they are used.
- Have students create a chart examining the impact of both petroleum and hydrogen on the economy, society and the environment.
- There have been time periods throughout history, and technological advancements and discoveries that have shaped our world — including the Industrial Revolution (e.g., the inventions of the spinning jenny, steam locomotive, telegraph, canal system, transcontinental railroad system, Interstate highway system); medical successes, from the development of antibiotics and vaccines to the creation of X-rays and CAT-scans; and communication system developments, including the telephone and World Wide Web. Ask students to choose an invention or period in history and examine its impact on the economy, society and the environment.

Web Extension — gmability.com/education

Please visit GM's education web site where you can find up-to-date materials and resources for both you and your students.

At gmability.com/education, you will find:

- additional lesson plans for grades K through 12
- downloadable files of this curriculum, along with a Spanish-language version
- games designed to be both fun and educational, including trivia quizzes and crossword puzzles that are great for assessment
- interactive photo tours and diagrams, including a comprehensive look at how fuel cells work
- articles on fuel cells and energy, technology, the environment, making vehicles and more
- a glossary and homework help

Resources & Bibliography

Energy Information Administration's Energy Kid's Page - www.eia.doe.gov/kids

Hydrogen R&D Task Force - www.hydrogen.gov

Rifkin, Jeremy. *The Hydrogen Economy: The Creation of the Worldwide Energy Web and the Redistribution of Power on Earth*. New York: Jeremy P. Tarcher/Penguin, 2002.

Saucerman, Linda. *Understanding the Elements of the Periodic Table™: Hydrogen*. New York: The Rosen Publishing Group, Inc., 2005.

U.S. Department of Energy's Hydrogen Energy Program - www.hydrogen.energy.gov

