Transportation Fuels Enigma

2011-2012

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

TRANSPORTATION

Grade Level:
- Intermediate
- Secondary

Subject Areas:
- Science
- Social Studies
- Language Arts

NEED
National Energy Education Development Project

Teacher Advisory Board

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NEED
National Energy Education Development

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Correlations to National Science Education Standards: Grades 5-8

This book has been correlated to National Science Education Content Standards.
For correlations to individual state standards, visit **www.NEED.org**.

Content Standard B | *PHYSICAL SCIENCE*

- **Transfer of Energy**
  - Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
  - In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light mechanical motion, or electricity might all be involved in such transfers.
  - The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Content Standard D | *EARTH AND SPACE SCIENCE*

- **Earth in the Solar System**
  - The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day.

Content Standard E | *SCIENCE AND TECHNOLOGY*

- **Understandings about Science and Technology**
  - Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology.
  - Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

Correlations to National Science Education Standards: Grades 9-12

This book has been correlated to National Science Education Content Standards.
For correlations to individual state standards, visit **www.NEED.org**.

Content Standard D | *EARTH AND SPACE SCIENCE*

- **Energy in the Earth System**
  - Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the earth's original formation.

Content Standard F | *SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES*

- **Natural Resources**
  - Human populations use resources in the environment in order to maintain and improve their existence. Natural resources have been and will continue to be used to maintain human populations.
  - The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.
  - Humans use 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.
- **Science and Technology in Local, National, and Global Challenges**
  - 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, or global challenges.

Content Standard B | *PHYSICAL SCIENCE*

- **Structure and Properties of Matter**
  - Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.
- **Chemical Reactions**
  - Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies.
  - Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.

Content Standard E | *SCIENCE AND TECHNOLOGY*

- **Understandings about Science and Technology**
  - Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.
  - Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world.

Content Standard F | *SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES*

- **Natural Resources**
  - The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.

Teacher Guide

TRANSPORTATION

A critical thinking activity 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 Infosheets* (each group needs two) (pages 9-11)
- *Transportation Fuels Enigma Data Sheet* (each group needs nine) (page 12)
- *Transportation Fuels Enigma Clue Cards* (each group needs nine) (page 13)
- *Transportation Fuels Enigma Ballot* (each group needs one) (page 14)
- *Transportation Fuels Enigma Clue Order Envelope* (each group needs one) (page 15)
- *Transportation Fuels Enigma Source Clue Sheets* (one copy of each) (pages 16-24)

Procedure

Step One: Preparation

1. Make copies of the materials as listed above.
2. Cut the *Clue Cards* and clip together seven stacks of nine.
3. Cut the *Data Sheets* and staple together seven stacks of nine. Clip together the remaining sheets.
4. Fold the *Clue Order Envelopes* in half and tape the sides closed.
5. Make transparencies of each of the nine *Transportation Fuels Enigma Source Clue Sheets*. Cut each sheet into its eight clues and clip them together by fuel.
6. Divide the students into seven groups with three to five students per group.
7. Choose seven out of the nine fuel sources to assign to the groups. Next, place the *Clue Cards* 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.
8. On each table, place one stack of *Data Sheets*, two sets of *Infosheets*, and a *Clue Order 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 make our vehicles move, 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 *Transportation Fuels 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 everyday 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 designed 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 Order Envelope* and arrange them in one column A through H. Place your completed *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 Order 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 Order 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 Order Envelopes* when you are finished and check your rationale for clue selection.

Step Five: Developing Opposing Teams' Data Sheets

Pick up the *Clue Order Envelopes* and give each team the remaining *Data Sheets*. Read the following instructions to the students:

- Using the *Infosheets*, develop the remaining eight *Data Sheets*. Be sure to indicate which fuel you are working on in the space provided at the top of each sheet. Divide the eight 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 nine *Clue Cards*. Read the following instructions to the students:

- I have placed nine *Clue Cards* and a *Ballot* on your table. Number the *Clue Cards* one through nine. 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 two energy sources. Shortly, I will project the first clue of each of the nine 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 nine.
- Two or more members of your team should write the information for each clue in the top box (marked "Clue 1") of the appropriate *Clue Card*.
- 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 bottom 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 *Clue Cards*.
- Here are the first clues for round one; write them in the top box (marked "Clue 1") on your *Clue Cards*. 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*
- *Ballot Scores—60 points* (The number of grading points a team receives is based on the team's *Ballot* score.)
- Explanation to class—*15 points*

Transportation Fuels Infosheets

TRANSPORTATION

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 (B2) or 20 percent (B20) biodiesel. Lower percentage blends of biodiesel, like these, usually require little to no modifications on traditional diesel engines. Because of the ability to make and use blends, combined with the ability to use an engine without much modification, biodiesel 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 toxins. Currently biodiesel is produced domestically, but is only available 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 is a nonrenewable fossil fuel with plentiful supplies in the United States, and the majority of U.S. imports come from Canada. When natural gas is compressed, it can be used as a clean burning transportation fuel. Today, there are about 114,000 compressed natural gas (CNG) vehicles in operation in the U.S., mostly in the South and West. There are about 830 compressed 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 $8,000-12,000, 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 fossil fuel made of hydrogen and carbon molecules (hydrocarbons) that contain energy. About one half of U.S. petroleum is imported from other countries, thus, our nation relies on imports to produce diesel fuel. 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 is readily available and is offered at over half of all fuel retail sites in the U.S.

Diesel fuel has a wide range of applications and is uniquely qualified to perform demanding work. In agriculture, diesel powers more than two-thirds of all farm equipment in the U.S. 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.

A new generation of clean diesel cars, light trucks, and SUVs are now available and offer consumers a new choice in fuel-efficient and low-emissions technology. Diesel-powered cars achieve 20-40 percent better fuel economy than gasoline powered equivalents.

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), nitrogen oxide (NOx), and particulate matter. Significant progress has been made in reducing emissions from diesel engines. Refiners can produce ultra low sulfur diesel, which has reduced the sulfur content in diesel fuel by 97 percent. 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 over 56.000 dedicated, specially designed vehicles in use in the United States, mostly in the South and West. 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 500+ refueling stations found in California and the Southwest. Soon there will be thousands of public stations available for use.

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. 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 EV's therefore have found a niche market as neighborhood or low speed vehicles for consumers. These private vehicles can go short distances at speeds of 30 mph or less. Also, dedicated EV's are 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, biodegradable alcohol fuel made by fermenting the sugars found in grains, such as corn, grain sorghum, wheat, and sugar cane. 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 embargoes in the 1970s. Today, there are more than 140 ethanol plants, mostly in the Midwest, produce over nine billion gallons of ethanol. Gasoline containing ten percent ethanol—E10—is widely used across the United States. 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 seven million flex-fuel vehicles on the road and one million more are produced each year. However, less than 400,000 of these vehicles operate on E85. Nearly half of these are private vehicles; the rest are federal, state and local government fleet vehicles. There are only about 2000 refueling stations equipped to distribute E85 in the US, but this number is expected to grow.

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. private passenger vehicles with internal combustion engines. Americans use more than 18 million barrels of crude oil, or nearly 378 million gallons of gasoline, every day. With the U.S. population at about 304.5 million people, that is more than a gallon of gasoline every day for each man, woman and child. Nearly half of our crude oil supply is imported from other countries.

Today, gasoline is the fuel used by a vast majority of passenger vehicles in the U.S. There are 246 million vehicles in the U.S. that fill their tanks at the 162,000 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 (HEV's) are specifically designed and powered by two energy sources—an energy conversion unit (such as a combustion engine or fuel cell) and an energy storage device (such as a battery, flywheel, or ultracapacitor). The energy conversion unit can be powered by gasoline, methanol, compressed natural gas, hydrogen, or other alternative fuels. Most rely on the use of fossil fuels today, like gasoline. HEV's 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. The federal government also offers tax incentives to those who purchase and use hybrid electric vehicles.

There are nearly 30 hybrids on the market today that are readily available for private and fleet use. 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 about 50 mpg and can travel almost 540 miles before refueling. The Ford Escape averages over 32 mpg and can go about 435 miles on a tank of fuel.

Plug-in hybrid electric vehicles (PHEVs) are similar to HEVs. They have an internal combustion engine, an electric motor, and a large battery pack. The larger battery pack allows the PHEV to travel 10-40 miles on an electric only range. When the battery is depleted the car continues to operate as a hybrid or gasoline vehicle. Batteries can be recharged with a regular 120 volt electric outlet.

Hydrogen Fuel Cells

In the future, hydrogen may provide a significant contribution to the alternative fuel mix. The space shuttles used hydrogen for fuel. Fuel cells can also 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.

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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. As hydrogen requires another fuel source in order for it to be produced, it is considered a secondary source. The U.S. has a plentiful supply of natural gas, so hydrogen can be produced domestically.

In the future, hydrogen may provide a significant contribution to the alternative fuel mix. The space shuttles used hydrogen for fuel. Fuel cells can also 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.

There are no hydrogen fueled vehicles available to consumers today. High production costs have limited hydrogen as a fuel to date except in research vehicles, but research is progressing in more efficient ways to produce and use it. The largest drawback to widespread vehicle use will be storage—the lower energy density 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.

Propane

Propane, C_3H_8, is an energy –rich fossil fuel product 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. Most of the propane we use is produced domestically. 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 ranging between $4,000 to $12,000), and there are only about 2,500 LPG vehicle-fueling stations in the U.S.—much fewer than 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 sources)

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 sources)

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 sources)

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 sources)

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*

CLUE CARD

TEAM ____________________

CLUE 1

CLUE 2

CLUE 3

CLUE 4

TRANSPORTATION FUELS *Enigma*

CLUE CARD

TEAM ____________________

CLUE 1

CLUE 2

CLUE 3

CLUE 4

TRANSPORTATION FUELS *Enigma*

CLUE CARD

TEAM ____________________

CLUE 1

CLUE 2

CLUE 3

CLUE 4

TRANSPORTATION FUELS *Enigma*

CLUE CARD

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
- ____ PROPANE

ROUND TWO *25 points*

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

ROUND THREE *15 points*

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

ROUND FOUR *10 points*

- ____ BIODIESEL
- ____ CNG
- ____ DIESEL
- ____ ELECTRICITY
- ____ ETHANOL
- ____ GASOLINE
- ____ HYBRID ELECTRIC
- ____ HYDROGEN
- ____ 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*

- ____ ROUND ONE
- ____ ROUND TWO
- ____ ROUND THREE
- ____ ROUND FOUR

Transportation Fuels *Enigma*

CLUE ORDER ENVELOPE

LETTER

1. ______________ ***least revealing*** *(use first)*
2. ______________
3. ______________
4. ______________ ***most revealing*** *(use last)*

TEAM NUMBER ______ SOURCE ______

fold here

TRANSPORTATION

Transportation Fuels Enigma Source 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

Transportation Fuels Enigma Source Clues

GROUP __________ • 2A **It uses two different energy sources.**	GROUP __________ • 2B **It combines an internal combustion engine with a battery and electric motor.**
GROUP __________ • 2C **It uses a battery.**	GROUP __________ • 2D **The federal government offers tax incentives for people using it.**
GROUP __________ • 2E **Vehicles using it have a range between 450 and 600 miles.**	GROUP __________ • 2F **Requires a specially manufactured vehicle.**
GROUP __________ • 2G **It reduces pollutants by one third to one half.**	GROUP __________ • 2H **In certain cities, users can drive in HOV (High Occupancy Vehicle) lanes.**

Team 2 Hybrid Electric

TRANSPORTATION

Transportation Fuels Enigma Source Clues

GROUP ________ • 3A **It is made from a fossil fuel.**	GROUP ________ • 3B **There are about 2,500 refueling stations in the United States.**
GROUP ________ • 3C **It is colorless and odorless.**	GROUP ________ • 3D **It adds no carbon or sludge to the engine.**
GROUP ________ • 3E **Most widely used and most accessible alternative fuel.**	GROUP ________ • 3F **Often fuels vehicles and equipment used indoors.**
GROUP ________ • 3G **It is often used in fleet vehicles.**	GROUP ________ • 3H **It burns very cleanly.**

Team 3 Propane

TRANSPORTATION

Transportation Fuels Enigma Source Clues

GROUP __________ • 4A **It is colorless and odorless.**	GROUP __________ • 4B **Half of the vehicles that use a high percentage blend are part of fleets; half are privately owned.**
GROUP __________ • 4C **It is produced by fermentation of sugars.**	GROUP __________ • 4D **It can be produced domestically.**
GROUP __________ • 4E **It is often blended with a petroleum based fuel.**	GROUP __________ • 4F **It is biodegradable.**
GROUP __________ • 4G **Most refueling stations in the U.S. are located in the Midwest.**	GROUP __________ • 4H **To be used, it requires a specially manufactured vehicle.**

Team 4 Ethanol

TRANSPORTATION

Transportation Fuels Enigma Source Clues

GROUP ________ • 5A It fuels the majority of U.S. passenger vehicles.	GROUP ________ • 5B It produces air pollutants when burned.
GROUP ________ • 5C It is refined from crude oil.	GROUP ________ • 5D It is made from a fossil fuel
GROUP ________ • 5E It has 162,000 refueling stations in the United States.	GROUP ________ • 5F In the U.S., 246 million vehicles use it.
GROUP ________ • 5G It is highly flammable.	GROUP ________ • 5H It is used in an internal combustion engine.

Team 5 Gasoline

TRANSPORTATION

Transportation Fuels Enigma Source Clues

GROUP __________ · 6A **It uses batteries.**	GROUP __________ · 6B **Most popular for vehicles going short distances and making frequent stops.**
GROUP __________ · 6C **It can be produced domestically.**	GROUP __________ · 6D **It is a secondary source that often requires fossil fuels to produce.**
GROUP __________ · 6E **Vehicles using it have a range between 50 and 130 miles.**	GROUP __________ · 6F **It dramatically reduces vehicle maintenance.**
GROUP __________ · 6G **It produces no harmful tailpipe emissions.**	GROUP __________ · 6H **Most refueling stations are located in California and the Southwest.**

Team 6 Electricity

TRANSPORTATION

Transportation Fuels Enigma Source Clues

GROUP __________ •7A

It is often used in fleet vehicles.

GROUP __________ • 7B

Half the vehicles that use it are part of fleets; half are privately owned.

GROUP __________ • 7C

It can be produced domestically; imports usually come from Canada.

GROUP __________ •7D

It requires a specially manufactured vehicle or engine conversion.

GROUP __________ • 7E

It burns very cleanly.

GROUP __________ • 7F

It has 830 refueling stations in the United States.

GROUP __________ • 7G

The federal government offers tax incentives for those who use it.

GROUP __________ • 7H

One of every five new transit buses in the U.S. is fueled by it.

Team 7 Compressed Natural Gas (CNG)

TRANSPORTATION

Transportation Fuels Enigma Source Clues

GROUP __________ • 8A **Two-thirds of all farm equipment use it.**	GROUP __________ • 8B **Next generation passenger vehicles that use it provide higher fuel economy.**
GROUP __________ • 8C **It's refined from crude oil.**	GROUP __________ • 8D **It is made from a fossil fuel.**
GROUP __________ • 8E **It fuels the majority of U.S. buses.**	GROUP __________ • 8F **It produces air pollutants when burned.**
GROUP __________ • 8G **It is the predominant fuel for U.S. shipping of goods.**	GROUP __________ • 8H **About half of U.S. supply is imported.**

Team 8 Diesel

TRANSPORTATION

Transportation Fuels Enigma Source Clues

GROUP ________ • 9A **It is a secondary source that often requires fossil fuels to produce.**	GROUP ________ • 9B **Vehicles using it are not available to the general public.**
GROUP ________ • 9C **Steam reforming is the most popular way to make it.**	GROUP ________ • 9D **It can be produced domestically.**
GROUP ________ • 9E **It has been used to fuel space shuttles.**	GROUP ________ • 9F **It is the most abundant element in the universe.**
GROUP ________ • 9G **It produces no harmful tailpipe emissions.**	GROUP ________ •9H **Electrolysis is one way to produce it.**

Team 9 Hydrogen Fuel Cells

TRANSPORTATION

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:

____

____

____

____

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Manassas, VA 20108
FAX: 1-800-847-1820

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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
New Orleans Solar Schools Initiative
New York Power Authority
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