2015-2016

Transportation Fuels Enigma

Students put on their detective hats to research clues that uncover the capabilities of the major transportation fuels. This cooperative learning activity encourages students to use langauge arts, critical thinking, and organizational skills to conceal the identity of their fuel while guessing the fuels other teams represent.

Grade Levels:

Int Intermediate

Sec Secondary

Subject Areas:

Science

Social Studies

Language Arts

NEED

National Energy Education Development Project

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NEED
National Energy Education Development

1.800.875.5029
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Transportation Fuels Enigma

Data for This Guide is Taken From:

- **U.S. Department of Energy Office of Energy Efficiency and Renewable Energy**
  - Alternative Fuels and Advanced Vehicles Data Center
  - Clean Cities Program
- ***U.S. Department of Energy Transportation Energy Data Book,* 33rd Edition**
- **Fueleconomy.gov**
- **U.S. Energy Information Administration**

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Standards Correlation Information

www.NEED.org/curriculumcorrelations

Next Generation Science Standards

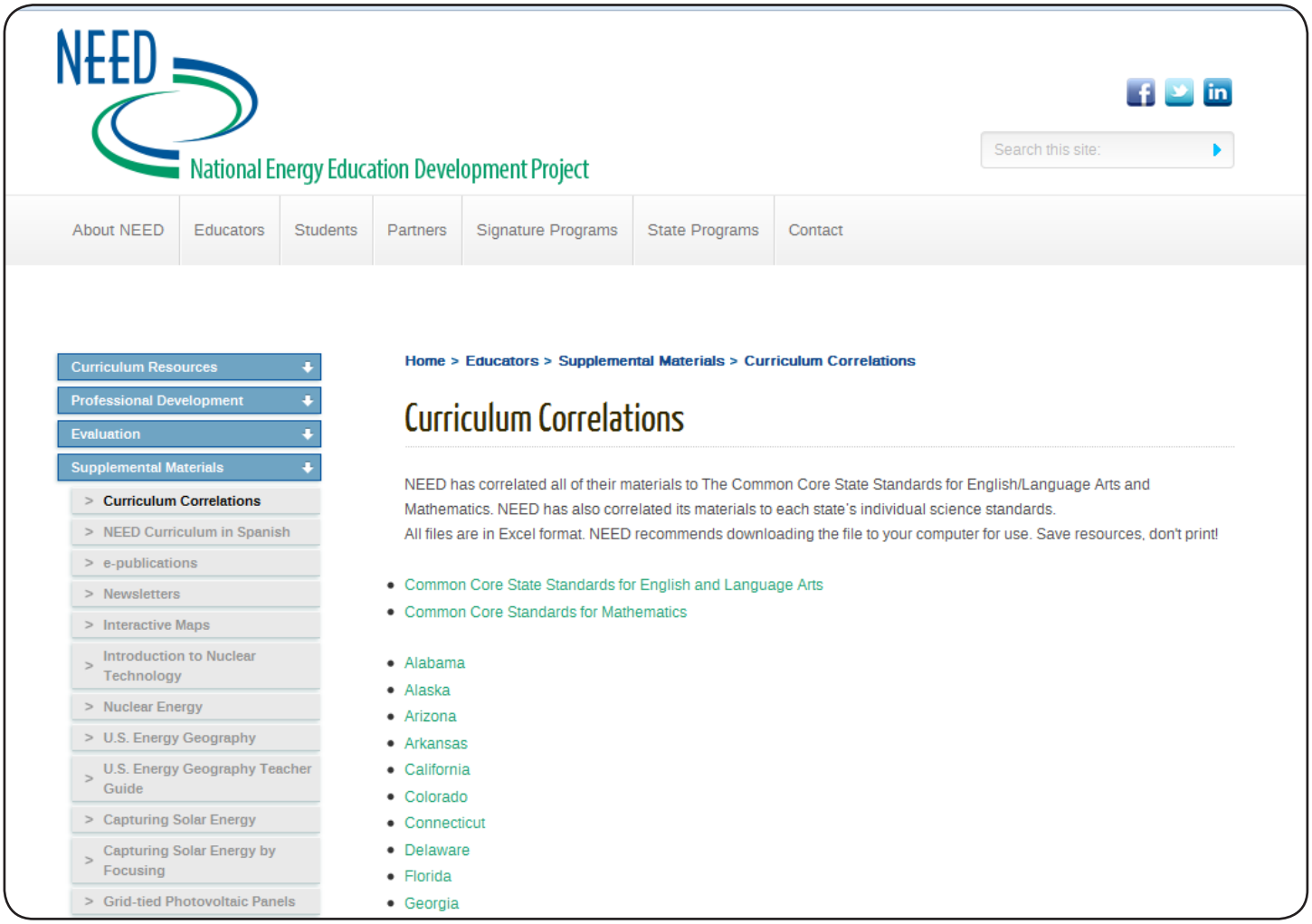
- This guide effectively supports many Next Generation Science Standards. This material can satisfy performance expectations, science and engineering practices, disciplinary core ideas, and cross cutting concepts within your required curriculum. For more details on these correlations, please visit NEED's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



Teacher Guide

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 conceal the identity of their team's fuel while trying to guess which transportation fuels the other teams represent.

Objectives

- Students will be able to differentiate between renewable and nonrenewable sources of energy.
- Students will be able to differentiate between the various transportation fuels.
- Students will be able to describe benefits and limitations to using each of the various transportation fuels.

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.

Materials

- *Transportation Fuels Infosheets* (two copies of each per group), pages 9-11
- *Transportation Fuels Enigma Data Sheets* (each group needs nine Data Sheets), page 12
- *Transportation Fuels Enigma Clue Cards* (each group needs nine Clue Cards), page 13
- *Transportation Fuels Enigma Score Card* (one per group), page 14
- *Transportation Fuels Enigma Clue Order Envelope* (one per group), page 15
- *Transportation Fuels Enigma Source Clues* (one paper copy or transparency of each), pages 16-24
- Optional: *Transportation Fuels Enigma* computer file—available at www.NEED.org

Procedure

Step One: Preparation

- Divide the students into seven groups with three to five students per group.*
- Make copies of the materials as listed above.
- Cut the *Transportation Fuels Enigma Clue Cards* and clip together seven stacks of nine.
- Cut the *Transportation Fuels Enigma Data Sheets* and staple together seven stacks of eight. Set aside the remaining sheets, as they will be passed out individually.
- Fold the *Transportation Fuels Enigma Clue Order Envelopes* in half and tape the sides closed.
- Download the *Transportation Fuels Enigma* computer file from www.NEED.org. Or, prepare the *Transportation Fuels Enigma Source Clues* sheets to project for the class. If using an overhead projector, make a transparency of each of the nine *Transportation Fuels Enigma Source Clues* sheets. Cut each sheet into its eight clues and clip together.
- Choose seven out of the nine fuel sources to assign to the groups. Next, place the *Transportation Fuels Enigma Clue Cards* for the seven sources you chose in separate envelopes. Write the team number and name of the fuel source in the space provided. You will need to determine the clue order for the two fuel sources not represented by student groups.*
- On each table, place one individual *Transportation Fuels Enigma Data Sheet*, one stack of *Transportation Fuels Enigma Data Sheets*, two sets of *Transportation Fuels Infosheets*, and a *Transportation Fuels Enigma Clue Order Envelope* face down.

Grade Levels

- Intermediate, grades 7-8
- Secondary, grades 9-12

Time

Three 45-minute class periods

Additional Resources

NEED has several resources on transportation fuels available to download online at www.NEED.org.

- *Transportation Fuels Infobook*
- *Exploring Hybrid Buses*
- *Transportation Fuels Debate*
- *Transportation Fuels Rock Performances*
- *Energy Expos*
- *H_2 Educate*

The *Transportation Fuels Enigma* computer file is an HTML, browser-based method for revealing clues during the activity. It can be a substitute for an overhead projector or extra printing and can be downloaded for easy use at www.NEED.org with instructions.

***NOTE:** *Transportation Fuels Enigma can easily be played with up to nine groups, or fewer than seven groups. If playing with a different number of groups than specified in the instructions, you must adjust the numbers of copies and stacks of each sheet to reflect the number of groups playing.*

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 activity 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 an activity in which teams look for clues that will help unlock the mysteries of the nation's common and upcoming transportation fuels. You will need 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 *Transportation Fuels Enigma Clue Order 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 of Enigma Eliminators is to learn something about your fuel. To accomplish this objective, each team has been given *Transportation Fuels Infosheets*. Each team also has a *Transportation Fuels Enigma 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 *Transportation Fuels 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 these questions, 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

Read the following instructions to the students:

- Now, each team should take out the eight clues from their *Transportation Fuels Enigma 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 the opposing teams. Try to come up with the four clues as a group.
- When you've completed this task, take the four eliminated clues and put them back in the envelope because you no longer need them.

- 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. Write the order on the front of the envelope. Place all the cards back inside the 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 *Transportation Fuels Enigma Clue Order Envelopes* when you are finished and check your rationale for clue selection.

Step Five: Developing Opposing Teams' Data Sheets

Pick up the *Transportation Fuels Enigma Clue Order Envelopes* and give each team a stack of eight stapled data sheets. Read the following instructions to the students:

- Using the *Transportation Fuels Infosheets*, develop fuel data sheets for the other eight fuels. 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 activity, I will take away your infosheets—you can only use your completed data sheets.

Step Six: Completing the Activity (Day Two)

Option: Use the Transportation Fuels Enigma computer file to reveal clues rather than using an overhead. You can download this file for free at www.NEED.org.

Give each team a *Transportation Fuels Enigma Score Card* and a stack of nine *Transportation Fuels Enigma Clue Cards*. Read the following instructions to the students:

- I have placed nine *Transportation Fuels Enigma Clue Cards* and a *Transportation Fuels Enigma Score Card* on your table. Number the clue cards one through nine. Write your team number and the name of your team's transportation fuel on the score card.
- Now, it is time for solving mysteries! Each team has given me the clue order for their transportation fuels, and I have chosen the clue order for the remaining two transportation fuels*. Shortly, I will project the first clue of each of the nine fuels on the screen. The first column of five clues will be for one through five, and the second row of clues for six through nine.

**If playing with less than nine groups.*

- Members of your team should write the information for each clue in the top box (marked "Round 1") of the appropriate clue card. You must work together to complete all of the clue cards.
- Your team will then have six minutes to decide if you wish to guess which transportation fuel is represented by an opposing team. This is done by writing the number of the team on the line next to the transportation fuel you think they represent on your *Transportation Fuels Enigma Score Card* 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 on the line at the bottom of the score card. 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 reveal the clues, I will give the teams 90 seconds to devise a plan on how they will monitor the *Transportation Fuels Enigma Clue Cards*.
- Here are the first clues for round one; write them in the top box (marked "Round 1") on your clue cards. You will have six minutes to make a guess for any or all of the nine fuels. Remember, incorrect guesses will cost your team ten points, so it may be better to leave some of them blank for the first round or two. At the end of the six minutes no score cards 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 score cards 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 and 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?

Read the following instructions to the students:

- 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 *Transportation Fuels Enigma Data Sheets —15 points*
- Working together as a team during the activity—*10 points*
- The number of points a team receives based on the team's *Transportation Fuels Enigma Score Card —60 points*
- 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 fryer grease. 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 gaining acceptance as an alternative transportation fuel in the U.S. that can be domestically produced.

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 (neat biodiesel) 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 294 public biodiesel refueling stations in the United States as well as numerous private refueling stations. Biodiesel is very 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 a small amount of U.S. imports, mostly from Canada. When natural gas is compressed, it can be used as a clean burning transportation fuel. Today, there are about 118,200 compressed natural gas (CNG) vehicles in operation in the U.S. Most are fleet vehicles, either owned privately or by government agencies. Some garbage trucks and about one-fifth of all transit buses in the U.S. are powered by compressed natural gas.

There are 799 public compressed natural gas refueling stations in the United States. It is even possible to refuel natural gas vehicles at home using a small refueling appliance! Private businesses and public agencies with fleets of ten or more have their own refueling stations, too.

Vehicles manufactured to run on CNG are available from a few manufacturers. A gasoline engine can also be converted to run on CNG at a cost of $12,000-18,000, depending on the number of fuel tanks installed. Tax incentives, which vary by state, can help offset the cost of conversion.

Compressed natural gas vehicles emit the same amount of smog-producing pollutants as other fuels and 6-11 percent less greenhouse gas emissions than gasoline-powered vehicles.

Diesel

Diesel is a petroleum–based fossil fuel made of hydrogen and carbon molecules (hydrocarbons) that contain energy. Forty-one percent of U.S. petroleum is imported from other countries, thus, our nation relies on imports to produce diesel fuel. Approximately 11 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 is offered at more than half of all fuel retail sites in the U.S.

Diesel fuel has a wide range of applications and is uniquely qualified to perform the demanding work of heavy duty vehicles. In agriculture, diesel provides two-thirds of the energy used to power 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; over 90 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 20-35 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 (NO_x), and particulate matter. Significant progress has been made in reducing emissions from diesel engines. Refiners produce ultra low sulfur diesel (ULSD), which has reduced the sulfur content in diesel fuel by 97 percent. Since 2014, ULSD is the only diesel fuel sold in the U.S. With new clean diesel technologies, today's trucks and buses have decreased emission levels by over 90 percent.

Electricity

Electric vehicles (EVs) have been around since 1891, and today there are over 67,000 dedicated, specially designed vehicles in use in the United States, mostly in bigger cities where the population is dense. Dedicated electric vehicles run on batteries that need to be recharged frequently. Recharging can be done at home in the evening. There are also nearly 22,000 public electric charging outlets found at 9,000 public refueling stations in large cities around the country. California has more than any other state. Electric charging outlets are found at airports and shopping centers, too.

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 travel about 100 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. Fully recharging the batteries of an EV can take four to eight hours. Some vehicles offer a quick charge option that takes 30 minutes, but only charges the batteries up to 80 percent.

Also, dedicated EVs are low maintenance —including no tune–ups, oil changes, water pumps, radiators, injectors, or tailpipes. These vehicles are great for use when traveling shorter distances or when making many stops or deliveries.

Dedicated electric vehicles produce no tailpipe emissions, but producing the electricity to charge them can. Electricity is a secondary energy source. EVs are really coal, natural gas, nuclear, hydropower, and oil cars, because these fuels produce most of the electricity in the U.S. Coal alone generates 39.1 percent 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 was revived during the oil embargoes of the 1970s. Today, there are 187 ethanol plants, mostly in the Midwest, producing more than 13 billion gallons of ethanol. Gasoline containing ten percent ethanol—E10—is widely used across the United States. E10 is not considered an alternative fuel under the Energy Policy Act, but a replacement fuel. Using ethanol as a fuel additive decreases fuel economy slightly, but can increase vehicle power and performance.

Flexible fuel vehicles (FFVs) are designed and manufactured to use any combination of ethanol and gasoline up to 85 percent ethanol. There are more than 17.4 million flex-fuel vehicles on the road and millions more are produced each year. It is unknown how many private citizens use E85 as their primary fuel. However, we do know that about 863,000 fleet vehicles operate on E85. Some of these are private company vehicles; many are federal, state, and local government fleet vehicles. Even Indycars race using E85 as their fuel source! There are more than 2,500 public refueling stations equipped to distribute E85 in the U.S., and this number is expected to grow. The largest concentration of refueling stations is currently in the Midwest.

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. The CO_2 released from the burning of ethanol can be balanced by the CO_2 captured by the growth of the crops used to make it.

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. To meet our transportation needs, Americans use more than 13 million barrels of crude oil, or nearly 252.3 million gallons of gasoline, every day. With the U.S. population at over 300 million people, that is almost one gallon of gasoline every day for each man, woman, and child. Forty-one percent of our crude oil supply is imported from other countries.

Today, gasoline is the fuel used by a vast majority of vehicles in the U.S. There are 235 million light duty passenger vehicles in the U.S. that fill their tanks at the 156,000 fueling stations that provide convenient accessibility for consumers. The production and distribution infrastructures are in place. Gasoline has a high energy content of about 116,000 Btu/gallon and octane ratings of 84-93. 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. In the last 40-50 years, stricter environmental standards have led to gasoline formulations and vehicle designs that have reduced vehicle exhaust emissions by 95 percent. Over the past ten years, emissions produced from highway driving has been reduced even more. 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 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, ethanol, compressed natural gas, hydrogen, or other alternative fuels. Most rely on the use of fossil fuels today, like gasoline. HEVs are typically more fuel-efficient than comparable conventional vehicles and have lower overall fuel costs.

An HEV battery is recharged by on-board sources. 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. This recovered energy is also used to recharge the batteries. The HEV provides extended range and rapid refueling, as well as significant environmental benefits, reducing tailpipe emissions.

There are nearly 50 hybrid models on the market today that are readily available for private and fleet use. Hybrid vehicles include two seat passenger cars, four and five seat sedans, SUVs, and even full size pickup trucks capable of towing.

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 using electric only. 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 whenever the car is parked and plugged into electrcity. In some cities, PHEVs are permitted in the HOV (High Occupancy Vehicle) lanes at all times. Both the federal and some state governments offer tax incentives to those who purchase and use plug-in hybrid electric vehicles.

Presently, there are 11 PHEV models available to consumers, with more expected to be on the market in the future.

Hydrogen Fuel Cells

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 into hydrogen and oxygen. 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.

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 energy 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. NASA space shuttles once used hydrogen for fuel. Fuel cells can also use hydrogen and oxygen to produce electricity without harmful tailpipe 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 few hydrogen fueled vehicles being made commercially. They are only available to consumers in select markets, such as California. Historically, high production costs limited hydrogen as a fuel mostly for research vehicles. 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 much larger than gasoline tanks. Refueling is also an issue. There are only 13 public hydrogen refueling stations in the U.S. at this time. The environmental benefits, however, mean that in the future, hydrogen fuel cell vehicles could 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 since the 1920s. 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 may reduce some tailpipe emissions, and greenhouse gas emissions are nearly 10 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 2,670 public 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 ______________________________

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TRANSPORTATION FUELS *Enigma*

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5. Does it pollute? How? ____________________
____

6. Fuel available to the public? Where?
____

7. Facts particular to your fuel:
____
____
____

TRANSPORTATION FUELS *Enigma*

CLUE CARD

TEAM _____

ROUND 1

ROUND 2

ROUND 3

ROUND 4

TRANSPORTATION FUELS *Enigma*

CLUE CARD

TEAM _____

ROUND 1

ROUND 2

ROUND 3

ROUND 4

TRANSPORTATION FUELS *Enigma*

CLUE CARD

TEAM _____

ROUND 1

ROUND 2

ROUND 3

ROUND 4

TRANSPORTATION FUELS *Enigma*

CLUE CARD

TEAM _____

ROUND 1

ROUND 2

ROUND 3

ROUND 4

Transportation Fuels Enigma Score Card

Team Number: **Transportation Fuel:**

Points Won *(game leader's use only)*

_____ **Biodiesel**
_____ **CNG**
_____ **Diesel**
_____ **Electricity**
_____ **Ethanol**
_____ **Gasoline**
_____ **Hybrid Electric**
_____ **Hydrogen Fuel Cells**
_____ **Propane**

NOTES: Subtract 10 points for every incorrect answer. If you have already made a correct choice, do not mark your choice again in subsequent rounds.

Round One *30 Points for each correct answer*

_____ **Biodiesel**
_____ **CNG**
_____ **Diesel**
_____ **Electricity**
_____ **Ethanol**
_____ **Gasoline**
_____ **Hybrid Electric**
_____ **Hydrogen Fuel Cells**
_____ **Propane**

Round Two *25 Points for each correct answer*

_____ **Biodiesel**
_____ **CNG**
_____ **Diesel**
_____ **Electricity**
_____ **Ethanol**
_____ **Gasoline**
_____ **Hybrid Electric**
_____ **Hydrogen Fuel Cells**
_____ **Propane**

Round Three *15 Points for each correct answer*

_____ **Biodiesel**
_____ **CNG**
_____ **Diesel**
_____ **Electricity**
_____ **Ethanol**
_____ **Gasoline**
_____ **Hybrid Electric**
_____ **Hydrogen Fuel Cells**
_____ **Propane**

Round Four *10 Points for each correct answer*

_____ **Biodiesel**
_____ **CNG**
_____ **Diesel**
_____ **Electricity**
_____ **Ethanol**
_____ **Gasoline**
_____ **Hybrid Electric**
_____ **Hydrogen Fuel Cells**
_____ **Propane**

Transportation Fuels Enigma
Clue Order Envelope

LETTER

1. _____ *Least revealing*

2. _____

3. _____

4. _____ *Most revealing*

Team Number: **Team Name:** **Transportation Fuels:**

Fold Here

Transportation Fuels Enigma Source Clues

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

Team 1 Biodiesel

Transportation Fuels Enigma Source Clues

2A **It uses two different energy sources.**	2B **It combines an internal combustion engine with a battery and electric motor.**
2C **It uses a battery.**	2D **Both the federal and some state governments offer tax incentives for people using it.**
2E **Energy from braking recharges the vehicle's battery.**	2F **Requires a specially manufactured vehicle.**
2G **It provides high fuel economy and low emissions.**	2H **In certain cities, certain users can drive in HOV (High Occupancy Vehicle) lanes.**

Team 2 Hybrid Electric

Transportation Fuels Enigma Source Clues

3A **It is made from a fossil fuel.**	3B **There are 2,670 refueling stations in the United States.**
3C **It is colorless and odorless.**	3D **It adds no carbon or sludge to the engine.**
3E **It is a portable fuel.**	3F **Often fuels vehicles and equipment used indoors.**
3G **It is often used in fleet vehicles.**	3H **It burns very cleanly.**

Team 3 Propane

Transportation Fuels Enigma Source Clues

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

Team 4 Ethanol

Transportation Fuels Enigma Source Clues

5A **It fuels the majority of U.S. passenger vehicles.**	5B **It produces air pollutants when burned.**
5C **It is refined from crude oil.**	5D **It is made from a fossil fuel.**
5E **It has over 156,000 refueling stations in the United States.**	5F **In the U.S., 235 million light duty passenger vehicles use it.**
5G **It is highly flammable.**	5H **It is used in an internal combustion engine.**

Team 5 Gasoline

Transportation Fuels Enigma Source Clues

6A **It uses batteries.**	6B **Most popular for vehicles going short distances and making frequent stops.**
6C **It can be produced domestically.**	6D **It is a secondary source that often requires fossil fuels to produce.**
6E **Vehicles using it have a range of about 100 miles.**	6F **It has very low vehicle maintenance.**
6G **It produces no harmful tailpipe emissions.**	6H **Refueling stations are located in large cities across the country, with many in California.**

Team 6 Electricity

Transportation Fuels Enigma Source Clues

7A **It is often used in fleet vehicles.**	7B **It is possible to refuel your vehicle at home using a special refueling appliance.**
7C **It can be produced domestically; imports usually come from Canada.**	7D **It requires a specially manufactured vehicle or engine conversion.**
7E **It burns very cleanly.**	7F **It has almost 800 public refueling stations in the United States.**
7G **Some state governments offer tax incentives for those who use it.**	7H **Garbage trucks and transit buses in the U.S. can be fueled by it.**

Team 7 Compressed Natural Gas (CNG)

Transportation Fuels Enigma Source Clues

8A **It is often used by heavy duty vehicles.**	8B **Passenger vehicles that use it provide higher fuel economy.**
8C **It is refined from crude oil.**	8D **It is made from a fossil fuel.**
8E **It fuels the majority of U.S. buses.**	8F **It produces air pollutants when burned.**
8G **It is the predominant fuel for U.S. shipping of goods.**	8H **41% of U.S. supply is imported.**

Team 8 Diesel

Transportation Fuels Enigma Source Clues

9A **It is a secondary source that often requires fossil fuels to produce.**	**9B** **Very few vehicles using it are available to the general public.**
9C **Steam reforming is the most popular way to make it.**	**9D** **It can be produced domestically.**
9E **It has been used to fuel space shuttles.**	**9F** **It is the most abundant element in the universe.**
9G **It produces no harmful tailpipe emissions.**	**9H** **There are very few public refueling stations in the U.S.**

Team 9 Hydrogen Fuel Cells

Glossary

biodegradable	organic matter, such as plant and animal matter, and other substances originating from living organisms capable of decomposing back into natural elements
electrolysis	a process that uses an electric current to break molecules apart
feedstock	any material that is converted to another form of fuel or energy product; corn, for example, is used as a feedstock for ethanol production
fermentation	the enzymatic transformation by microorganisms of organic compounds such as sugars into alcohols; the process by which organic material is converted into ethanol, for example
fleet vehicles	groups of motor vehicles owned or leased by a business or government agency, rather than by an individual or family
flywheel	a device that is used to store energy during coasting and braking, storing energy as it rotates
fossil fuel	a fuel formed from the remains of plants and animals over millions of years with the addition of heat and pressure
fuel cell	a device that produces a reaction between chemicals and generates an electric current in the process
hydrocarbon	a chemical compound containing hydrogen and carbon
internal combustion engine	an engine where fuel is burned within the chamber, creating motion
oxidation	a chemical reaction in which atoms or ions lose electrons
regenerative braking system	a system that converts wasted energy from braking into electricity that is stored in a battery
secondary fuel source	a fuel source that requires another energy source in order to create it, like a fossil fuel
semiconductor	a material that has a conductivity between that of a conductor and an insulator
steam reforming	using high-temperature steam to separate hydrogen from carbon atoms in methane
synthesis gas production	a process creating syngas, a mixture of hydrogen, carbon monoxide, and carbon dioxide; reacting carbon based material at high temperatures to create a gas
ultra capacitor	a device that stores energy in an electric field, made of two metal plates and an electrolyte

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. Was the allotted time 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**
8408 Kao Circle
Manassas, VA 20110
FAX: 1-800-847-1820

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Mojave Unified School District
Montana Energy Education Council
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National Hydropower Association
National Ocean Industries Association
National Renewable Energy Laboratory
Nebraska Public Power District
New Mexico Oil Corporation
New Mexico Landman's Association
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North Shore Gas
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Ohio Energy Project
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Paxton Resources
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