2015-2016

H_2 Educate
Teacher Guide

Information and hands-on activities to teach students about hydrogen as a transportation fuel, a fuel for electricity generation, and its uses in industrial processes.

Grade Levels:

- Int Intermediate
- Sec Secondary

Subject Areas:

- Science
- Social Studies
- Language Arts
- Math
- Technology

NEED
National Energy Education Development Project

Teacher Advisory Board

NEED Mission Statement

The mission of The NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

Teacher Advisory Board Statement

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

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Energy Data Used in NEED Materials

NEED believes in providing the most recently reported energy data available to our teachers and students. Most statistics and data are derived from the U.S. Energy Information Administration's Annual Energy Review that is published yearly. Working in partnership with EIA, NEED includes easy to understand data in our curriculum materials. To do further research, visit the EIA website at www.eia.gov. EIA's Energy Kids site has great lessons and activities for students at www.eia.gov/kids.

NEED
National Energy Education Development

1.800.875.5029
www.NEED.org

H_2 Educate

Teacher Guide

H_2 Educate was developed by NEED's Teacher Advisory Board Hydrogen Committee with funding from the U.S. Department of Energy Hydrogen Program.

H_2 Educate Kit

- 8 600 mL Beakers
- 16 9-volt Batteries
- 4 AA Batteries
- 1 Container sodium sulfate
- 8 Electrolysis apparatuses (contains test tubes and tongs)
- 2 Extra test tubes
- 100 ft Fringe
- 10 Flashing bulb pins
- 2 Flashlights (batteries included)
- 2 Fuel cell car kits
- 1 Funnel
- 1 100 mL Beaker
- 2 Packages clay
- 25 Wooden splints
- 100 Small straws
- 10 Alligator clip sets
- 30 Student Guides

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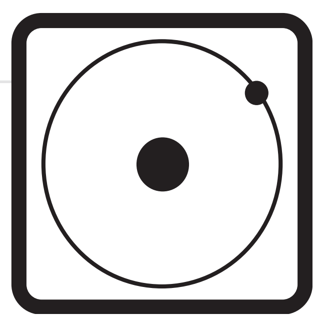


Standards Correlation Information

www.NEED.org/curriculumcorrelations

Next Generation Science Standards

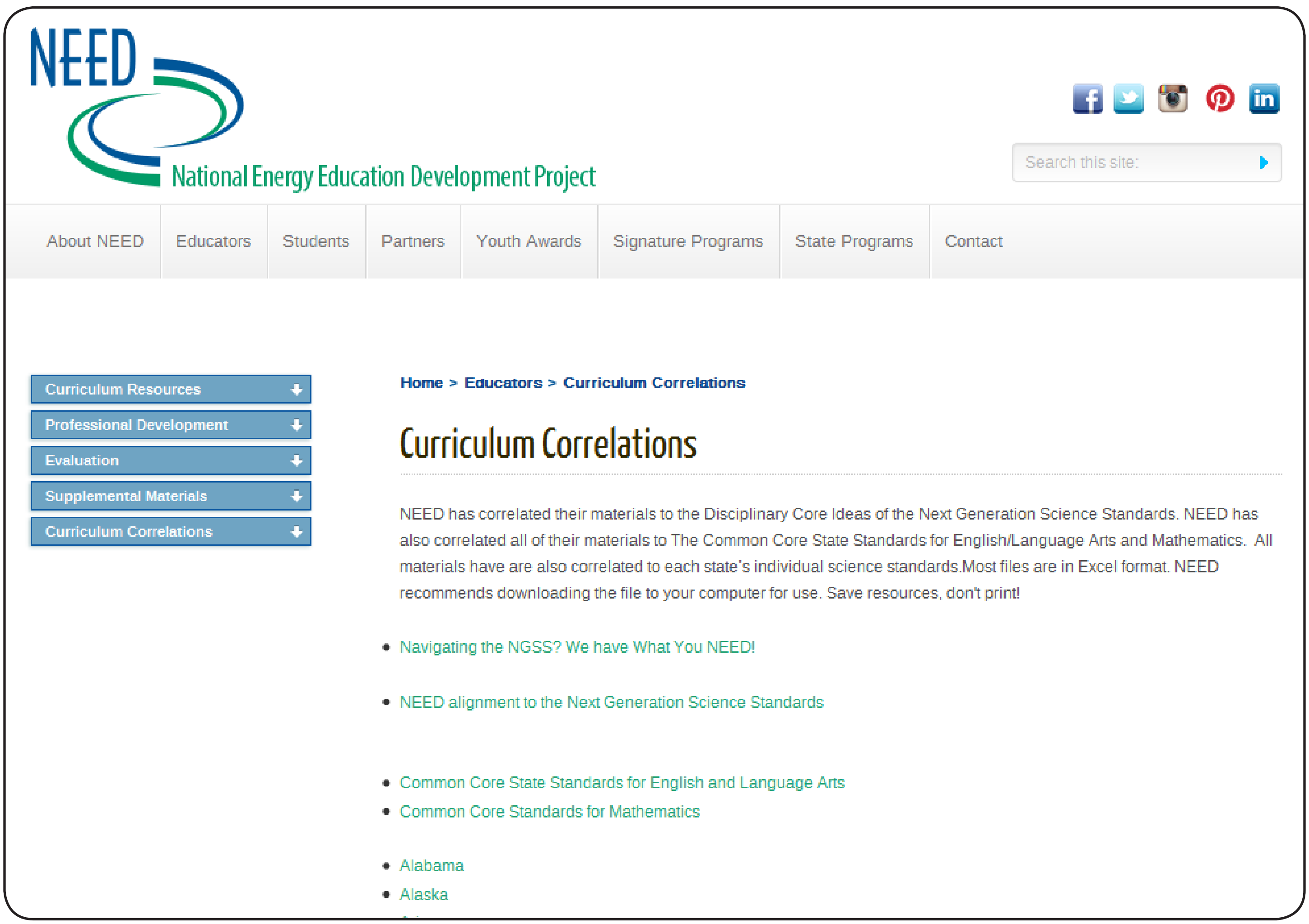
- This guide effectively supports many Next Generation Science Standards. This material can satisfy performance expectations, science and engineering practices, disciplinary core ideas, and cross cutting concepts within your required curriculum. For more details on these correlations, please visit NEED's curriculum correlations website.

Common Core State Standards

- This guide has been correlated to the Common Core State Standards in both language arts and mathematics. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED curriculum correlations website.

Individual State Science Standards

- This guide has been correlated to each state's individual science standards. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED website.



H_2 Educate Materials

The table below lists activities that require kit materials and supplies other than paper and pencils. Contact NEED with any questions about kit materials or how to procure items not included within the kit.

A set of consumables is available for purchase. Materials in the consumables package are also listed below. Call NEED to order a consumables pack at 1-800-875-5029.

ACTIVITY	MATERIALS IN KIT	ADDITIONAL MATERIALS NEEDED
Setting the Stage for Hydrogen	▪Hydrogen fuel cell car	▪Distilled water
Hydrogen in Society Jigsaw		▪Poster board
Electrolysis	▪Sodium sulfate ▪Electrolysis apparatuses (with test tubes and tongs) ▪600 mL Beakers ▪Splints ▪9-volt Batteries ▪Alligator clips ▪Funnel ▪100 mL Beakers	▪Distilled water ▪Safety matches ▪Safety glasses ▪Gloves
Element Modeling	▪Straws ▪Clay—three different colors	▪Scissors
Fuel Cell Simulation	▪Flashing bulbs ▪Fringe ▪Flashlight	▪Colored tape ▪String ▪Scissors ▪Cardstock
Hydrogen in the Round		▪Cardstock

Warning

Do not substitute sodium sulfate with calcium chloride or any other chloride salt! If you do not have access to sodium sulfate, magnesium sulfate (Epsom salt) may be used as a substitute. Epsom salt can be purchased at most pharmacies.

Set of Consumables

- 16 9-volt Batteries and 4 AA batteries
- 2 Packages clay
- 1 Container sodium sulfate
- 25 Splints
- 100 Straws
- 100 Feet of fringe
- 5 Teacher and 30 Student Guides

Teacher Guide

Grade Levels

- Intermediate, grades 6–8
- Secondary, grades 9-12

Time

- Approximately 5-10 class periods, depending on activities selected and the structure of the unit

Science Notebooks

Throughout this curriculum, science notebooks are referenced. If you currently use science notebooks or journals, you may have your students continue using these.

In addition to science notebooks, student worksheets have been included in the guides. Depending on your students' level of independence and familiarity with the scientific process, you may choose to use these worksheets instead of science notebooks. Or, as appropriate, you may want to make copies of worksheets and have your students glue or tape the copies into their notebooks.

Background

This hydrogen unit is designed as a multidisciplinary curriculum with a hands-on science kit, fuel cell simulation equipment, element modeling materials, fuel cell car kit for demonstration, and language arts, social studies, and technology activities. The unit explores the energy picture in the United States today, the challenges for the future, the role of hydrogen in meeting those challenges, and the scientific basis for hydrogen as a fuel, with an exploration of electrolysis as a method to generate hydrogen.

Preparation

- Read the Teacher and Student Guides for an overview of all activities in the unit. Familiarize yourself with the student text. Select activities you will use if not conducting the entire unit.
- Examine the equipment in the kit to become familiar with its design and to make sure nothing was damaged in shipment. Refer to the Operating Instructions and Experiment Instructions Manual in the *Fuel Cell Car Kit* to gain a more comprehensive understanding of how the car works.
- Decide how you will structure the unit—as a single class unit or as an integrated unit with other teachers. If this will be an integrated unit, meet with the other teachers to plan and schedule the activities. A suggested integrated unit is as follows:

  Pre/Post Assessment—Science

  Fuel Cell Car Demonstrations—Science

  Comparing Energy Systems—Social Studies

  Background Reading and Graphic Organizers—Language Arts

  Electrolysis and Element Modeling—Science

  Hydrogen in Society Jigsaw Activity—Social Studies

  Fuel Cell Simulation and Report—Language Arts

  Hydrogen Economy Comparison Activity—Social Studies

  Hydrogen in the Round Game—Language Arts
- Collect the materials needed for the activities selected. A listing of necessary materials can be found on page 5.
- Make copies of the pages in the Teacher and Student Guides that you want the students to complete or have the students copy them into science notebooks as they need them. It is suggested that the students not write in the Student Guides, but keep science notebooks in which they record all of their activities.
- Prepare a copy of the *Lab Safety Rules* master for projection during lab activities.
- Pre-select student groups and assign roles as appropriate for the following activities:

  Activity 2: Jigsaw—seven role groups

  Activity 2: Jigsaw—three to five presentation groups with one representative of each role group

  Activities 5 and 6: Electrolysis and Element Modeling—groups of two lab partners

Activity 1: Setting the Stage for Hydrogen

✪ Objective

- Students will be able to identify basic information about hydrogen and energy.

Materials

- Hydrogen Fuel Cell Car
- *Assembly and Operation of the Fuel Cell Car*, Teacher Guide page 20
- *Pre/Post Hydrogen Assessment*, Teacher Guide page 30

✔ Procedure

1. Introduce the unit to the class. Ask students to brainstorm a list of things they associate with the word "hydrogen".
2. Demonstrate the Hydrogen Fuel Cell Car to stimulate interest. Use the assembly and operation instructions for assistance as needed.
3. Have the students take the *Pre/Post Hydrogen Assessment* and collect the results to send to NEED at the conclusion of the unit.

Activity 2: Hydrogen in Society Jigsaw

✪ Objective

- Students will be able to identify basic information about hydrogen and energy.

Materials

- Poster boards
- *Jigsaw Role Questions and Presentation Questions,* Teacher Guide page 21
- *Hydrogen Information Web Links*, Student Guide page 14
- *Hydrogen in Society* role group worksheet, Student Guide page 15
- *Hydrogen in Society Presentation Organizer*, Student Guide page 16
- Student informational text, Student Guide pages 3-13
- *Rubrics for Assessment*, Teacher Guide page 15

✔ Procedure

1. Divide the students into seven groups. Assign each group one of seven specific roles, as listed below. These groups are the role groups. Also assign the students to presentation groups, in which they will share their role expertise. Each presentation group should include at least one member from each role group.

   Role Groups:

Physicist	Hydrogen Producer
Hydrogen Distributor	Energy Security Advisor
Energy Economist	Energy Efficiency and Reliability Expert
Environmental Scientist	

2. Explain the jigsaw assignment to the students. Give each student the list of role questions for his/her role group and a copy of the role group worksheet. Explain that the questions will guide their reading and research. Explain that they will be involved in completing the organizer over several days as they participate in the readings and other hydrogen-related activities. They will use the information they have gathered to design and present projects at the end of the unit in their presentation groups.
3. Instruct the students to use the informational text, as well as outside sources, to answer their questions as completely as possible. Guide them to the list of hydrogen websites where they can go to find additional information.
4. At the end of the electrolysis and simulation activities, after the students have read all of the text sections, and completed their research and their worksheets, have the role groups meet to discuss their findings. Instruct the students to add to their worksheets any additional information provided by group members.

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5. After the students have met in the role groups and completed their discussions, assign them to their presentation groups. Explain that the presentation groups will synthesize the information collected by the different role groups.
6. Distribute copies of the presentation questions and presentation organizer to each student. Instruct the presentation groups to work together to answer the presentation questions, using poster boards to collect members' ideas from each of the role areas.
7. After the groups have answered all of the presentation questions, instruct each presentation group to choose a format with which to present their findings. Suggested formats include a PowerPoint presentation, a brochure, an expo display board, a song or rap, a letter to the editor of the school newspaper, a persuasive essay, an advertisement, a video, or any other format acceptable to the teacher.
8. Give the groups a timeframe in which to complete and present their projects.
9. Use the *Presentation Rubric* to evaluate the projects.

Activity 3: Comparing Energy Systems

✪ Objective

- Students will be able to analyze the energy system in use in the United States and compare it to an ideal energy system.

Materials

- Student informational text, Student Guide pages 3-4
- *Comparing Energy Systems*, Student Guide page 17

✔ Procedure

1. Have the students read the following informational text sections:

    The Energy Picture in the United States Today and *Looking to the Future*, including The Ideal Energy System

2. Have the students draw Venn diagrams or use the worksheet to compare the energy system in the United States today with the ideal energy system.
3. Discuss as a class the problems with our energy system today.
4. Brainstorm ideas for making today's energy system more ideal.

Activity 4: The Science of Hydrogen

✪ Objective

- Students will be able to identify physical and chemical properties of hydrogen.

Materials

- *The Science of Hydrogen* graphic organizer, Student Guide page 18
- Student informational text, Student Guide pages 4-6

✔ Procedure

1. Have the students complete the graphic organizer as they read the following background sections:

    What is Hydrogen?, Atomic Structure, Chemical Bonding, and *The Periodic Table of the Elements*

2. Discuss any questions the students have.

Activity 5: Electrolysis

Objective

- Students will be able to describe how a water molecule can be separated into hydrogen and oxygen.

Materials *TO MAKE ELECTROLYTE SOLUTION*

- 1 Gallon distilled water
- 100 mL Beaker
- Funnel
- Sodium sulfate (Na_2SO_4)
- *Lab Safety Rules* master, Teacher Guide page 19
- *Electrochemistry and Electrolysis*, Student Guide page 19
- *Electrolysis Apparatus* diagram, Student Guide page 20
- *Electrolysis Exploration*, Student Guide page 21
- *Electrolysis Data Recording Form*, Student Guide page 22

Materials *AT EACH LAB STATION*

- 1 Electrolysis apparatus (with two test tubes and set of tongs)
- 1 9-volt Battery
- 1 600 mL Beaker with 500 mL of electrolyte solution
- 2 Alligator clips
- 1 Splint
- 1 Book of safety matches
- Lab safety equipment (safety glasses and gloves)

Classroom Management Tip

- This activity works best if completed at the same time as *Activity Six: Element Modeling*, as it allows students to work in pairs.

Preparation

- Assign students to groups of two and give each group a lab station or element modeling station. Sixteen students will participate in this lab during the first rotation and the remaining students will participate in the element modeling activity. In the second rotation, the students will switch activities. Write on the board or project the Discussion Questions and Variable Questions on page 10 of the Teacher Guide.
- Prepare 1 gallon of the electrolyte solution (100 cm^3 of Na_2SO_4 to 1 gallon water) as follows:
    - Measure 100 mL from your gallon of distilled water. Set aside in a clean container. (This distilled water is needed for any fuel cell car demonstrations).
    - Add 100 cm^3 (equal to 100 mL, or 167 grams) of sodium sulfate (Na_2SO_4) to the jug of distilled water using the small beaker and funnel. Close the jug and gently shake the jug until the sodium sulfate is dissolved.

NOTE: *The solution should be saved in the jug for subsequent group use after the first group of students has completed the experiment. The solution can be saved indefinitely in a plastic container. If you are saving it in the distilled water jug, be sure to clearly mark the jug with its contents.*

NOTE: *The electrolysis process will proceed more quickly if the electrolyte solution is very warm or more concentrated. If the chemical reaction is too slow, the students may lose interest. It is suggested that you place the container with the electrolyte solution in a hot water bath approximately an hour before the lab is scheduled. If this is not feasible, you may increase the concentration of the solution by adding 10 cm^3 more sodium sulfate to the solution.*

- Fill eight 600 mL beakers with 500 mL of the electrolyte solution.
- Set up eight lab stations with the equipment listed above.

Lab Safety

1. Go over the *Lab Safety Rules* master and the Material Safety Data Sheet (MSDS) for Sodium Sulfate included in the kit with the students. Reinforce any other lab safety rules that you require.
2. Decide if you want the students to use the matches and splints on their own or only with teacher supervision. Be prepared to explain to the students any changes in the lab procedure.

Warning

Do not substitute sodium sulfate with calcium chloride or any other chloride salt! If you do not have access to sodium sulfate, magnesium sulfate (Epsom salt) may be used as a substitute. Epsom salt can be purchased at most pharmacies.

✔ Procedure

1. Have the students read and familiarize themselves with the following informational text sections and worksheets in the Student Guide: *How Is Hydrogen Made?*, *Electrochemistry and Electrolysis*, *Electrolysis Exploration*, and *Electrolysis Data Recording Form*. Answer any student questions and provide instructions about recording the data in the students' notebooks. If necessary, review the lab procedure on the *Electrolysis Exploration* worksheet.
2. Assign student pairs to lab stations and monitor their work.
3. When the students have completed the lab, have them return the electrolyte solution to the beakers and rinse the electrolysis apparatus, test tubes, and tongs under running water. Collect the electrolyte solution from the beakers and store in the marked container for reuse.
4. Instruct the students to answer the Discussion Questions below in their science notebooks.
5. Have the students who were participating in the *Element Modeling* activity conduct the lab, switching activities with their partner. Follow the same procedures.
6. When all students have completed the lab, have them formulate hypotheses and design lab procedures to answer the Variable Questions below.

Discussion Questions

1. What did you learn about the composition of water?
2. Explain how electrical energy decomposes water. Use the terms anode, cathode, oxidation, and reduction in your explanation.
3. Which gas is attracted to the positive electrode and which gas is attracted to the negative electrode? Explain why each gas is attracted to each electrode.
4. Explain how to test for hydrogen and oxygen gases.
5. Balance this equation for the decomposition of water: $8\ H_20$ = __H_2 + __O_2. (*Answer: $8\ H_2 + 4\ O_2$*)

Variable Questions

1. How would using distilled water with no electrolyte affect the results?
2. How would increasing the concentration of the electrolyte affect the results?
3. How would increasing the voltage affect the results? (connecting 2-4 batteries in parallel)
4. How would increasing the current affect the results? (connecting 2-4 batteries in series)
5. How would changing the temperature of the solution affect the results?

Extensions

▪ Exploring Variables

1. Have groups of students conduct the lab experiments that they designed to explore the variables in the questions listed above.
2. Have the student groups share the results of their variable experiments with the class.

▪ Graphing Results

1. On graph paper or using a computer-graphing program, have each lab group graph the volume of hydrogen (y-axis) in cubic centimeters vs. time (x-axis) in minutes. On the same graph, plot the volume of oxygen vs. time.
2. Have the students interpret the results of the graphs.
3. Have the students calculate the slope of the hydrogen line and the slope of the oxygen line. These slopes represent the average of the volumes of both gases over time. By dividing the slope of the hydrogen by the slope of the oxygen and expressing the result as a rounded whole number over 1, you will have a more accurate determination of the gas ratios.

Activity 6: Element Modeling

Objectives

- Students will be able to construct elements to model atomic structure.
- Students will be able to describe how atoms bond to form elements.

Materials

- Straws
- Three different colors of clay
- Scissors
- Student Informational text, Student Guide pages 5-6
- *Element Models* worksheet, Student Guide page 23
- *Element Models* master, Teacher Guide page 22

Classroom Management Tip

- This activity works best if completed at the same time as *Activity Five: Electrolysis*, as it allows students to work in pairs.

Preparation

- Prepare one or more work areas large enough for sixteen students to complete the activity.

Procedure

1. Have the students read *Atomic Structure, Chemical Bonding*, and *The Periodic Table of the Elements* in the informational text. Review the information to make sure the students understand atoms and their component particles, elements, molecules, and chemical bonds. Instruct the students to define the key terms in their science notebooks.
2. Have the students examine the Periodic Table of the Elements to find elements with which they are familiar.
3. Have the students read the *Element Models* activity. Answer any student questions. Emphasize to the students that the models will not be realistically representative of the structure of atoms and molecules.
4. Assign students to the work area and instruct them to complete the first model of the activity—a hydrogen atom. Check the students' models to make sure they are correct, as shown in the *Element Models* master. When all students have correctly created the hydrogen atom model, instruct them to create each additional model in turn, monitoring for understanding before proceeding to the next model.
5. When the students have completed the activity, which may not take as much time as the lab activity, instruct them to work on the jigsaw activity.

Element Modeling Performance Assessment

- Students should be able to distinguish between atoms and molecules and draw diagrams of simple molecules. Students' knowledge of basic molecular structure should be significantly enhanced.

Extension

- To reinforce student understanding of atomic structure and the relative distance of electrons from the nucleus, have a student stand in the middle of the football field holding a marble to represent the nucleus of an atom, while other students stand at each end zone to represent the position of the electrons, emphasizing that the electrons themselves would be too small to see.

Simulation Vocabulary

- anode
- atom
- catalyst
- cathode
- circuit
- electrode
- electrolysis
- electrolyte
- electron
- hydrogen
- ion
- membrane
- molecule
- oxygen
- PEM
- polymer

Simulation Suggestions

1. Students will need a 10' x 10' open space; use a hallway, outside area, or gym to allow enough room for movement and observers. Have the students set up the simulation according to the diagram.
2. Let students determine how to conduct the simulation. Part of the learning value of this activity is allowing students to discover and learn by doing, extending, and reinforcing prior knowledge.

Activity 7: Fuel Cell Simulation

Objectives

- Students will be able to explain how hydrogen is used to carry energy and generate electricity.
- Students will be able to explain the components of a PEM fuel cell and how it works.
- Students will be able to trace the flow of the system of a PEM fuel cell by accurately drawing and labeling a diagram.

Materials

- Flashing bulbs
- Flashlight
- Fringe
- Colored tape
- Scissors
- String
- Cardstock
- *Fuel Cell* master, Teacher Guide page 23
- *Fuel Cell Simulation*, Teacher Guide page 24
- Hang tag master, Teacher Guide page 25
- *Simulation Rubric*, Teacher Guide page 15
- Student informational text, Student Guide page 10
- *What is a Fuel Cell?* worksheet, Student Guide page 24

Preparation

- Write or display the vocabulary list on the left onto the board.
- Prepare a copy of the *Fuel Cell* master to project for the class.
- Make four copies of the hang tag master onto cardstock, cut out the hang tags and attach string to each tag. The hydrogen and oxygen hang tags are two-sided tags, folded on the dotted lines.

Procedure

1. Have the students review the vocabulary terms using the *Glossary* in the Student Guide.
2. Use the *Fuel Cell* master to introduce the operation of a fuel cell to the students.
3. Have the students read the *What is a Fuel Cell?* section of the informational text and the *What is a Fuel Cell?* activity instructions. Answer any student questions.
4. Assign roles to the students. Some students may be observers during the first simulation, then assume roles in a second simulation while the other students observe.

Assessment

1. After participating in and observing the simulation several times, have the students imagine they are writing to other students to explain how a fuel cell works, with an explanation of how fuel cells are used. Students must use the vocabulary words and draw diagrams to support their explanations. Alternatively, you could also assign students to write a fictional story detailing their journey through a fuel cell as hydrogen or oxygen.
2. Use the *Simulation Rubric* to assess vocabulary acquisition and understanding of concepts.

Activity 8: Hydrogen in Our Energy System

Objective

- Students will be able to describe the advantages, disadvantages, and challenges to the nation moving toward a hydrogen inclusive economy.

Materials

- Student informational text, Student Guide pages 8-9, 11-13
- *Hydrogen in Our Energy System*, Student Guide page 25

Procedure

1. Have students read the following informational text sections:

   Hydrogen as a Fuel, *Uses of Hydrogen*, and *The Challenges of Hydrogen,* including all subsections.

2. Have students use the graphic organizer to compare a hydrogen economy with the ideal energy system.
3. Discuss the advantages and disadvantages of hydrogen as a part of our economy, and the challenges that the nation will have transitioning towards more hydrogen use. Ask the students for their personal opinions about the feasibility of the United States making hydrogen fuels more of a priority.

Activity 9: Hydrogen in the Round

Objective

- Students will be able to properly identify hydrogen vocabulary definitions.

Materials

- *Hydrogen in the Round* cards, Teacher Guide pages 26-29
- Cardstock

Preparation

- Make copies of the *Hydrogen in the Round* cards on cardstock.
- Cut out the individual cards.

Procedure

1. Distribute the cards randomly to the students. If you have fewer than 30 students in the class, give some students two cards. All of the cards must be distributed for the game to succeed. If you have more than 30 students, assign a few students to work in pairs. These students can also serve as arbiters of disputes.
2. Explain the instructions for the game, as follows:
   - Select a student to start Round 1 by reading the first question on their card, "Who has....."
   - The student who has the answer to the question stands up and responds by reading his/her card, "I have...... Who has.....?'
   - This procedure continues until every person has read his/her card and the question has returned to the Starter, who answers the last question. It does not matter which student you start with, as the cards will go in a continuous round.
3. Use the answer key to follow along with students and help settle any disputes, if necessary. An answer key is found on page 14.
4. Proceed to play Round 2 in the same way.
5. Repeat this activity throughout the unit to reinforce vocabulary.

☑Evaluation

1. Have the students take the *Pre/Post Hydrogen Assessment* on page 30. Collect the results.
2. Play *Hydrogen Bingo* with students as a formative assessment. Instructions are found on pages 16-17 and the bingo card can be found on page 31.
3. Complete the unit *Evaluation Form* with the students on page 35.
4. Return the *Pre/Post Hydrogen Assessment* results and the *Evaluation Form* to The NEED Project.

Answer Key To Assessment

1. C **2.** A **3.** C **4.** C **5.** C **6.** T **7.** F **8.** D **9.** C **10.** C **11.** D **12.** F **13.** T **14.** T **15.** T

Hydrogen in the Round Answers

ROUND 1 – STARTING WITH HYDROGEN'S CLUE:

- Element
- Proton
- Neutron
- Electron
- Energy Level
- Radiant Energy
- Nuclear Fusion
- Steam Reforming
- Electrolysis
- Photoelectrolysis
- Biomass Gasification
- Photobiological Microbial Production
- Energy Carrier
- Fuel Cell
- Electrochemical Energy Conversion Device
- Circuit
- PEM
- Anode
- Catalyst
- Cathode
- Ion
- Ionic Bond
- Covalent Bond
- Energy
- Nonrenewable
- Renewable
- Endothermic
- Carbon Capture, Utilization, and Storage
- Periodic Table
- Hydrogen

ROUND 2 – STARTING WITH HYDROGEN'S CLUE:

- Photoelectrolysis
- Cathode
- Element
- Biomass Gasification
- Ion
- Proton
- Photobiological Microbial Production
- Ionic Bond
- Neutron
- Energy Carrier
- Covalent Bond
- Electron
- Fuel Cell
- Energy
- Energy Level
- Electrochemical Energy Conversion Device
- Nonrenewable
- Radiant Energy
- Circuit
- Renewable
- Nuclear Fusion
- PEM
- Endothermic
- Steam Reforming
- Anode
- Carbon Capture, Utilization, and Storage
- Electrolysis
- Catalyst
- Periodic Table
- Hydrogen

Rubrics For Assessment

Simulation Rubric

GRADE	SCIENTIFIC CONCEPTS	DIAGRAMS	PROCEDURES	SUMMARY
4	Written explanations illustrate accurate and thorough understanding of scientific concepts underlying inquiry.	Comprehensive diagrams are accurately and neatly labeled and make the designs easier to understand.	Procedures are listed in clear steps. Each step is numbered and is written as a complete sentence.	Summary describes information and skills learned, as well as some future applications to real life situations.
3	Written explanations illustrate an accurate understanding of most scientific concepts underlying inquiry.	Necessary diagrams are accurately and neatly labeled.	Procedures are listed in a logical order, but steps are not numbered or are not in complete sentences.	Summary describes the information learned and a possible application to a real life application.
2	Written explanations illustrate a limited understanding of scientific concepts underlying inquiry.	Necessary diagrams are labeled.	Procedures are listed but are not in a logical order or are difficult to understand.	Summary describes the information learned.
1	Written explanations illustrate an inaccurate understanding of scientific concepts underlying inquiry.	Necessary diagrams or important components of diagrams are missing.	Procedures do not accurately reflect the steps of the design process.	Summary is missing or inaccurate.

Presentation Rubric

GRADE	CONTENT	ORGANIZATION	ORIGINALITY	WORKLOAD
4	Topic is covered in depth with many details and examples. Subject knowledge is excellent.	Content is very well organized and presented in a logical sequence.	Presentation shows much original thought. Ideas are creative and inventive.	The workload is divided and shared equally by all members of the group.
3	Presentation includes essential information about the topic. Subject knowledge is good.	Content is logically organized.	Presentation shows some original thought. Work shows new ideas and insights.	The workload is divided and shared fairly equally by all group members, but workloads may vary.
2	Presentation includes essential information about the topic, but there are 1-2 factual errors.	Content is logically organized with a few confusing sections.	Presentation provides essential information, but there is little evidence of original thinking.	The workload is divided, but one person in the group did not do his/her fair share of the work.
1	Presentation includes minimal information or there are several factual errors.	There is no clear organizational structure, just a compilation of facts.	Presentation provides some essential information, but no original thought.	The workload is not divided, or several members are not doing their fair share of the work.

Hydrogen BINGO Instructions

***Hydrogen Bingo* is a great icebreaker for a NEED workshop or conference. As a classroom activity, it also makes a great introduction to an energy unit.**

Preparation

- 5 minutes

Time

- 45 minutes

Bingos are available on several different topics. Check out these resources for more bingo options!

- Biomass Bingo—*Energy Stories and More*
- Change a Light Bingo—*Energy Conservation Contract*
- Energy Bingo—*Energy Games and Icebreakers*
- Energy Efficiency Bingo—*Monitoring and Mentoring* and *Learning and Conserving*
- Hydropower Bingo—Hydropower guides
- Marine Renewable Energy Bingo—*Ocean Energy*
- Nuclear Energy Bingo—Nuclear guides
- Offshore Oil and Gas Bingo—*Ocean Energy*
- Oil and Gas Bingo—Oil and Gas guides
- Science of Energy Bingo—*Science of Energy* guides
- Solar Bingo—Solar guides
- Transportation Bingo—*Transportation Fuels Infobooks*
- Wind Energy Bingo—Wind guides

Get Ready

Duplicate as many *Hydrogen Bingo* sheets (found on page 31) as needed for each person in your group. In addition, decide now if you want to give the winner of your game a prize and what the prize will be.

Get Set

Pass out one *Hydrogen Bingo* sheet to each member of the group.

Go

PART ONE: FILLING IN THE BINGO SHEETS

Give the group the following instructions to create bingo cards:

- This bingo activity is very similar to regular bingo. However, there are a few things you'll need to know to play this game. First, please take a minute to look at your bingo sheet and read the 16 statements at the top of the page. Shortly, you'll be going around the room trying to find 16 people about whom the statements are true so you can write their names in one of the 16 boxes.
- When I give you the signal, you'll get up and ask a person if a statement at the top of your bingo sheet is true for them. If the person gives what you believe is a correct response, write the person's name in the corresponding box on the lower part of the page. For example, if you ask a person question "D" and he or she gives you what you think is a correct response, then go ahead and write the person's name in box D. A correct response is important because later on, if you get bingo, that person will be asked to answer the question correctly in front of the group. If he or she can't answer the question correctly, then you lose bingo. So, if someone gives you an incorrect answer, ask someone else! Don't use your name for one of the boxes or use the same person's name twice.
- Try to fill all 16 boxes in the next 20 minutes. This will increase your chances of winning. After the 20 minutes are up, please sit down and I will begin asking players to stand up and give their names. Are there any questions? You'll now have 20 minutes. Go!
- During the next 20 minutes, move around the room to assist the players. Every five minutes or so tell the players how many minutes are remaining in the game. Give the players a warning when just a minute or two remains. When the 20 minutes are up, stop the players and ask them to be seated.

PART TWO: PLAYING BINGO

Give the class the following instructions to play the game:

- When I point to you, please stand up and in a LOUD and CLEAR voice give us your name. Now, if anyone has the name of the person I call on, put a big "X" in the box with that person's name. When you get four names in a row—across, down, or diagonally—shout "Bingo!" Then I'll ask you to come up front to verify your results.
- Let's start off with you (point to a player in the group). Please stand and give us your name. (Player gives name. Let's say the player's name was "Joe.") Okay, players, if any of you have Joe's name in one of your boxes, go ahead and put an "X" through that box.
- When the first player shouts "Bingo," ask him (or her) to come to the front of the room. Ask him to give his name. Then ask him to tell the group how his bingo run was made, e.g., down from A to M, across from E to H, and so on.

- Now you need to verify the bingo winner's results. Ask the bingo winner to call out the first person's name on his bingo run. That player then stands and the bingo winner asks him the question which he previously answered during the 20-minute session. For example, if the statement was "can name two renewable sources of energy," the player must now name two sources. If he can answer the question correctly, the bingo winner calls out the next person's name on his bingo run. However, if he does not answer the question correctly, the bingo winner does not have bingo after all and must sit down with the rest of the players. You should continue to point to players until another person yells "Bingo."

HYDROGEN BINGO

ANSWERS

A. Knows the atomic number of hydrogen

B. Knows the percentage of U.S. energy consumption supplied by renewables

C. Knows the process that produces energy in the sun's core

D. Can define energy carrier

E. Knows what a fuel cell is

F. Can define distributed generation

G. Knows a process that separates water into hydrogen and oxygen

H. Knows the number of neutrons in a hydrogen atom

I. Knows in what form energy from the sun travels to the Earth

J. Can name four renewable energy sources

K. Knows the percentage of U.S. energy consumption supplied by fossil fuels

L. Knows the top energy carrier used in the U.S.

M. Knows the U.S. percentage of world population

N. Can name four nonrenewable energy sources

O. Knows the U.S. percentage of world energy consumption

P. Can name two ways hydrogen is used today

A the atomic number for hydrogen is 1	**B** renewables supply a little over 9 percent of U.S. energy consumption	**C** FUSION of hydrogen into helium produces energy in the sun's core	**D** a system or substance that moves energy from one place to another
E a device that uses chemical reaction to produce electricity - a battery	**F** distributed generation is electricity produced near the site of the consumer	**G** ELECTROLYSIS separates water into hydrogen and oxygen	**H** no neutrons in a simple hydrogen atom (deuterium and tritium isotopes have neutrons)
I energy from the sun travels to Earth in the form of radiant energy	**J** renewables: solar, wind, hydropower, biomass, geothermal	**K** fossil fuels supply about 82 percent of total U.S. consumption	**L** electricity is the top energy carrier in the U.S.
M the U.S. contains just under 5 percent of total world population	**N** nonrenewables: petroleum, natural gas, propane, coal, uranium	**O** the U.S. accounts for under 20 (18.5) percent of total world energy consumption	**P** used by industry for refining, treating metals, and processing foods; to fuel small hydrogen fuel cells to produce electricity; hydrogen fueled vehicles

Hydrogen Information Web Links

Ames Laboratory: www.ameslab.gov

Argonne National Laboratory: www.anl.gov

Brookhaven National Laboratory: www.bnl.gov

California Fuel Cell Partnership: http://cafcp.org

Energy Information Administration: www.eia.gov

Fuel Cells 2000: www.fuelcells.org

Fuel Cell and Hydrogen Energy Association: www.fchea.org

Hydrogen and Fuel Cells Interagency Working Group: www.hydrogen.gov

International Partnership for the Hydrogen Economy: www.iphe.net

Lawrence Berkeley National Laboratory: www.lbl.gov

Lawrence Livermore National Laboratory: www.llnl.gov

Los Alamos National Laboratory: www.lanl.gov

National Energy Technology Laboratory: www.netl.doe.gov

National Renewable Energy Laboratory: www.nrel.gov/hydrogen

Oak Ridge National Laboratory: www.ornl.gov

Pacific Northwest National Laboratory: www.pnl.gov

Sandia National Laboratory: www.sandia.gov

Savannah River National Laboratory: http://srnl.doe.gov

The National Energy Education Development Project: www.need.org

U.S. Department of Energy Hydrogen and Fuel Cells Program: www.hydrogen.energy.gov

Lab Safety Rules

Eye Safety

- Always wear safety glasses when conducting experiments.

Fire Safety

- Do not heat any substance or piece of equipment unless specifically instructed to do so.
- Be careful of loose clothing. Do not reach across or over a flame.
- Always keep long hair pulled back and secured.
- Do not heat any substance in a closed container.
- Always use the tongs or protective gloves when handling hot objects. Do not touch hot objects with your hands.
- Keep all lab equipment, chemicals, papers, and personal effects away from a flame.
- Extinguish a flame as soon as you are finished with the experiment and move it away from the immediate work area.

Heat Safety

- Always use tongs or protective gloves when handling hot objects and substances.
- Keep hot objects away from the edge of the lab table—in a place where no one will accidentally come into contact with them.
- Do not use the steam generator without the assistance of your teacher.
- Remember that many objects will remain hot for a long time after the heat source is removed or turned off.

Glass Safety

- Never use a piece of glass equipment that appears cracked or broken.
- Handle glass equipment carefully. If a piece of glassware breaks, do not attempt to clean it up yourself. Inform your teacher.
- Glass equipment can become very hot. Use tongs if glass has been heated.
- Clean glass equipment carefully before packing it away.

Chemical Safety

- Do not smell, touch, or taste chemicals unless instructed to do so.
- Keep chemical containers closed except when using them.
- Do not mix chemicals without specific instructions.
- Do not shake or heat chemicals without specific instructions.
- Dispose of used chemicals as instructed. Do not pour chemicals back into a container without specific instructions to do so.
- If a chemical accidentally touches you, immediately wash the area with water and inform your teacher.

Assembly and Operation of the Fuel Cell Car

The Fuel Cell Car should be used only by a knowledgeable teacher or by students under the supervision of the teacher. The teacher must ensure proper handling and draw attention to potential dangers. Before using the car, review the User Manual in the car kit to fully understand operational safety precautions. All participants should wear safety glasses.

The car should be assembled and operated on a solid, level surface, with the ambient temperature between 20°C and 30°C. It is recommended that you operate the car indoors to protect it from the weather.

Make sure that the Fuel Cell Car is not charged or operated near an open flame.

Basic Function

Here are the basics of how the fuel cell works. Refer to the User Manual for additional technical data.

1. Use ONLY THE POWER SUPPLY INCLUDED to provide the electricity to power the electrolysis process.
2. The electric current splits the water molecules into hydrogen and oxygen gases in the charge mode of the reversible fuel cell. The gases are stored in the storage cylinders.
3. In the discharge mode, the fuel cell uses the hydrogen and oxygen gases as fuel to generate an electric current that runs the electric motor of the car, producing water and heat as by-products.

Assembly of the Fuel Cell Car

MATERIALS: Fuel Cell Car Kit with User Manual, 2 AA batteries (3-volt maximum), scissors, distilled water

1. Follow the instructions on pages 6–7 of the User Manual to assemble the car.
2. To HYDRATE the fuel cell, follow the instructions on page 7 of the User Manual. *CAUTION*: Only distilled water should be used. Use of any other liquid, even tap water, may destroy the fuel cell membrane.

Electrolysis: Producing Hydrogen

MATERIALS: Assembled Fuel Cell Car, power pack with 2 AA batteries, distilled water

1. Follow the instructions on pages 8-11 of the User Manual to produce hydrogen using the fuel cell.
2. Use ONLY the power pack provided.
3. Use ONLY distilled water.
4. DO NOT PROCEED near an open flame.
5. DO NOT PROCEED until you have hydrated the fuel cell as explained in the assembly section above.

Operation of the Fuel Cell Car

MATERIALS: Charged Fuel Cell Car

1. Follow the instructions on page 12 of the User Manual to operate the Fuel Cell Car.
2. When the car stops running, it can be recharged following the Electrolysis Procedure.
3. The AA batteries in the power pack may need to be replaced after several charges.

Advice and Troubleshooting

1. Follow the advice on page 13 of the User Manual for optimal operation.
2. Use the Troubleshooting section on page 14 of the User Manual if your car does not work properly.

Jigsaw Role Questions and Presentation Questions

SUSTAINABILITY: PHYSICIST

1. What are the physical and chemical properties of hydrogen?
2. How can hydrogen be stored?
3. What are the different sources of hydrogen on Earth?
4. Which sources of hydrogen hold promise for a long-term energy solution?

PRODUCTION: HYDROGEN PRODUCER

1. What are the processes currently being used to separate hydrogen?
2. What are the challenges of producing hydrogen in large amounts?
3. What safety issues are associated with separating hydrogen?
4. How does the cost of producing hydrogen compare to other fuels?

DELIVERY/DISTRIBUTION: HYDROGEN DISTRIBUTOR

1. In what forms can hydrogen be stored and transported?
2. What distribution technologies are currently in use?
3. What are the challenges of refueling hydrogen operations?
4. Identify and explain the properties of hydrogen that make it difficult to transport.

ENERGY SECURITY: ENERGY SECURITY ADVISOR

1. What is energy security and why is it important to the United States?
2. Why is it important to reduce our dependence on imported energy?
3. How could the use of hydrogen decrease our dependence on imported energy?
4. What other alternatives would reduce our dependence on imported energy?

ECONOMICS: ENERGY ECONOMIST

1. What are the advantages of using hydrogen?
2. How would using hydrogen in our cars look different than our current system?
3. How does the cost of hydrogen applications compare to other alternative fuels?
4. What would help a transition from nonrenewable fuels to hydrogen fuels?

EFFICIENCY AND RELIABILITY: ENERGY EFFICIENCY AND RELIABILITY EXPERT

1. What current technologies use hydrogen as a fuel?
2. How would the use of hydrogen be more efficient than the fuels we currently use?
3. How does the reliability of fuel cells compare to the reliability of other power systems?
4. What technological advances would make the use of hydrogen more efficient and reliable?

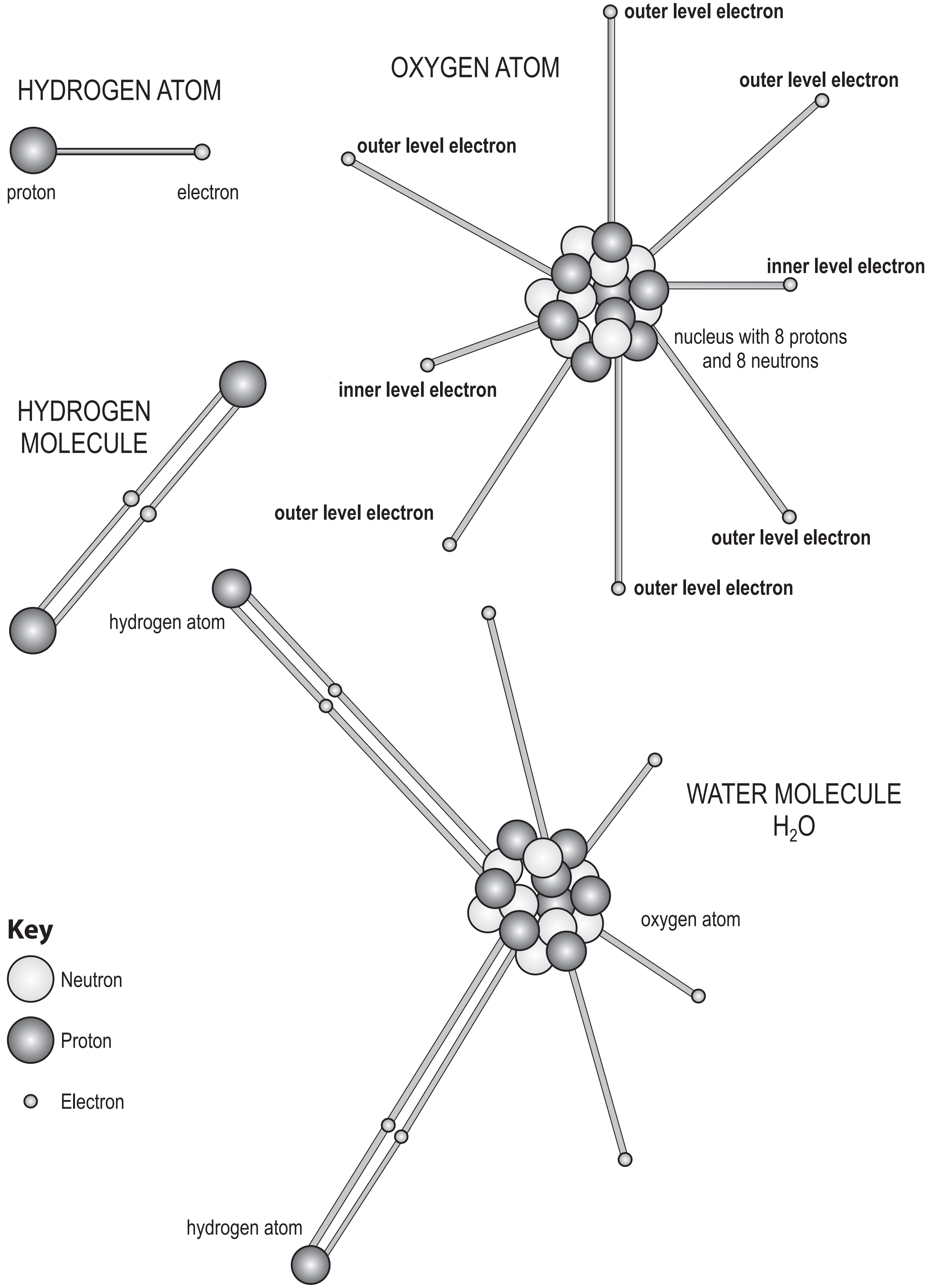
ENVIRONMENT: ENVIRONMENTAL SCIENTIST

1. What are the resources from which hydrogen can be produced (extracted)?
2. What are the environmental advantages of each of these sources?
3. What are the environmental disadvantages of each of these sources?
4. How does hydrogen compare environmentally to the fuels used in the U.S. today?

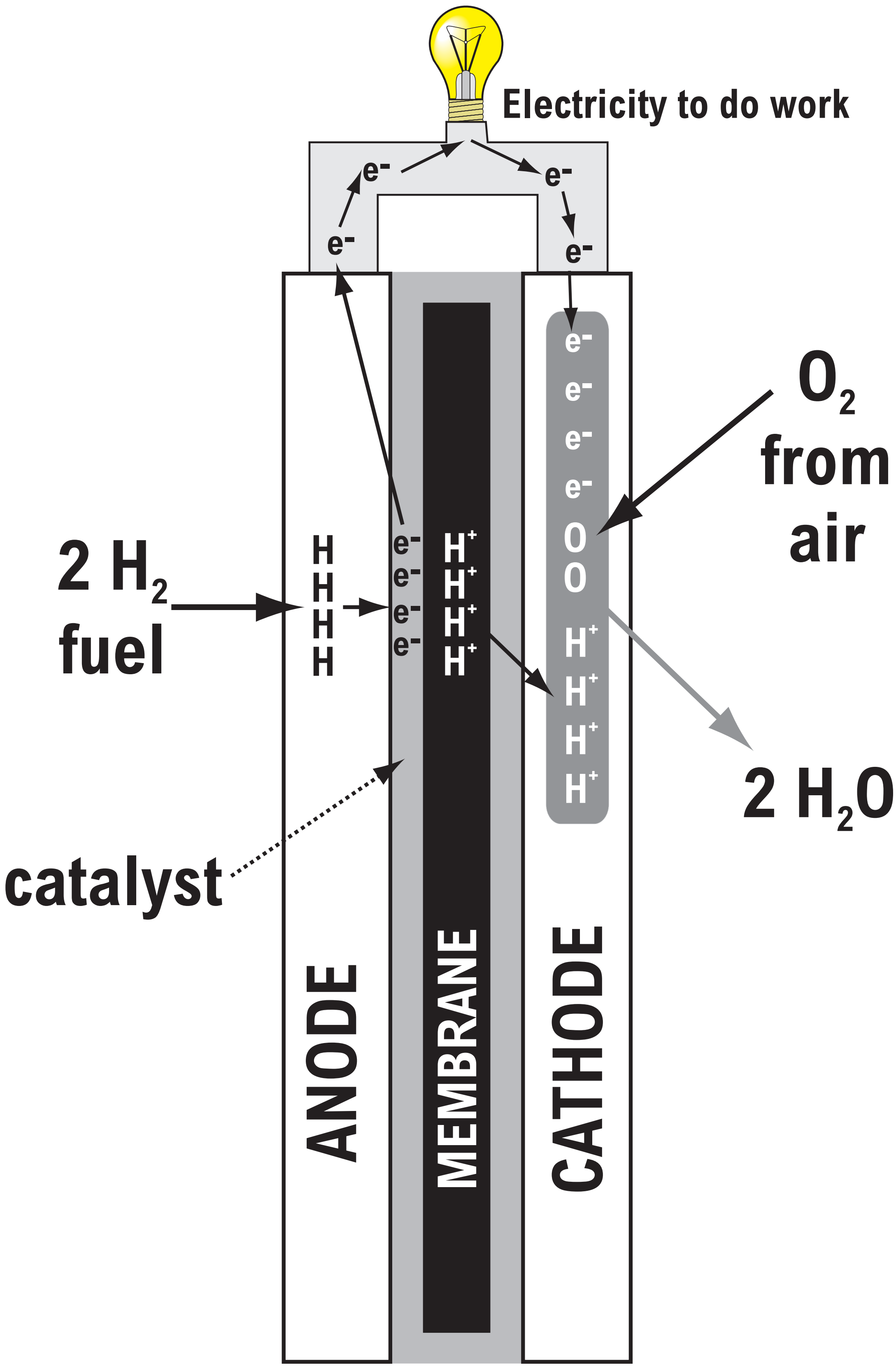
PRESENTATION QUESTIONS

1. What important facts have you learned about hydrogen?
2. What are the advantages of hydrogen?
3. What are the disadvantages of hydrogen?
4. What are the ways hydrogen could be used in the future?
5. What are your opinions about hydrogen?

Element Models



Fuel Cell


Electricity to do work
e-
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e-
O_2
from
air
O
O
2 H_2
fuel
H
H
H
H
e-
e-
e-
e-
H^+
H^+
H^+
H^+
H^+
H^+
H^+
H^+
2 H_2O
catalyst
ANODE
MEMBRANE
CATHODE

Fuel Cell Simulation

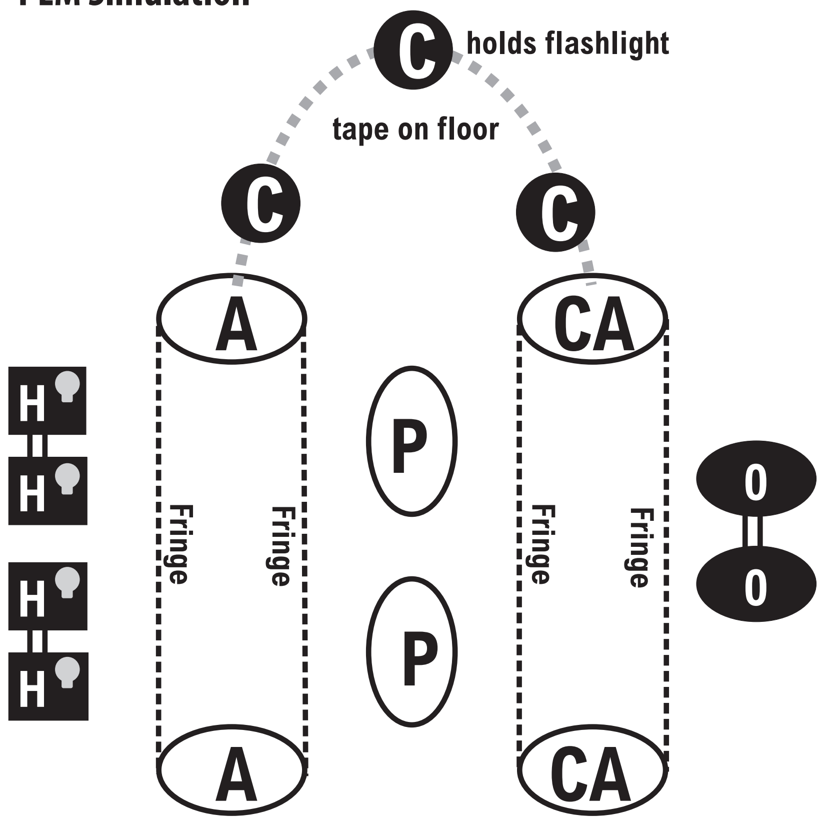
Students (15) Representing The Following Roles

- 4 Hydrogen atoms (H)
- 2 Oxygen atoms (O)
- 2 Anodes (A)
- 2 Cathodes (CA)
- 2 PEMs (P)
- 3 Circuit Members (C)

Materials

- 4 Pieces of fringe (each six feet long)
- 4 Flashing bulbs
- 1 Flashlight
- 1 Piece of colored tape to make circuit on floor
- 1 Hang tag for each student

PEM Simulation



✔ Procedure

1. All students wear hang tags representing their roles. The Hydrogen hang tags have H on one side and H+ on the other. The Oxygen hang tags have O on one side and O^{--} on the other.
2. The two Anodes hold up two pieces of six-foot fringe forming a rectangle. The two Cathodes hold up two pieces of six-foot fringe forming a rectangle.
3. The two PEMs stand between the Anode and Cathode.
4. Two sets of two Hydrogens link arms to create two Hydrogen molecules on the outside of the Anode. Each Hydrogen carries a flashing bulb (turned off) that represents its electron.
5. Two Oxygens link arms to create an Oxygen molecule on the outside of the Cathode.
6. The Hydrogens pass through the fringe into the Anode and each separate into two Hydrogen atoms.
7. The Oxygens pass through the fringe into the Cathode and separate into two Oxygen atoms.
8. The Hydrogen atoms pass through the inner fringe.
9. The PEMs stop the Hydrogen atoms from moving.
10. The Hydrogen atoms hand their electrons to the first Circuit Member and turn their hang tags to H^+ ions.
11. The PEMs allow the H^+ ions to pass through to the Cathode.
12. The Circuit Member turns on the flashing bulbs and hands them to the middle Circuit Member, who turns on a flashlight as he/she receives the electrons and turns the flashlight off as he/she passes the electrons to the last Circuit Member. The last Circuit Member hands two electrons to each Oxygen atom in the Cathode, who switches his/her hang tag to Oxygen ion (O^{--}).
13. Two Hydrogen ions link arms with an Oxygen ion (with the Oxygen in the middle), turning their hang tags and forming a water molecule. The water molecules then exit the outside of the Cathode.

H

H^{+}

O

O^{--}

A

CA

C

P

Hydrogen in the Round

I have Hydrogen.

1. Who has a name for a substance in which all of the atoms are identical?
2. Who has an experimental method of producing hydrogen using a semiconductor to absorb sunlight?

I have Electron.

1. Who has the name of an area around the nucleus of an atom where an electron is most likely to be found?
2. Who has a device like a battery that uses an external source of fuel to produce electricity, and releases water and thermal energy?

I have Element.

1. Who has the positively charged subatomic particle in the nucleus of an atom?
2. Who has a method of producing hydrogen gas from biomass?

I have Energy Level.

1. Who has the form of energy that travels in electromagnetic waves?
2. Who has a battery or fuel cell that generates electricity through a chemical reaction?

I have Proton.

1. Who has the neutral subatomic particle in the nucleus of an atom?
2. Who has an experimental process to produce hydrogen using bacteria and algae?

I have Radiant Energy.

1. Who has the process that releases energy in the core of the sun?
2. Who has a closed loop that carries electrical energy?

I have Neutron.

1. Who has the subatomic particle that moves outside the nucleus of an atom?
2. Who has the term for a substance that moves energy and sometimes requires another energy source to create it?

I have Nuclear Fusion.

1. Who has the process that uses steam to split methane molecules to produce hydrogen and oxygen?
2. Who has a membrane that allows hydrogen ions to pass through, but not electrons?

Hydrogen in the Round

I have Steam Reforming. 1. Who has the process that uses moving electrons to split water into hydrogen and oxygen? 2. Who has the side of a PEM fuel cell through which hydrogen fuel enters?	**I have Photobiological Microbial Production.** 1. Who has a substance or system that moves energy in a usable form from one place to another? 2. Who has the chemical bond usually found between metals and nonmetals?
I have Electrolysis. 1. Who has the method of using sunlight to split water into hydrogen and oxygen? 2. Who has the special material that splits hydrogen gas into hydrogen ions and electrons?	**I have Energy Carrier.** 1. Who has a device that uses hydrogen fuel to produce electricity, water, and heat? 2. Who has the chemical bond that occurs between nonmetals such as hydrogen and oxygen?
I have Photoelectrolysis. 1. Who has the method of producing hydrogen by superheating wood and agricultural waste? 2. Who has the side of a fuel cell with the channels to distribute oxygen to the catalyst?	**I have Fuel Cell.** 1. Who has a device that produces electricity through a chemical reaction? 2. Who has the ability to make a change in temperature, position, size, or state of matter?
I have Biomass Gasification. 1. Who has the process by which algae and bacteria use sunlight to produce hydrogen? 2. Who has the name of the particle formed when an atom loses or gains electrons?	**I have Electrochemical Energy Conversion Device.** 1. Who has a path through which electricity travels? 2. Who has coal, natural gas, petroleum, propane, and uranium?

Hydrogen in the Round

I have Circuit. 1. Who has a short name for Polymer Electrolyte Membrane? 2. Who has wind, solar, geothermal, hydropower, and biomass?	**I have Cathode.** 1. Who has an atom or group of atoms that have an electrical charge? 2. Who has the substances organized in the Periodic Table?
I have PEM. 1. Who has the negative side of a fuel cell? 2. Who has a chemical reaction that draws energy in from its surroundings?	**I have Ion.** 1. Who has the attraction or bond between two oppositely charged ions? 2. Who has the subatomic particle in the nucleus that determines atomic number?
I have Anode. 1. Who has a substance that speeds up a reaction, without being consumed in the reaction, such as in a fuel cell? 2. Who has a method for reducing greenhouse gases produced by fossil fuel combustion and steam reformation?	**I have Ionic Bond.** 1. Who has the chemical bond in which two atoms share electrons? 2. Who has the subatomic particle with which the strong nuclear force is associated, and which helps hold the nucleus together?
I have Catalyst. 1. Who has the positive side of a fuel cell? 2. Who has the system of organizing all of the known elements?	**I have Covalent Bond.** 1. Who has the ability to do work? 2. Who has the subatomic particle that carries a negative charge?

Hydrogen in the Round

I have Energy. 1. Who has energy sources that are limited and cannot be replenished in a short time? 2. Who has the name of the area at a precise distance where the electrons are held in an atom?	**I have Endothermic.** 1. Who has the name for the trapping, storage, and use of carbon gases? 2. Who has the most cost effective method of producing hydrogen fuel today?
I have Nonrenewable. 1. Who has energy sources that are unlimited or can be replenished in a short period of time? 2. Who has the form of energy that comes from the sun and powers photosynthesis?	**I have Carbon Capture, Utilization, and Storage.** 1. Who has the arrangement of elements by their physical and chemical properties? 2. Who has a simple method of using electricity to produce very pure hydrogen?
I have Renewable. 1. Who has a chemical reaction that absorbs energy? 2. Who has the process that combines very small atoms into larger atoms, releasing vast amounts of radiant energy?	**I have Periodic Table.** 1. Who has an abundant, clean, domestically available, flexible fuel? 2. Who has a clean fuel that can be produced by steam reforming and electrolysis?

Pre/Post Hydrogen Assessment

1. The average American uses how much energy compared to the average world citizen?
- **a.** half as much
- **b.** twice as much
- **c.** about four times as much
- **d.** ten times as much

2. What percentage of U.S. energy consumption is from renewable energy sources?
- **a**. less than 10%
- **b.** 11-20%
- **c.** 21-40%
- **d.** more than 40%

3. About how much of total crude oil supply does the United States import from foreign countries?
- **a.** 5-10%
- **b.** 30-35%
- **c.** 40-50%
- **d.** 75-80%

4. How much of total U.S. energy consumption is used by the transportation sector of the economy?
- **a.** 8%
- **b.** 18%
- **c.** 28%
- **d.** 48%

5. An ideal energy system would ____________
- **a.** include domestic and imported energy sources.
- **b.** use only nonrenewable energy sources.
- **c.** use a variety of energy sources.
- **d.** All of the above.

6. Hydrogen is one of the most abundant elements in the universe. **True** **False**

7. Hydrogen gas is abundant in underground reservoirs on Earth. **True** **False**

8. Hydrogen fuel can be produced from __________
- **a.** water.
- **b.** natural gas.
- **c.** biomass.
- **d.** All three.

9. Hydrogen can be used ____________
- **a.** as a vehicle fuel.
- **b.** to produce electricity.
- **c.** Both a and b.
- **d.** Neither a nor b.

10. Electrolysis is a process in which electricity is used to ____________
- **a.** turn water into steam.
- **b.** combine hydrogen and oxygen molecules to make water.
- **c.** split water molecules into hydrogen and oxygen gases.
- **d.** produce light and heat.

11. A fuel cell ____________
- **a.** produces electricity.
- **b.** uses hydrogen as fuel.
- **c.** emits only water and heat.
- **d.** All of the above.

12. A fuel cell must be replaced often, like a non-rechargeable battery. **True** **False**

13. Hydrogen can be transported as a liquid or a gas. **True** **False**

14. Hydrogen is as safe as gasoline or diesel fuel when handled properly. **True** **False**

15. Hydrogen could meet many of our energy needs in the future. **True** **False**

HYDROGEN BINGO

A. Knows the atomic number of hydrogen

B. Knows the percentage of U.S. energy consumption supplied by renewables

C. Knows the process that produces energy in the sun's core

D. Can define energy carrier

E. Knows what a fuel cell is

F. Can define distributed generation

G. Knows a process that separates water into hydrogen and oxygen

H. Knows the number of neutrons in a hydrogen atom

I. Knows in what form energy from the sun travels to the Earth

J. Can name four renewable energy sources

K. Knows the percentage of U.S. energy consumption supplied by fossil fuels

L. Knows the top energy carrier used in the U.S.

M. Knows the U.S. percentage of world population

N. Can name four nonrenewable energy sources

O. Knows the U.S. percentage of world energy consumption

P. Can name two ways hydrogen is used today

A NAME	**B** NAME	**C** NAME	**D** NAME
E NAME	**F** NAME	**G** NAME	**H** NAME
I NAME	**J** NAME	**K** NAME	**L** NAME
M NAME	**N** NAME	**O** NAME	**P** NAME

NEED's Online Resources

NEED'S SMUGMUG GALLERY

http://need-media.smugmug.com/

On NEED's SmugMug page, you'll find pictures of NEED students learning and teaching about energy. Would you like to submit images or videos to NEED's gallery? E-mail info@NEED.org for more information.
Also use SmugMug to find these visual resources:

Videos
Need a refresher on how to use Science of Energy with your students? Watch the Science of Energy videos. Also check out our Energy Chants videos! Find videos produced by NEED students teaching their peers and community members about energy.

Online Graphics Library
Would you like to use NEED's graphics in your own classroom presentations, or allow students to use them in their presentations? Download graphics for easy use in your classroom.

SUPPLEMENTAL MATERIALS

Looking for more resources? Our supplemental materials page contains PowerPoints, animations, and other great resources to compliment what you are teaching in your classroom! This page is available under the Educators tab at www.NEED.org.

THE BLOG

We feature new curriculum, teacher news, upcoming programs, and exciting resources regularly. To read the latest from the NEED network, visit www.NEED.org/blog_home.asp.

EVALUATIONS AND ASSESSMENT

Building an assessment? Searching for standards? Check out our Evaluations page for a question bank, NEED's Energy Polls, sample rubrics, links to standards alignment, and more at www.NEED.org/evaluation.

E-PUBLICATIONS

The NEED Project offers e-publication versions of various guides for in-classroom use. Guides that are currently available as an e-publication will have a link next to the relevant guide title on NEED's curriculum resources page, www.NEED.org/curriculum.

SOCIAL MEDIA

Stay up-to-date with NEED. "Like" us on Facebook! Search for The NEED Project, and check out all we've got going on!

Follow us on Twitter. We share the latest energy news from around the country, @NEED_Project.

Follow us on Instagram and check out the photos taken at NEED events, instagram.com/theneedproject.

Follow us on Pinterest and pin ideas to use in your classroom, Pinterest.com/NeedProject.

NEED ENERGY BOOKLIST

Looking for cross-curricular connections, or extra background reading for your students? NEED's booklist provides an extensive list of fiction and nonfiction titles for all grade levels to support energy units in the science, social studies, or language arts setting. Check it out at www.NEED.org/booklist.asp.

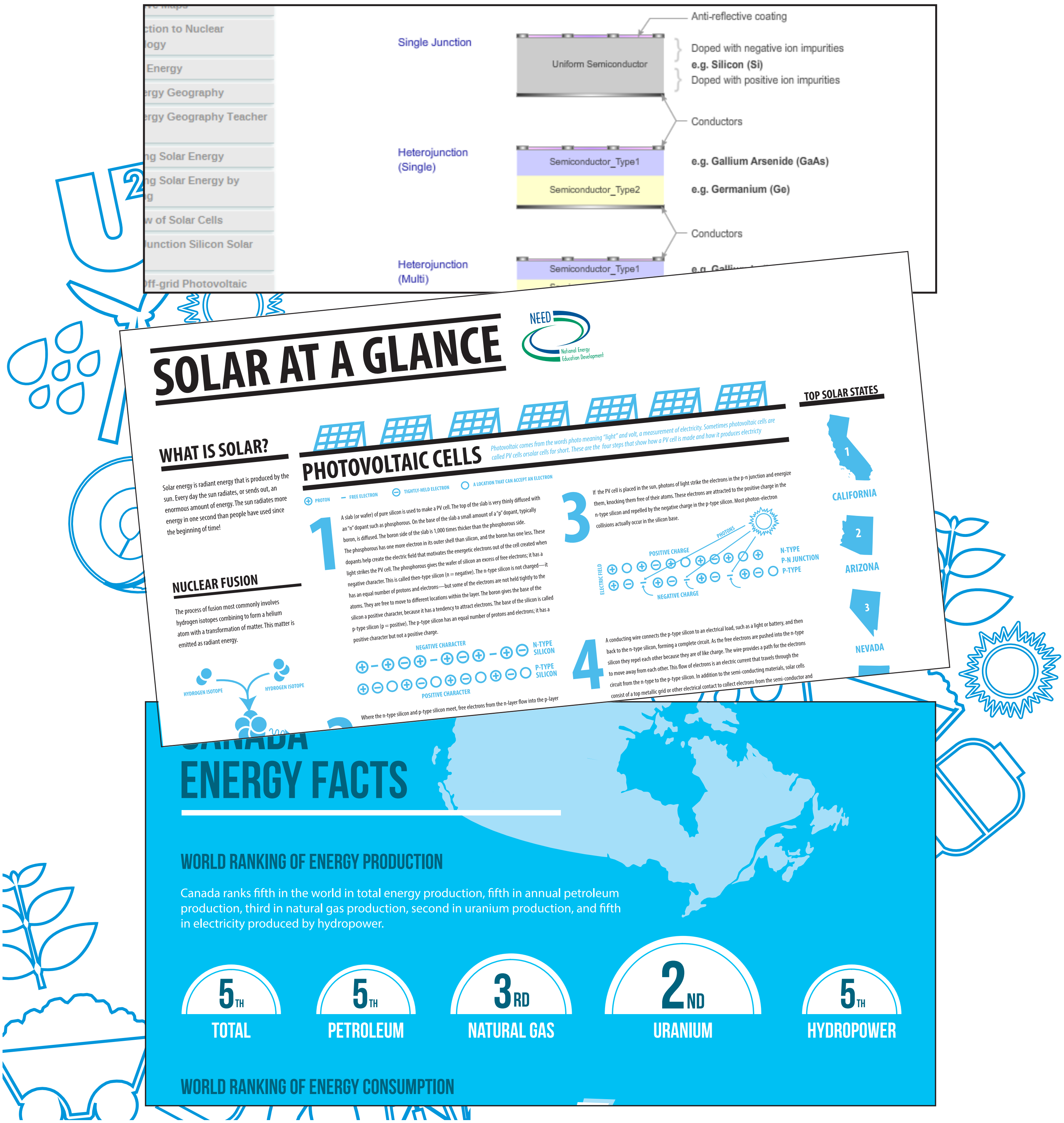
U.S. ENERGY GEOGRAPHY

Maps are a great way for students to visualize the energy picture in the United States. This set of maps will support your energy discussion and multi-disciplinary energy activities. Go to www.NEED.org/maps to see energy production, consumption, and reserves all over the country!

Looking For More Resources?

Our supplemental materials page contains PowerPoints, animations, and other great resources to compliment what you are teaching!

This page is available at www.NEED.org/educators.



Youth Awards Program for Energy Achievement

All NEED schools have outstanding classroom-based programs in which students learn about energy. Does your school have student leaders who extend these activities into their communities? To recognize outstanding achievement and reward student leadership, The NEED Project conducts the National Youth Awards Program for Energy Achievement.

This program combines academic competition with recognition to acknowledge everyone involved in NEED during the year—and to recognize those who achieve excellence in energy education in their schools and communities.

What's involved?

Students and teachers set goals and objectives, and keep a record of their activities. Students create a digital project to submit for judging. In April, digital projects should be uploaded to the online submission site.

Want more info? Check out **www.NEED.org/Youth-Awards** for more application and program information, previous winners, and photos of past events.

H_2 Educate Evaluation Form

State: ____________ **Grade Level:** ____________ **Number of Students:** ___________

1. Did you conduct the entire unit?	❑ Yes	❑ No
2. Were the instructions clear and easy to follow?	❑ Yes	❑ No
3. Did the activities meet your academic objectives?	❑ Yes	❑ No
4. Were the activities age appropriate?	❑ Yes	❑ No
5. Were the allotted times sufficient to conduct the activities?	❑ Yes	❑ No
6. Were the activities easy to use?	❑ Yes	❑ No
7. Was the preparation required acceptable for the activities?	❑ Yes	❑ No
8. Were the students interested and motivated?	❑ Yes	❑ No
9. Was the energy knowledge content age appropriate?	❑ Yes	❑ No
10. Would you teach this unit again?	❑ Yes	❑ No

Please explain any 'no' statement below.

How would you rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor
How would your students rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor

What would make the unit more useful to you?

Other Comments:

Please fax or mail to: **The NEED Project**
8408 Kao Circle
Manassas, VA 20110
FAX: 1-800-847-1820

National Sponsors and Partners

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Arizona Science Center
Armstrong Energy Corporation
Association of Desk & Derrick Clubs
Audubon Society of Western Pennsylvania
Barnstable County, Massachusetts
Robert L. Bayless, Producer, LLC
BP America Inc.
Blue Grass Energy
Boulder Valley School District
Brady Trane
California State University
Cape Light Compact–Massachusetts
Chevron
Chugach Electric Association, Inc.
Colegio Rochester
Columbia Gas of Massachusetts
ComEd
ConEdison Solutions
ConocoPhillips
Constellation
Cuesta College
Daniel Math and Science Center
David Petroleum Corporation
Desk and Derrick of Roswell, NM
Dominion
DonorsChoose
Duke Energy
East Kentucky Power
Eastern Kentucky University
Elba Liquifaction Company
El Paso Corporation
E.M.G. Oil Properties
Encana
Encana Cares Foundation
Energy Education for Michigan
Energy Training Solutions
Eversource
Exelon Foundation
First Roswell Company
FJ Management. Inc.
Foundation for Environmental Education
FPL
The Franklin Institute
Frontier Associates
Government of Thailand–Energy Ministry
Green Power EMC
Guilford County Schools – North Carolina
Gulf Power
Gerald Harrington, Geologist
Granite Education Foundation
Harvard Petroleum
Hawaii Energy
Houston Museum of Natural Science
Idaho Power
Idaho National Laboratory
Illinois Clean Energy Community Foundation
Independent Petroleum Association of America
Independent Petroleum Association of New Mexico
Indiana Michigan Power – An AEP Company
Interstate Renewable Energy Council
James Madison University
Kentucky Clean Fuels Coalition
Kentucky Department of Education
Kentucky Department of Energy Development and Independence
Kentucky Power – An AEP Company
Kentucky River Properties LLC
Kentucky Utilities Company
Kinder Morgan
Leidos
Linn County Rural Electric Cooperative
Llano Land and Exploration
Louisiana State University Cooperative Extension
Louisville Gas and Electric Company
Maine Energy Education Project
Massachusetts Division of Energy Resources
Michigan Oil and Gas Producers Education Foundation
Miller Energy
Mississippi Development Authority–Energy Division
Mojave Environmental Education Consortium
Mojave Unified School District
Montana Energy Education Council
NASA
National Association of State Energy Officials
National Fuel
National Grid
National Hydropower Association
National Ocean Industries Association
National Renewable Energy Laboratory
Nebraska Public Power District
New Mexico Oil Corporation
New Mexico Landman's Association
Nicor Gas – An AGL Resources Company
Northern Rivers Family Services
North Shore Gas
NRG Energy, Inc.
Offshore Energy Center
Offshore Technology Conference
Ohio Energy Project
Opterra Energy
Oxnard School District
Pacific Gas and Electric Company
Paxton Resources
PECO
Pecos Valley Energy Committee
Peoples Gas
Petroleum Equipment and Services Association
Phillips 66
PNM
Providence Public Schools
Read & Stevens, Inc.
Renewable Energy Alaska Project
Rhode Island Office of Energy Resources
River Parishes Community College
RiverQuest
Robert Armstrong
Roswell Geological Society
Salt River Project
Sandia National Laboratory
Saudi Aramco
Science Museum of Virginia
C.T. Seaver Trust
Shell
Shell Chemicals
Society of Petroleum Engineers
Society of Petroleum Engineers – Middle East, North Africa and South Asia
David Sorenson
Southern Company
Space Sciences Laboratory of the University of California Berkeley
Tennessee Department of Economic and Community Development–Energy Division
Tioga Energy
Toyota
Tri-State Generation and Transmission
TXU Energy
United States Energy Association
University of Georgia
United Way of Greater Philadelphia and Southern New Jersey
University of Nevada–Las Vegas, NV
University of North Carolina
University of Tennessee
University of Texas - Austin
University of Texas - Tyler
U.S. Department of Energy
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy–Wind for Schools
U.S. Department of the Interior–Bureau of Land Management
U.S. Energy Information Administration
West Bay Exploration
West Virginia State University
Yates Petroleum Corporation