TRANSPORTATION FUELS ENIGMA

TRANSPORTATION FUELS

GRADE LEVEL
7–12

SUBJECT AREAS
Science
Social Studies
Language Arts

Students put on their detective hats to uncover the mysteries of the major transportation fuels.

NEED 2008-2009
Putting Energy into Education

NEED Project PO Box 10101 Manassas, VA 20108 1-800-875-5029 www.NEED.org

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 Vision 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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TABLE OF CONTENTS

Correlations to National Standards 4

Teacher Guide 5

Infosheets 9

Datasheets 13

Gamesheets 14

Ballot 15

Envelope 16

Source Clue • Biodiesel 17

Source Clue • Methanol 18

Source Clue • Hybrid Electric 19

Source Clue • Propane 20

Source Clue • Ethanol 21

Source Clue • Gasoline 22

Source Clue • Electricity 23

Source Clue • CNG 24

Source Clue • Diesel 25

Source Clue • Hydrogen 26

Evaluation Form 27

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Putting Energy into Education

Correlations to National Science Standards

INTERMEDIATE (GRADES 4–8) STANDARD E: SCIENCE AND TECHNOLOGY

1. Abilities of Technological Design

a. Identify appropriate problems for technological design.
b. Design a solution or product.
c. Implement a proposed design.
d. Evaluate completed technological designs or products.
e. Communicate the process of technological design.

2. Understandings about Science and Technology

c. Technological solutions are temporary and have side effects. Technologies cost, carry risks, and have benefits.
f. Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Risk is part of living in a highly technological world. Reducing risk often results in new technology.

INTERMEDIATE–F: SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

3. Natural Hazards

b. Human activities can induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal.
c. Hazards can present personal and societal challenges because misidentifying the change or incorrectly estimating the rate and scale of change may result in either too little attention and significant human costs or too much cost for unneeded preventive measures.

4. Risks and Benefits

b. Students should understand the risks associated with natural hazards, chemical hazards, biological hazards, social hazards, and personal hazards.
c. Students can use a systematic approach to thinking critically about risks and benefits.
d. Important personal and social decisions are made based on perceptions of benefits and risks.

5. Science and Technology in Society

a. Science influences society through its knowledge and world view. The effect of science on society is neither entirely beneficial nor entirely detrimental.
b. Societal challenges often inspire questions for scientific research, and societal priorities often influence research priorities.
c. Technology influences society through its products and processes. Technological changes are often accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and to society. Social needs, attitudes, and values influence the direction of technological development.
d. Science and technology have contributed enormously to economic growth and productivity among societies and groups within societies.
e. Science cannot answer all questions and technology cannot solve all human problems or meet all human needs. Students should appreciate what science and technology can reasonably contribute to society and what they cannot do. For example, new technologies often will decrease some risks and increase others.

SECONDARY (GRADES 9–12) STANDARD E: SCIENCE AND TECHNOLOGY

1. Abilities of Technological Design

a. Identify a problem or design an opportunity.
b. Propose designs and choose between alternative solutions.
c. Implement a proposed solution.
d. Evaluate the solution and its consequences.
e. Communicate the problem, process, and solution.

SECONDARY–F: SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

3. Natural Resources

a. Human populations use resources in the environment to maintain and improve their existence.
b. The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and depletes those resources that cannot be renewed.
c. Humans use many natural systems as resources. Natural systems have the capacity to reuse waste but that capacity is limited. Natural systems can change to an extent that exceeds the limits of organisms to adapt naturally or humans to adapt technologically.

4. Environmental Quality

c. Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, overconsumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and different ways humans view the earth.

5. Natural and Human-induced Hazards

b. Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change.
d. Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. Students should understand the costs and trade-offs of various hazards—ranging from those with minor risk to a few people to major catastrophes with major risk to many people.

6. Science and Technology in Local, National, and Global Challenges

b. Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science and technology related challenges. However, understanding science alone will not resolve local, national, and global challenges.

Teacher Guide

A CRITICAL THINKING GAME THAT FOCUSES ON THE TRANSPORTATION FUELS OF TODAY AND TOMORROW.

BACKGROUND

In **Transportation Fuels Enigma**, student teams are each assigned a different fuel source. Working cooperatively, students use their reading, brainstorming, and organizational skills to hide the identity of their team's fuel while trying to guess which transportation fuels the other teams represent. The game is appropriate for grades seven through 12.

CONCEPTS

- We use petroleum products for most transportation fuels today.
- Some fuels are nonrenewable while others are renewable.
- Some fuels may affect the environment more than others.
- There are many conventional and alternative transportation fuels; some are widely used, others are not.
- Some transportation fuels are more suitable for fleet vehicles, others for personal vehicles.

TIME

Three 45 minute class periods.

MATERIALS

- **Transportation Fuels Enigma Ballot** (seven copies)
- **Transportation Fuels Infosheets** (14 copies of each)
- **Transportation Fuels Enigma Game Sheet** (18 copies)
- **Transportation Fuels Enigma Data Sheet** (18 copies)
- **Clue Order Envelope** (seven copies)
- **Transportation Fuels Enigma Source Clue Sheets** (one transparency of each)

PROCEDURE

Step One—Preparation

- Make copies of the materials listed above.
- Cut the **Game Sheets** and clip together seven stacks of ten.
- Cut the **Data Sheets** and staple together seven stacks of nine. Clip together the remaining sheets.
- Fold the **Clue Order Envelopes** in half and tape the sides closed.
- Make transparencies of each of the ten **Clue Sheets**. Cut each sheet into its eight clues and clip them together by fuel.

- ➤ Divide the students into seven groups with three to five students per group.
- ➤ Choose seven out of the ten fuel sources to assign to the groups. Next, place the **Clues** for the seven sources you chose in separate envelopes, and write the team number and name of the fuel source in the space provided. You will need to determine the clue order for the three fuel sources not represented by student groups.
- ➤ On each table, place one **Data Sheet**, two sets of **Infosheets**, and a **Clue Envelope**.

Step Two—Introduce Unit to the Class (Day One)

Explain to the students that they will be working in small groups and how they must work together. Give students the following introduction:

The name of this game is Transportation Fuels Enigma. Everyone knows that transportation fuels help our vehicles go, but the word enigma may be a complete mystery to you. Actually, a mystery is a good way to define enigma. It means something that is hard to understand or explain. So, if we put together TRANSPORTATION FUELS and ENIGMA, we get a game where teams research information, or clues, which will help unlock the mysteries of the nation's common and upcoming transportation fuels. Transportation Fuels Enigma will also help each of you unlock the mysteries of working together. You will be asked to communicate with others, solve problems, and use your academic and critical thinking skills.

Step Three—Developing the Data Sheet

Read the following instructions to the students:

- ➤ *Each team has been assigned a transportation fuel. To find out which fuel your team is, pick up your clue envelope. Your team's goal is to be the best at eliminating fuel enigmas. You will do this by identifying which fuels the other teams represent, using as few clues as possible. Naturally, it's best if the other team(s) can't guess which fuel you represent, or take a lot of clues guessing who you are, because this will give them a lower score.*
- ➤ *The first thing you must do to become the best team is to learn something about your fuel. To accomplish this objective, each team has been given two Transportation Fuel Source Infosheets. Each team also has a Data Sheet. Someone from the team should write the name of your fuel in the space at the top of the Data Sheet. When the Data Sheet is completed, it will be for your eyes only; no other team should see it.*
- ➤ *To successfully complete the data sheet, you'll need to run an efficient team. This means each team will need a facilitator and a recorder. A facilitator keeps the session orderly and your team moving smoothly. The facilitator calls on people with their hands raised to prevent everyone from yelling out their facts all at once. He or she will point to members of the group, keeping pace with the writing speed of the recorder. The recorder writes down the information on the data sheet for the team. You have one minute to select your team's facilitator and recorder.*
- ➤ *To answer the questions on your Data Sheet, you must consult the Infosheets. Find your fuel source and read the paragraphs. You will have ten minutes to complete the Data Sheet on your source. When reading the Infosheet, try to answer the following questions:*
- ➤ *Is the source used in fleet vehicles like taxi cabs, buses, or government cars or is your fuel used by every day people to run their private cars and trucks?*
- ➤ *For question two, is your fuel a fossil fuel, biodegradable, or is it a secondary fuel source that needs another energy source to create it?*
- ➤ *Is your fuel imported from other countries, or do we have a good supply or the ability to create it in the United States?*
- ➤ *Do you need a special car specifically desgined and manufactured to run on this fuel, or does this fuel work with most cars available on the market? Does it require an engine modification or any other special maintenance?*
- ➤ *Does your source pollute the air? If yes, does it pollute a little or a lot? More or less than other fuel sources?*
- ➤ *Is your fuel readily available to the public? If so, where can you buy it?*
- ➤ *After you have answered questions 1-6, list any other information that is unique and interesting about your fuel source. How is your fuel produced? Do other things besides cars and trucks use your fuel? Does your source need a battery? Does the government offer any tax incentives for using your source?*

Step Four—Determining the Sequence of Clues

- ➤ *Now, each team should take out the eight clues from their Clue Envelope and arrange them in one column A through H. Place your completed Energy Enigma Data Sheet next to this column. Your opponents will construct data sheets on your source of energy using the same resources you did—keep this in mind as you complete the next task.*
- ➤ *Starting with clue A, the facilitator should call upon members of the group to comment on the clue, i.e., this clue gives away too much information and why. You have two minutes to discuss the strengths and weaknesses of the clues.*
- ➤ *Before deciding which clues you will be giving to the opposing teams, the facilitator should lead a discussion on the pros and cons of keeping or eliminating each of the clues. You will need to select four of the least revealing clues. These clues will be given to your opposing teams. Try to come up with the four clues through discussion with members of the group.*
- ➤ *When you've completed this task, take the four eliminated clues and put them back in the Clue Envelope.*
- ➤ *Now, you must arrange the remaining four clues so the first clue is the least revealing of the four, the second clue should be a little more revealing, and so on. You may decide as a team to arrange the clues so that they confuse your opposing teams. Put the least revealing clue on the top of the stack and the most revealing clue on the bottom. Once the clues are in order, clip the stack of clues to the front of the Clue Envelope.*
- ➤ *At the end of this unit, your group will explain to the class why you kept or eliminated each clue. What were your reasons for choosing the four clues that you kept? Why were the others eliminated? How did you decide on the order of the clues? You have ten minutes to select your clues, to write down your reasons for choosing or eliminating them, and to organize the clues from least revealing to most revealing. I will pick up your Clue Envelopes when you are finished and check your rationale for clue selection.*

Step Five—Developing Opposing Teams' Data Sheets

Pick up the Clue Envelopes and give each team a set of nine stapled Data Sheets. Read the following instructions to the students:

- ➤ *Using the Infosheets, develop the remaining nine Data Sheets. Be sure to indicate which fuel you are working on in the space provided at the top of each sheet. Divide the nine sheets equally among the team members. During the game, I will take away your infosheets—you can only use your Data Sheets.*

Step Six—Playing the Game (Day Two)

Give each team a Ballot and a stack of ten Game Sheets. Read the following instructions to the students:

- ➤ *I have placed ten Game Sheets and a Ballot on your table. Number the Game Sheets one through ten. Write your team number and the name of your team's energy source on the Ballot.*
- ➤ *Now, it is time for the evaluation portion of this game. The seven teams have given me the clue order for their transportation sources, and I have chosen the clue order for the remaining three energy sources. Shortly, I will project the first clue of each of the ten teams on the screen. The first column of five clues will be for teams one through five, and the second row of clues for teams six through ten.*
- ➤ *Two or more members of your team should write the information for each clue in the top box (marked clue one) of the appropriate game sheet.*
- ➤ *Your team will then have six minutes to decide if you wish to guess which energy source is represented by an opposing team. This is done by writing the number of the team in the box next to the energy source you think they represent on your Ballot for round one.*
- ➤ *Your team receives 30 points for guessing correctly during the first round, 25 points for the second round, 15 points for the third, and 10 points for the fourth round. If you guess correctly, I'll circle your choice, and I will put the number of points you won in the box at the top of the ballot. If you guess wrong, I'll put an X through your choice. At the end of the game, I'll deduct 10 points for every X or incorrect guess the team has made.*
- ➤ *Before I turn on the overhead projector and reveal the clues, I will give the teams 90 seconds to devise a plan on how they will monitor the Game Sheets.*
- ➤ *Here are the first clues for round one; write them in the top box (marked clue one) on your game sheets. You will have six minutes to make a guess for any or all of the ten sources. Remember, incorrect guesses will cost your team ten points, so it may be better to leave most of them blank for the first round or two. At the end of the six minutes no ballots will be accepted.*

➤ *The first round is over. We will follow the same procedure as before, and you will have six minutes again to fill any boxes on your Ballot for round two. If you have already made a correct choice, there is no need to mark your choice in subsequent rounds.*

➤ Continue giving the same instructions and following the same scoring procedures for the remaining rounds. For rounds three and four allow only four minutes. After the fourth round, have teams add their scores—check their math.

Step Seven—Discussion (Day Three)

Discuss with the students the following questions about the fuels:

➤ What type of questions might you ask about an unknown fuel?

1. *Is the fuel used for fleet vehicles, private vehicles, or both?*
2. *Is the fuel imported or produced domestically?*
3. *Is the fuel a fossil fuel or a renewable, biodegradable fuel?*
4. *Does the fuel require a special vehicle, engine conversion, or any other alterations to the vehicle?*
5. *Does the fuel release pollution when being used?*

➤ What things were similar about the fuels?

1. *Which fuels have you used before?*
2. *Which fuels produce air pollution when consumed?*
3. *Which fuels are readily available? Which are still being developed?*
4. *Which fuels are more popular in certain areas of the country?*

➤ *One at a time, each team will come to the front of the class and place their eight clues on the overhead projector. Arrange the four clues that you chose to keep on one side of the projector and the four clues that you eliminated on the other side. Explain your reasons for keeping or eliminating the clues.* (Follow with discussion.)

Step Eight–Grading

You can use the grading outline below, or come up with your own grading scheme.

➤ Working together as a team while developing **Data Sheet**—15 points

➤ Working together as a team during the game—10 points

➤ **Enigma Ballot Scores**—60 points (The number of grading points a team receives is based on the team's **Enigma Ballot** score.)

➤ Explanation to class—15 points

Transportation Fuels Infosheets

Biodiesel

Biodiesel is a fuel made by chemically reacting alcohol with vegetable oils, fats, or greases, such as recycled restaurant greases. It is most often mixed with petroleum products in blends of two percent or 20 percent (B20) biodiesel. It can also be used as neat biodiesel (B100). It is the fastest growing alternative transportation fuel in the U.S.

Biodiesel contains virtually no sulfur, so it can reduce sulfur levels in the nation's diesel fuel supply. Biodiesel is a superior lubricant and can restore the lubricity of diesel fuel in blends of only one or two percent. Biodiesel can also improve the smell of diesel fuel, sometimes smelling like french fries. B100 and biodiesel blends are sensitive to cold weather and may require special anti-freeze, as petroleum-based diesel fuel does.

Biodiesel is renewable, safe, and biodegradable, and reduces serious air pollutants such as particulates, carbon monoxide, hydrocarbons, and air toxics. Currently, biodiesel is available only through bulk suppliers; there are a growing number of public biodiesel refueling stations in the United States, but they are not widespread. Biodiesel, therefore, is more practical for fleets with their own fueling facilities. Biodiesel is delivered by distributors directly to fleet operators.

Compressed Natural Gas

Natural gas, CH_4, is a nonrenewable fossil fuel with plentiful supplies in the United States, and the majority of the U.S.'s imports come from Canada. When natural gas is compressed, it can be used as a clean burning transportation fuel. Today, there are about 144,000 compressed natural gas (CNG) vehicles in operation in the U.S., mostly in the South and West. There are about 770 natural gas refueling stations in the United States, and many business and public agencies have their own refueling stations. One in every five new transit buses in the U.S. is powered by compressed natural gas.

Vehicles manufactured to run on CNG are available from several manufacturers. A gasoline engine can also be converted to run on CNG at a cost of $2,000-3,000, depending on the number of fuel tanks installed. Tax incentives can help offset the cost of conversion. About half the vehicles running on CNG are privately owned and half are vehicles owned by local, state, and Federal government agencies.

Compressed natural gas vehicles emit 85-90 percent less carbon monoxide, 10-20 percent less carbon dioxide, and 90 percent fewer reactive non-methane hydrocarbons than gasoline-powered vehicles.

Diesel

Diesel is a petroleum-based fuel made of hydrogen and carbon molecules (hydrocarbons) that contain energy. Two-thirds of U.S. petroleum is imported from other countries, and approximately 10 gallons of diesel can be refined from each 42–gallon barrel of crude oil. Diesel can only be used in a specifically designed diesel engine, a type of internal combustion engine used in many cars, boats, trucks, trains, buses, and farm and construction vehicles.

Diesel fuel has a wide range of applications. In agriculture, diesel powers more than two-thirds of all farm equipment in the U.S. because diesel engines are uniquely qualified to perform demanding work. In addition, it is the predominant fuel for public transit buses, school buses and intercity buses throughout the United States. Diesel power dominates the movement of America's freight in trucks, trains, boats and barges; 94 percent of our goods are shipped using diesel-powered vehicles. No other fuel can match diesel in its ability to move freight economically.

Diesel automobiles are very popular in Europe, where nearly half the cars sold are diesel-powered. Advanced European diesel passenger vehicles exceed today's U.S. gasoline-electric hybrids in fuel efficiency by more than 25 percent. Combining the superior fuel efficiency of diesel engines with the efficiencies of hybrid electric vehicles can provide even greater fuel efficiency.

The major disadvantage of diesel fuel is its harmful emissions. Pollutants associated with the burning of diesel fuel are gaseous emissions, including sulfur dioxide (SO_2) and nitrogen oxide (NOx), and particulate matter. Significant progress has been made in reducing emissions from diesel engines. With new clean diesel technologies, today's trucks and buses are eight times cleaner than those built just a dozen years ago.

Electricity

Electric vehicles (EVs) have been around since 1891, and today there are about 10,500 dedicated electric vehicles in use in the United States, mostly in the West and South. Dedicated electric vehicles run on batteries that need to be recharged frequently, which can be done at home in the evening or at one of the 600 refueling stations found in California and the southwest.

The batteries limit the range of a dedicated EV, which is determined by the amount of energy stored in its battery pack. The more batteries a dedicated EV can carry, the more range it can attain, to a point. Too many batteries can weigh down a vehicle, reducing its load-carrying capacity and range, and causing it to use more energy. The typical dedicated EV can only travel 50 to 130 miles between charges. This driving range assumes perfect driving conditions and vehicle maintenance. Weather conditions, terrain, and some accessory use can significantly reduce the range. Dedicated EVs, therefore, have found a niche market as neighborhood or low speed vehicles for consumers going short distances at speeds of 30 mph or less. Also, dedicated EVs require low maintenance—including no tune-ups, oil changes, water pumps, radiators, injectors, or tailpipes.

Dedicated electric vehicles produce no tailpipe emissions, but producing the electricity to charge them can. EVs are really coal, nuclear, hydropower, oil, and natural gas cars, because these fuels produce most of the electricity in the U.S. Coal alone generates more than half of our electricity. When fossil fuels are burned, pollutants are produced like those emitted from the tailpipe of a gasoline-powered automobile. Power plant emissions, however, are easier to control than tailpipe emissions. Emissions from power plants are strictly regulated, controlled with sophisticated technology, and monitored continuously. In addition, power plants are usually located outside major centers of urban air pollution.

Ethanol

Ethanol is a clear, colorless alcohol fuel made by fermenting the sugars found in grains, such as corn, grain sorghum and wheat, as well as potato wastes, cheese whey, corn fiber, rice straw, urban wastes, and yard clippings. There are several processes that can produce alcohol (ethanol) from biomass. The most commonly used processes today use yeast to ferment the sugars and starch in the feedstock to produce ethanol.

Used before the Civil War and in the first vehicles, interest in ethanol revived during the oil embargos in the 1970s. Today, 95 ethanol plants, mostly in the Midwest, produce over four billion gallons of ethanol. Gasoline containing ten percent ethanol—E10—is widely used in urban areas that fail to meet standards for carbon monoxide and ozone. Since ethanol contains oxygen, using it as a fuel additive results in up to 25 percent fewer carbon monoxide emissions than conventional gasoline. E10 is not considered an alternative fuel under EPACT, but a replacement fuel.

Flexible fuel vehicles (FFVs) are designed and manufactured to use any combination of ethanol and gasoline up to 85 percent ethanol. There are now more than four million flex-fuel vehicles on the road and one million more are produced each year. E85, a fuel that is 85 percent ethanol and 15 percent gasoline is used mainly in the Midwest and South. There are about 150,000 light-duty vehicles using this fuel, serviced by ethanol fueling stations. Nearly half of these are private vehicles; the rest are federal, state and local government fleet vehicles. Ethanol is made from domestic, renewable feedstocks and may help to reduce U.S. dependence on foreign oil. Using ethanol can also reduce carbon monoxide and carbon dioxide emissions.

Gasoline

Gasoline is a petroleum-based fuel made of different hydrocarbons that contain energy. It is used as a fuel in most U.S. passenger vehicles with internal combustion engines. Americans use more than 18 million barrels of crude oil, or more than 380 million gallons of gasoline, every day. With U.S. population at about 299 million people, that is more than a gallon of gasoline every day for each man, woman, and child.

Today, gasoline is the fuel used by a vast majority of passenger vehicles in the U.S. There are 230 million vehicles in the U.S. that fill their tanks at the 180,000 fueling stations that provide convenient accessibility for consumers. The production and distribution infrastructures are in place. Gasoline has a high energy content of about 114,000 Btu/gallon and octane ratings of 86–94. It is highly flammable and toxic—gasoline vapors can cause dizziness, vomiting and even death if inhaled in strong concentrations.

Gasoline is a nonrenewable fossil fuel that produces air pollutants when it is burned. Since the 1960s, stricter environmental standards have led to gasoline formulations and vehicle designs that have reduced vehicle exhaust emissions by 95 percent. Even with reductions in emissions, the impact of gasoline on the environment is immense, because there are so many vehicles in the United States driving so many miles.

Hybrid Electric Vehicles

Hybrid Electric Vehicles (HEVs) are powered by two energy sources—an energy conversion unit (such as a combustion engine or fuel cell) and an energy storage device (such as battery, flywheel, or ultracapacitor). The energy conversion unit can be powered by gasoline, methanol, compressed natural gas, hydrogen, or other alternative fuels. HEVs have the potential to be two to three times more fuel-efficient than conventional vehicles.

An HEV battery doesn't have to be recharged. It has a generator powered by the internal combustion engine to recharge the batteries whenever they are low. A regenerative braking system captures excess energy when the brakes are engaged. The recovered energy is also used to recharge the batteries. The HEV provides extended range and rapid refueling, as well as significant environmental benefits, reducing pollutants by one-third to one half. In some cities, HEVs are permitted in the HOV (High Occupancy Vehicle) lanes.

There are several hybrids on the market today. The Honda Insight is a two-seat hybrid that averages over 60 mpg and can travel 600 miles on a tank of gasoline. The Toyota Prius is a five-seat sedan that averages over 50 mpg and can travel almost 600 miles before refueling. The Ford Escape averages over 30 mpg and can go about 450 miles on a tank of fuel. The federal government currently offers tax incentives when purchasing a hybrid. By 2008, there will be at least 24 hybrid models available to the general public.

Hydrogen Fuel Cells

In the future, hydrogen may provide a significant contribution to the alternative fuel mix. The space shuttles use hydrogen for fuel. Fuel cells use hydrogen and oxygen to produce electricity without harmful emissions; water is the main by-product. Hydrogen is a gas at normal temperatures and pressures, which presents greater transportation and storage hurdles than liquid fuels.

Hydrogen is the most abundant element in the universe, but it doesn't exist on Earth as a gas; it is produced using various methods, including electrolysis and synthesis gas production from steam reforming or partial oxidation. Electrolysis uses electricity to split water molecules into hydrogen and oxygen. The photolytic process uses sunlight to illuminate a semiconductor immersed in water splitting the water. Photobiological systems use natural photosynthetic activity of bacteria and green algae to produce hydrogen. The Department of Energy does not expect any of these methods to be the predominant method of producing large quantities of hydrogen fuel.

Today, the predominant method of producing hydrogen is steam reforming of natural gas (a fossil fuel), although biomass and coal can also be used as feedstocks. The U.S. has a plentiful supply of natural gas, so hydrogen can be produced domestically.

High production costs have limited hydrogen as a fuel to date except in research vehicles, but research is progressing on more efficient ways to produce and use it. The largest drawback to widespread vehicle use will be storage—the lower energy content of hydrogen requires fuel tanks six times larger than gasoline tanks. Its environmental benefits, however, mean that in 20 years, hydrogen fuel cell vehicles may be a common sight on the roadways of America.

Methanol

Methanol, or wood alcohol, is a toxic, colorless liquid with a slight odor of alcohol. Methanol is the simplest alcohol (CH_3OH), produced by replacing one hydrogen atom of methane with a hydroxyl radical (OH). Methanol can be produced from natural gas, coal, residual oil, or biomass. Today, most of the methanol in the United States is produced by the steam reforming of natural gas (methane), a nonrenewable fossil fuel.

Although vehicles can operate on pure methanol fuel (M100), methanol blended with 15 percent unleaded gasoline (M85) is more practical for real world applications. Because methanol is a liquid fuel, it does not require major changes in the distribution system or in car engines, but no major auto manufacturers offer M85 compatible vehicles at this time. Vehicles using methanol, however, must use a special, expensive lubricant. The fuel's superior combustion means that engines designed for methanol typically develop more horsepower, which gives methanol cars faster acceleration than comparable gasoline-powered cars. As a matter of fact, methanol is used in several drag racing classes and has been the only fuel used in Indianapolis 500 races for 30 years.

Methanol is not a perfect fuel. It can help reduce hydrocarbon emissions in nonattainment areas, but it produces more formaldehyde emissions than gasoline engines. Formaldehyde—besides being an eye and respiratory system irritant—contributes to ozone formation and is toxic.

Propane

Propane, C_3H_8, is an energy-rich fossil fuel often called liquefied petroleum gas (LPG). It is colorless and odorless; an odorant called mercaptan is added to serve as a warning agent. Propane is a by-product of petroleum refining and natural gas processing. Under normal atmospheric pressure and temperature, propane is a gas. Under moderate pressure and/or lower temperature, however, propane can easily be changed into a liquid and stored in pressurized tanks. Propane is 270 times more compact in its liquid state than it is as a gas, making it a portable fuel.

Propane has been used as a transportation fuel for more than 75 years and is the most widely used and most accessible alternative fuel. Taxicab companies, government agencies, and school districts often use propane instead of gasoline to fuel their fleets. Because it is portable and cleaner burning than gasoline, propane is ideal for vehicles and equipment used indoors. It leaves no lead, varnish, or carbon deposits that cause the premature wearing of pistons, rings, valves, and spark plugs. The engine stays clean, free of carbon and sludge. This means less maintenance and an extended engine life. Propane-fueled engines produce less air pollution than gasoline engines; carbon monoxide emissions are 50 to 92 percent lower than emissions from gasoline-fueled engines.

Propane is not more widely used as a transportation fuel because a conventional automobile engine has to be converted to use propane (at a cost of approximately $2,500), and there are only about 3,000 LPG vehicle-fueling stations in the U.S.—much fewer that gasoline stations.

TRANSPORTATION FUELS *enigma*
DATA SHEET

FUEL SOURCE ____________________

1. Uses: ___ Mostly Fleet ___ Mostly Private
 ___ Half Fleet and Half Private

2. Type: ___ Fossil Fuel ___ Biodegradable
 ___ Secondary Source (produced by other source)

3. ___ Mostly Imported ___ Mostly Domestic

4. Requires a special car or engine conversion:
 ___ Yes ___ No

5. Does it pollute? How? ____________________
____

6. Fuel available to the public? Where?
____

7. Facts particular to your fuel:
____
____
____

TRANSPORTATION FUELS *enigma*
DATA SHEET

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TRANSPORTATION FUELS *enigma*
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1. Uses: ___ Mostly Fleet ___ Mostly Private
 ___ Half Fleet and Half Private

2. Type: ___ Fossil Fuel ___ Biodegradable
 ___ Secondary Source (produced by other source)

3. ___ Mostly Imported ___ Mostly Domestic

4. Requires a special car or engine conversion:
 ___ Yes ___ No

5. Does it pollute? How? ____________________
____

6. Fuel available to the public? Where?
____

7. Facts particular to your fuel:
____
____
____

TRANSPORTATION FUELS *enigma*
DATA SHEET

FUEL SOURCE ____________________

1. Uses: ___ Mostly Fleet ___ Mostly Private
 ___ Half Fleet and Half Private

2. Type: ___ Fossil Fuel ___ Biodegradable
 ___ Secondary Source (produced by other source)

3. ___ Mostly Imported ___ Mostly Domestic

4. Requires a special car or engine conversion:
 ___ Yes ___ No

5. Does it pollute? How? ____________________
____

6. Fuel available to the public? Where?
____

7. Facts particular to your fuel:
____
____
____

TRANSPORTATION FUELS *enigma*
GAME SHEET

TEAM _____

CLUE *1*

CLUE *2*

CLUE *3*

CLUE *4*

TRANSPORTATION FUELS *enigma*
GAME SHEET

TEAM _____

CLUE *1*

CLUE *2*

CLUE *3*

CLUE *4*

TRANSPORTATION FUELS *enigma*
GAME SHEET

TEAM _____

CLUE *1*

CLUE *2*

CLUE *3*

CLUE *4*

TRANSPORTATION FUELS *enigma*
GAME SHEET

TEAM _____

CLUE *1*

CLUE *2*

CLUE *3*

CLUE *4*

Transportation Fuels Enigma Ballot

TEAM NUMBER _____ **ENERGY SOURCE** _____

ROUND ONE *30 points*

____ BIODIESEL
____ CNG
____ DIESEL
____ ELECTRICITY
____ ETHANOL
____ GASOLINE
____ HYBRID ELECTRIC
____ HYDROGEN
____ METHANOL
____ PROPANE

ROUND TWO *25 points*

____ BIODIESEL
____ CNG
____ DIESEL
____ ELECTRICITY
____ ETHANOL
____ GASOLINE
____ HYBRID ELECTRIC
____ HYDROGEN
____ METHANOL
____ PROPANE

ROUND THREE *15 points*

____ BIODIESEL
____ CNG
____ DIESEL
____ ELECTRICITY
____ ETHANOL
____ GASOLINE
____ HYBRID ELECTRIC
____ HYDROGEN
____ METHANOL
____ PROPANE

ROUND FOUR *10 points*

____ BIODIESEL
____ CNG
____ DIESEL
____ ELECTRICITY
____ ETHANOL
____ GASOLINE
____ HYBRID ELECTRIC
____ HYDROGEN
____ METHANOL
____ PROPANE

NOTE: *If you have already made a correct choice, do not mark your choice again in subsequent rounds.*

POINTS WON *game leaders use only*

____ BIODIESEL
____ CNG
____ DIESEL
____ ELECTRICITY
____ ETHANOL
____ GASOLINE
____ HYBRID ELECTRIC
____ HYDROGEN
____ METHANOL
____ PROPANE

TRANSPORTATION FUELS *enigma*

CLUE ORDER ENVELOPE

LETTER

1. _____ *least revealing*

2. _____

3. _____

4. _____ *most revealing*

TEAM NUMBER **TEAM NAME** **SOURCE**

fold here

TRANSPORTATION ENIGMA
FUEL CLUES

GROUP _____ • 1A **It is often used in fleet vehicles.**	GROUP _____ • 1B **It is an excellent lubricant.**
GROUP _____ • 1C **It is often blended with a petroleum based fuel.**	GROUP _____ • 1D **It is sensitive to cold weather.**
GROUP _____ • 1E **It can be produced domestically.**	GROUP _____ • 1F **It is biodegradable.**
GROUP _____ • 1G **It is produced by chemically reacting alcohol with vegetable oils, fats, or grease.**	GROUP _____ • 1H **Its exhaust can smell like french fries.**

TEAM 1 BIODIESEL

TRANSPORTATION ENIGMA
FUEL CLUES

GROUP _____ • 2A **Vehicles must also use an expensive lubricant when using it.**	GROUP _____ • 2B **Half the vehicles that use a high percentage blend are part of fleets; half are privately owned.**
GROUP _____ • 2C **It is colorless and has a slight alcohol odor.**	GROUP _____ • 2D **Vehicles using it are not available to the general public.**
GROUP _____ • 2E **It can be produced from fossil fuels or biomass.**	GROUP _____ • 2F **It has been used in Indianapolis 500 races for 30 years.**
GROUP _____ • 2G **Steam reforming is the most popular way to make it.**	GROUP _____ • 2H **It produces air pollutants when burned.**

TEAM 2 METHANOL

TRANSPORTATION ENIGMA
FUEL CLUES

GROUP _____ • 3A **It uses two different energy sources.**	GROUP _____ • 3B **It combines an internal combustion engine with a battery and electric motor.**
GROUP _____ • 3C **It uses a battery.**	GROUP _____ • 3D **The federal government offers tax incentives for people using it.**
GROUP _____ • 3E **Vehicles using it have a range between 450 and 600 miles.**	GROUP _____ • 3F **Requires a specially manufactured vehicle.**
GROUP _____ • 3G **It reduces pollutants by one third to one half.**	GROUP _____ • 3H **In certain cities, users can drive in HOV (High Occupancy Vehicle) lanes.**

TEAM 3 HYBRID ELECTRICITY

TRANSPORTATION ENIGMA
FUEL CLUES

GROUP _____ • 4A **It is a fossil fuel.**	GROUP _____ • 4B **There are 3,000 refueling stations in the United States.**
GROUP _____ • 4C **It is colorless and odorless.**	GROUP _____ • 4D **It adds no carbon or sludge to the engine.**
GROUP _____ • 4E **Most widely used and most accessible alternative fuel.**	GROUP _____ • 4F **Often fuels vehicles and equipment used indoors.**
GROUP _____ • 4G **It is often used in fleet vehicles.**	GROUP _____ • 4H **It burns very cleanly.**

TEAM 4 PROPANE

TRANSPORTATION ENIGMA
FUEL CLUES

GROUP _____ • 5A **It is colorless and odorless.**	GROUP _____ • 5B **Half the vehicles that use a high percentage blend are part of fleets; half are privately owned.**
GROUP _____ • 5C **It is produced by fermentation of sugars.**	GROUP _____ • 5D **It can be produced domestically.**
GROUP _____ • 5E **It is often blended with a petroleum based fuel.**	GROUP _____ • 5F **It is biodegradable.**
GROUP _____ • 5G **Most refueling stations in the U.S. are located in the Midwest.**	GROUP _____ • 5H **It requires a specially manufactured vehicle.**

TEAM 5 ETHANOL

TRANSPORTATION ENIGMA
FUEL CLUES

GROUP _____ • 6A **It fuels the majority of U.S. passenger vehicles.**	GROUP _____ • 6B **It produces air pollutants when burned.**
GROUP _____ • 6C **It is refined from crude oil.**	GROUP _____ • 6D **It is a fossil fuel.**
GROUP _____ • 6E **It has 180,000 refueling stations in the United States.**	GROUP _____ • 6F **In the U.S., 230 million vehicles use it.**
GROUP _____ • 6G **It is highly flammable.**	GROUP _____ • 6H **Two-thirds of U.S. supply is imported.**

TEAM 6 GASOLINE

TRANSPORTATION ENIGMA
FUEL CLUES

GROUP _____ • 7A **It uses a battery.**	GROUP _____ • 7B **Most popular for vehicles going short distances and making frequent stops.**
GROUP _____ • 7C **It can be produced domestically.**	GROUP _____ • 7D **It is a secondary source that often requires fossil fuels to produce.**
GROUP _____ • 7E **Vehicles using it have a range between 50 and 130 miles.**	GROUP _____ • 7F **It dramatically reduces vehicle maintenance.**
GROUP _____ • 7G **It produces no harmful tailpipe emissions.**	GROUP _____ • 7H **Most refueling stations are located in California and the southwest.**

TEAM 7 ELECTRICITY

TRANSPORTATION ENIGMA
FUEL CLUES

GROUP _____ • 8A **It is often used in fleet vehicles.**	GROUP _____ • 8B **Half the vehicles that use it are part of fleets; half are privately owned.**
GROUP _____ • 8C **It can be produced domestically; imports usually come from Canada.**	GROUP _____ • 8D **It requires a specially manufactured vehicle or engine conversion.**
GROUP _____ • 8E **Burns very cleanly.**	GROUP _____ • 8F **It has 780 refueling stations in the United States.**
GROUP _____ • 8G **It is a fossil fuel.**	GROUP _____ •8H **One of every five new transit buses in the U.S. is powered by it.**

TEAM 8 COMPRESSED NATURAL GAS (CNG)

TRANSPORTATION ENIGMA
FUEL CLUES

GROUP _____ • 9A **Two-thirds of all farm equipment use it.**	GROUP _____ • 9B **Passenger vehicles that use it are very popular in Europe.**
GROUP _____ • 9C **It's refined from crude oil.**	GROUP _____ • 9D **It is a fossil fuel.**
GROUP _____ • 9E **It fuels the majority of U.S. buses.**	GROUP _____ • 9F **It produces air pollutants when burned.**
GROUP _____ • 9G **It is the predominant fuel for U.S. shipping.**	GROUP _____ • 9H **Two-thirds of U.S. supply is imported.**

TEAM 9 DIESEL

TRANSPORTATION ENIGMA
FUEL CLUES

GROUP _____ • 10A **It is a secondary source that often requires fossil fuels to produce.**	GROUP _____ • 10B **Vehicles using it are not available to the general public.**
GROUP _____ • 10C **Steam reforming is the most popular way to make it.**	GROUP _____ • 10D **It can be produced domestically.**
GROUP _____ • 10E **It has been used to fuel space shuttles.**	GROUP _____ • 10F **It is the most abundant gas in the universe.**
GROUP _____ • 10G **It produces no harmful tailpipe emissions.**	GROUP _____ • 10H **Electrolysis is one way to produce it.**

TEAM 10 HYDROGEN FUEL CELLS

TRANSPORTATION FUELS ENIGMA

Evaluation Form

State: _____ **Grade Level:** _____ **Number of Students:** _____

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

How would you rate the activity overall (excellent, good, fair, poor)?

How would your students rate the activity overall (excellent, good, fair, poor)?

What would make the activity more useful to you?

Other Comments:

Please fax or mail to:
NEED Project
PO Box 10101
Manassas, VA 20108
FAX: 1-800-847-1820

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