

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 language arts, critical thinking, and organizational skills to conceal the identity of their fuel while guessing the fuels other teams represent.



Grade Levels:



Intermediate



Secondary

Subject Areas:



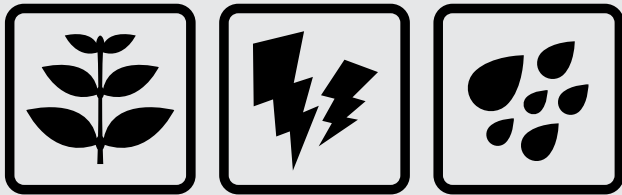
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In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

Energy Data Used in NEED Materials

NEED believes in providing teachers and students with the most recently reported, available, and accurate energy data. Most statistics and data contained within this guide are derived from the U.S. Energy Information Administration. Data is compiled and updated annually where available. Where annual updates are not available, the most current, complete data year available at the time of updates is accessed and printed in NEED materials. To further research energy data, visit the EIA website at www.eia.gov.



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Transportation Fuels Enigma

Data for this guide is taken from:

- Davis, Stacy C., and Robert G. Boundy. Transportation Energy Data Book: Edition 40. Oak Ridge National Laboratory, 2022, <https://doi.org/10.2172/1878695>.
- U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, Alternative Fuels Data Center, www.afdc.energy.gov
- U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, www.fueleconomy.gov
- U.S. Energy Information Administration, www.eia.gov

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Standards Correlation Information

www.need.org/educators/curriculum-correlations

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.



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NEED Curriculum Correlations



NEED materials are correlated to the Disciplinary Core Ideas of the Next Generation Science Standards, the Common Core State Standards for English/Language Arts and Mathematics, and also correlated to each state's individual science standards.

Most files are in Excel format. NEED recommends downloading the file to your computer for use. Save resources, don't print!

- **NEED alignment to the Next Generation Science Standards**
 - Navigating the NGSS? We Have What You NEED!
 - NGSS and NEED: Fourth Grade Energy
 - NGSS and NEED Guide
- Common Core State Standards for English and Language Arts
- Common Core Standards for Mathematics



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 and describe each.
- 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 per group), pages 9-13
- *Transportation Fuels Enigma Data Sheets* (each group needs nine Data Sheets), page 14
- *Transportation Fuels Enigma Clue Cards* (each group needs nine Clue Cards), page 15
- *Transportation Fuels Enigma Score Card* (one per group), page 16
- *Transportation Fuels Enigma Clue Order Envelope* (one per group), page 17
- *Transportation Fuels Enigma Source Clues* (one paper copy of each), pages 18-26
- Optional: *Transportation Fuels Enigma* Excel file—available at www.NEED.org/shop

Preparation

- Make copies of the materials as listed above.
- Download the *Transportation Fuels Enigma* Excel file from www.NEED.org/shop.
- Cut the *Transportation Fuels Enigma Clue Cards* and clip together seven stacks of nine.
- Cut the *Transportation Fuels Enigma Data Sheets* and clip 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 or staple the sides closed.
- Download the pre-prepared *Transportation Fuels Enigma* Excel file from www.NEED.org/shop to prepare the clues or prepare the *Transportation Fuels Enigma Source Clues* sheets. (If using an overhead projector, make a transparency of each of the nine sheets. Cut each sheet into its eight clues and clip together.)
- Divide the students into seven groups with three to five students per group.*
- Choose seven out of the nine fuel sources to assign to the groups. Next, place the *Transportation Fuels Enigma Source Clues* sheet for the seven sources you chose in separate envelopes (You do not have to cut these into individual cards). Write the team number and transportation fuel in the space provided. You will need to determine the clue order for the two fuel sources not represented by student groups.*
- Give each group a face down *Clue Order Envelope*, two sets of *Transportation Fuels Infosheets*, and a single *Data Sheet*.

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/shop.

- *Energy on the Move*
- *Energy Expos*
- *Exploring Hybrid Buses*
- *H₂ Educate*
- *Transportation Exploration*
- *Transportation Fuels Debate*
- *Transportation Fuels Live!*

The *Transportation Fuels Enigma* Excel file is a method for revealing clues during the activity. It can be downloaded for easy use at www.NEED.org/shop 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.

✓ Procedure

Step One: 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 Two: 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 teams 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. The facilitator 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:

1. Is your fuel a nonrenewable or renewable source of energy? Or neither?

2. Is your fuel made from fossil fuels or biomass? Is it a secondary source that is manufactured from other sources of energy?
3. How is your fuel produced or manufactured?
4. Is your fuel produced or manufactured in the United States or do we import it from other countries?
5. 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?
6. Is your fuel a conventional fuel or it is labeled an alternative fuel by the federal government?
7. Is your fuel 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? Or both?
8. Is your fuel readily available to the public? If so, where can you buy it?
9. Does using your fuel pollute the air? Does using your fuel release carbon dioxide emissions? Is this more or less than other fuel sources?
10. List any other information that is unique and interesting about your fuel source. Do other things besides cars and trucks use your fuel? Does your fuel need a battery? Does the government offer tax incentives for using your fuel?

Step Three: Determining the Sequence of Clues

Read the following instructions to the students:

■Now, each team should take out the clues from their *Transportation Fuels Enigma Clue Order Envelope*. If they are cut into individual cards, and arrange them in one column, A through H. Place your completed data sheet next to this column or your clue sheet. 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, or x - them out on your clues sheet.
- 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. Once the clues are in order, write the order on the front of the envelope. Place all the cards or your clue sheet back inside the envelope.
- At the end of this activity, 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 did? 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 Four: 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 Five: Enter the Clues

To use the *Transportation Fuels Enigma* Excel computer file to reveal clues, download the file from www.NEED.org/shop and save the file on your computer. For each round, select each team's clues as they designated on their *Clue Order Envelope*. Complete this step before starting the activity on day two.

Step Six: Completing the Activity (Day Two)

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 *Clue Cards* and a *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 the benefits and limitations, and similarities and differences, between the transportation fuels we use in the United States. Some discussion prompts include:

1. Which fuels are a nonrenewable source of energy? Which fuels are a renewable source of energy? What does it mean to be a secondary source of energy? Does it matter if a fuel's energy is nonrenewable or renewable?
2. Which fuels are made from fossil fuels? Which fuels are made from biomass? Which fuels are manufactured from other sources of energy?
3. Which fuels are produced or manufactured in the United States? Which fuels are imported from other countries? Does it matter if fuels are imported or produced domestically?

CONTINUED ON NEXT PAGE

4. Which fuels require a special car specifically designed and manufactured to run on their fuel? Which fuels work with most cars available on the market?
5. Which fuels are conventional fuels? Which fuels are labeled alternative fuels by the federal government?
6. Which fuels are used in fleet vehicles? Which fuels are used by everyday people to run their private cars and trucks? Which fuels are used by both fleets and private vehicles?
7. Which fuels are readily available to the public? Which fuels are not available to the public, or access is very limited?
8. Which fuels pollute the air? Which fuels do not pollute the air? Which fuels release carbon dioxide emissions? Which fuels do not release any carbon dioxide emissions? Does it matter if fuels impact the environment?
9. Which fuels offer government tax incentives? Would utility company rebates or government tax incentives entice you to purchase an alternative fueled vehicle?
10. In your opinion, which fuel is the most important/valuable resource today? Which fuel do you hope to use when you own a car in the future? Why?

Read the following instructions to the students:

- One at a time, each team will come to the front of the class and project their clues. 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 **biomass-based diesel fuel**. It is made at a **biodiesel refinery**, during a process that chemically reacts alcohol with vegetable oils, animal fats, or recycled restaurant grease, converting them into other products.

Pure biodiesel, B100, is rarely used as a **transportation** fuel. Instead, it is blended into **petroleum** diesel for use in diesel engines. The most common blends are B20 (6-20 percent biodiesel) and B5 (up to 5 percent biodiesel). Most diesel vehicles can safely use B20 and lower-level blends without engine modifications.

Biodiesel is an approved **alternative fuel**. Some government **fleet** vehicles powered by B20 include public school buses, city transit buses, snowplows, garbage trucks, U.S. Postal Service mail trucks, and military vehicles. Private companies and utility companies may use B20 in their fleets, too, powering ferries, delivery trucks, and utility trucks. For convenience, fleets typically have their own fueling **infrastructure** on-site. About 2.8 million consumer owned vehicles use B20 for fuel. It is sold at about 1,400 retail gas stations across the country. Some states have laws that require all petroleum diesel to contain a small percentage of biodiesel.

Pure biodiesel is **nontoxic** and **biodegradable**. If spilled, it causes less damage than petroleum diesel. In general, producing and using biodiesel is better for the environment than producing and using petroleum diesel. Biodiesel is clean burning, which improves air quality and offers considerable **greenhouse gas** emissions benefits. However, burning higher-level biodiesel blends gives off more **nitrogen oxide** emissions than petroleum diesel.

Biodiesel is a **renewable** substitute for petroleum diesel. Using it reduces the amount of **diesel fuel** we use. Biodiesel is a superior **lubricant** and can restore the **lubricity** of diesel fuel in blends as low as one percent, which keeps moving engine parts from wearing out. B100 and high-level blends are sensitive to cold weather. Fuel blenders add **cold flow improver**, a chemical that reduces friction and increases performance, to biodiesel sold in the winter.

Diesel

Diesel is a petroleum-based **fossil fuel** made of **hydrocarbons** (**hydrogen** and carbon molecules). It's manufactured at a petroleum refinery, where crude oil is made into different products. Each 42-gallon barrel of crude oil is refined into about 12 gallons of diesel. Most of the diesel fuel we consume is produced domestically. Since some of the diesel fuel produced in the U.S. is **exported** to other countries, we need to **import** a small amount of diesel, mostly from Canada, to balance our supply and demand.

Any vehicle built with a diesel compression ignition engine can use petroleum diesel fuel. Diesel engines have a lot of power and can do the most demanding work. For that reason, most **freight** and delivery trucks have diesel engines. Most buses, trains, boats, military vehicles, farm, and construction vehicles do, too. Passenger cars and pickup trucks can also have diesel engines.

Petroleum diesel is a conventional transportation fuel. Diesel power dominates the movement of America's freight. Over 90 percent of our goods are shipped using diesel-powered trucks, trains, boats, and barges. No other fuel can match diesel in its ability to move freight economically. Diesel fuels more than 14.3 million medium-duty trucks, such as tow trucks, box trucks, and combination trucks that pull trailers, better known as big rigs, semi-trucks or 18-wheelers. Diesel also powers most city transit buses and school buses. Fleets own an estimated 5.4 million diesel-powered light-duty vehicles, and consumers own another 7 million diesel-powered passenger cars, pickup trucks, and SUVs. Petroleum diesel is sold at about 71,000 retail gas stations across the U.S.

All diesel fuel sold in the U.S. is **ultra-low sulfur diesel (ULSD)**, which is a cleaner-burning diesel fuel. Today, 57% of commercial trucks have advanced diesel technology engines that produce near-zero **emissions**. Using petroleum diesel as a transportation fuel releases some harmful **pollutants**, including ground-level **ozone**, **particulate matter**, and **smog**-forming nitrogen oxides (NOx). Burning petroleum diesel also releases **carbon dioxide**, a greenhouse gas, into the environment. About 25% of the transportation sector's carbon dioxide emissions come from burning diesel fuel.

Petroleum diesel is a **nonrenewable** fuel. It contains 10-15 percent more **energy** than **gasoline**, and diesel engines are more fuel-efficient than gasoline engines (of similar size). So, diesel-powered cars can go 20-35 percent farther on a gallon of fuel than their gasoline-powered equivalents.

Electricity

Electricity is a **secondary energy source** since it must be generated by other sources. Most of our utility-scale electricity is produced domestically at electric **power plants** using a **turbine** to drive an electric generator. Moving steam, hot gases, flowing water, or wind spins the turbine blades in power plants. The turning blades rotate an **electromagnetic** shaft inside coils of wire in the **generator**, causing electric current to flow. Typically, we burn **natural gas** to produce the steam that powers the turbine that drives the electric generator. Electricity can also be generated without using a turbine, for example, at solar photovoltaic power plants. Electricity is not labeled renewable or nonrenewable. We use both types of resources to generate it, including natural gas, coal, uranium, wind, hydropower, solar energy, biomass, and geothermal energy.

Using electricity as a transportation fuel requires a specially manufactured **electric vehicle (EV)**. An **all-electric vehicle**, also called a Battery Electric Vehicle (BEV), runs on electricity alone; there's no conventional engine. Batteries on board are charged with electricity from the **grid** and through **regenerative braking** while the car is in motion. Energy stored in batteries powers electric motors that drive the car. Another specially manufactured EV is a **plug-in hybrid electric vehicle (PHEV)**, which is powered by electric motors and a conventional gasoline engine.

Electricity is an alternative transportation fuel. Consumers own about 3.6 million all-electric passenger cars, trucks, and SUVs, while fleets own an estimated 137,000. There are all-electric school buses, city transit buses, motor coaches, trolleys, box trucks, cargo vans, truck cabs, and motorcycles, too. Electric vehicles are charged using **electric vehicle supply equipment (EVSE)** which is classified by the rate at which the batteries are charged. Consumers can install a small Level 2 unit in their garage to conveniently charge PHEVs and BEVs at home using AC power. Most fleets and businesses will charge their vehicles on-site using Level 2 chargers, too. When a driver needs to refuel quickly, such as during a long-distance trip, they connect to a Direct Current Fast Charger and pay for **DC** power to rapid charge their batteries. Rapid charging stations are conveniently located at gas stations, in shopping plazas, and along heavy-traffic corridors. Today, there are over 66,000 public electric vehicle charging stations across the United States. Most locations have several charging ports, allowing multiple cars to charge at the same time.

An all-electric vehicle produces zero **tailpipe emissions**. However, air pollutants and greenhouse gases may be produced as the vehicle is manufactured and during electricity generation at a power plant. In some areas, consumers can purchase electricity generated by renewable resources which will decrease their vehicle's impact on the environment.

EVs generally cost more to purchase and have a shorter range than similar conventional vehicles, however, they have lower fueling and maintenance costs, and some EVs qualify for federal tax credits and utility company incentives. Charging the battery with

electricity from the grid takes significantly longer than refueling with other fuels, however, an EV can be charged conveniently at home. Widespread use of EVs could dramatically reduce petroleum consumption, increasing the nation's energy security and lessening our dependence on foreign oil supplies. Electricity in America is produced almost entirely from domestic resources and is typically more cost-efficient than gasoline.

Ethanol

Ethanol is a type of alcohol made from biomass (plant materials). In the U.S., it's made from corn, produced by **fermenting** the sugar in corn kernel starch. Most of the ethanol we use as fuel is produced domestically at ethanol production facilities in the Midwest. We export millions of barrels to other countries, and we import a small amount from Brazil. Brazilian ethanol is produced by fermenting the sugar in sugar cane. These imports are mostly consumed in California to help meet state standards requiring the use of low-carbon fuels.

After it's made, ethanol goes to a fuel terminal where it's blended with gasoline for use as a transportation fuel. All conventional vehicles with **internal combustion engines** can use gasoline containing about ten percent ethanol, called E10, without harming their engines. However, higher ethanol blends, such as **E85**, can only be used in specially manufactured **flexible fuel vehicles (FFVs)**. Flexible fuel vehicles can run on E85, gasoline, or any blend of the two.

E85 is an approved alternative fuel. The federal government requires some fleets to purchase vehicles that use alternative fuels. Historically, FFVs have been the most widely available alternative fueled vehicles. It's estimated about 2.9 million fleet vehicles run on E85 today. Consumers own more than 20 million FFVs, although not everyone uses E85 to fill their tank. Some owners don't realize their car is an FFV and they have a choice of fuel. Or, they might not have access to E85. While 4,428 public fueling stations offer E85, most are in the Midwest.

Ethanol is a biodegradable, renewable fuel. The federal **Renewable Fuel Standard** requires all transportation fuel sold in the U.S. to contain a minimum volume of renewable fuels. This program has led to an increased use of fuel ethanol, with E10 widely used across the U.S. as a replacement fuel. Replacing even a small volume of gasoline with fuel ethanol offers environmental benefits, reducing tailpipe emissions. Compared to petroleum fuels, producing and using fuel ethanol reduces lifecycle greenhouse gas emissions, too, since plants absorb carbon dioxide as they grow, offsetting the carbon dioxide released as fuel ethanol burns.

A gallon of fuel ethanol contains less energy than a gallon of gasoline, lowering **fuel economy**. However, ethanol is a high-octane fuel, so it offers increased power and performance. In fact, IndyCars now race using a 100 percent renewable fuel that contains a significant amount of ethanol produced from sugarcane. Since U.S. ethanol is made from crops grown in the U.S., using it may help reduce the amount of petroleum we import from other countries.

Gasoline

Gasoline is a nonrenewable petroleum-based fossil fuel made of hydrocarbons (hydrogen and carbon molecules). It's manufactured at a petroleum refinery, where crude oil is made into different products. Each 42-gallon barrel of crude oil is refined into about 20 gallons of unfinished gasoline blendstock. The unfinished gasoline goes to a blending terminal, where fuel ethanol and other chemicals are added, creating **finished motor gasoline**. Almost all gasoline we consume is produced domestically by U.S. petroleum refineries. A very small amount of gasoline is imported to cities on the east and west coasts when it's cheaper than shipping across the country.

Vehicles built with an internal combustion engine can use gasoline for fuel. This includes a wide variety of vehicles, such as passenger cars, pickup trucks, SUVs, motorcycles, boats, recreational vehicles like golf carts, snowmobiles and all-terrain vehicles.

Gasoline is a **conventional fuel**. It powers about 243 million consumer owned passenger cars, pickup trucks, and SUVs in the United States. Fleets use gasoline to power their vehicles, too. Commercial businesses, government agencies, utilities, and taxi and rental car companies own about 20 million cars, trucks, and SUVs. There are 142,000 **retail fueling stations** that provide convenient gasoline refueling for consumers.

Gasoline is a **toxic** and highly flammable fuel. It can make you very sick if you breathe in the vapors or get it on your skin. Gasoline will not mix with water, and if it spills on the ground, it is not biodegradable. Burning gasoline produces carbon dioxide, a greenhouse gas, and contributes to air pollution. Ethanol, a renewable fuel, is added to gasoline to reduce greenhouse gas emissions. Some areas of the country are required by law to use specially formulated gasoline to reduce tailpipe emissions of carbon monoxide, smog, and air toxins.

Gasoline is an efficient transportation fuel because it has a lot of chemical energy stored in it. This high energy content helps light-duty cars and trucks drive a long way on a few gallons of gas. Since petroleum is nonrenewable, our supply of oil might run out someday. Consuming less gasoline in our cars could mean depending less on other countries for our oil supply.

Hydrogen

Hydrogen is the most abundant element in the universe, but it doesn't exist on Earth as a gas. We can extract hydrogen from fossil fuels, biomass, or water, which makes hydrogen a secondary source of energy. It is produced domestically, mostly at large industrial facilities that make and use it on-site for industrial purposes. Most of these facilities produce hydrogen using a process called **steam reforming**, combining high-temperature steam with natural gas to extract hydrogen. Other ways to produce hydrogen include **gasification**, a process that reacts coal or biomass with high-temperature steam and oxygen to separate out the hydrogen, and **electrolysis**, where an electric current splits water into hydrogen and oxygen.

Using hydrogen as a transportation fuel requires a specially manufactured **Fuel Cell Electric Vehicle (FCEV)**. A fuel cell electric vehicle uses pure hydrogen gas stored in a tank onboard for fuel. A **fuel cell stack** inside the car turns hydrogen from the tank and oxygen from the air into electricity. The electricity powers an electric motor that drives the wheels.

Hydrogen is considered an alternative transportation fuel. It fuels about 17,000 FCEVs owned by consumers and an estimated 700 FCEVs owned by fleets. Auto manufacturers offer few FCEV models, and those are only for sale or lease in specific areas of California or Hawaii that have an adequate number of hydrogen fueling stations. Most of the 55 public retail stations are in California. Around the country there are also private stations supporting fleets and some stations primarily used for demonstration or research projects. California is adding hydrogen fuel pumps at existing gasoline stations in San Francisco, Los Angeles, and San Diego. Efforts are also underway to expand hydrogen stations in Hawaii and across the East Coast.

Fuel cell technology uses hydrogen to produce electrical power without emitting air pollutants, carbon dioxide, or greenhouse gases. The only tailpipe emissions are water and warm air. However, there may be life cycle emissions from manufacturing the vehicle and making the hydrogen it uses for fuel. For example, making hydrogen using the steam reforming process burns natural gas resulting in carbon dioxide emissions.

Hydrogen is not labeled renewable or nonrenewable. Hydrogen is stored as a compressed gas in a large high pressure fuel tank on board. The fuel tank refills in a few minutes, giving FCEVs 300 to 400 miles of range. To increase efficiency, FCEVs use a regenerative braking system, which captures the energy lost during braking and stores it in a battery. Electricity can be drawn from the battery to help power the vehicle when needed. At this time, there is very limited infrastructure to produce, deliver, and dispense hydrogen in the U.S.

Natural Gas

Natural gas is an energy-rich fossil fuel. It's a gaseous mixture of hydrocarbons, mostly **methane, CH₄**. Straight from the ground, it is wet gas, which is cleaned and separated into different products at a **natural gas processing plant**. After processing, dry natural gas has many uses, including heating homes and generating electricity. In the **transportation sector**, natural gas operates compressors that move products through **pipelines**, and a small amount is compressed or liquefied to fuel vehicles. Almost all the natural gas we use is produced domestically. A small amount is imported from Canada during the winter to help meet seasonal demand.

Currently, manufacturers build heavy-duty natural gas vehicles, like street sweepers, cargo trucks, shuttle buses, school buses, and waste collection vehicles. There are no **light-duty** cars or trucks for sale. However, most cars and trucks can be retrofitted to run on natural gas with an after-market engine conversion, as long as it's done by a qualified vehicle modifier.

Worldwide, about 23 million vehicles run on natural gas. But, in the U.S., less than 25,000 consumer owned, and an estimated 26,200 fleet owned vehicles use this alternative fuel. **Compressed natural gas (CNG)** is a good choice for fleets that drive a lot of miles but stay close to their fueling station. Most stations compress their natural gas on-site. You can also fuel a CNG vehicle at home using a small fueling appliance that attaches to your home's natural gas line. Ships and trucks that travel long distances have better range using **liquefied natural gas (LNG)**, since it's more energy dense. To change natural gas into its liquid state, it is cooled to -260°F at a liquefaction facility. Then it's delivered by tanker truck to an LNG fueling station. There are 738 CNG and 41 LNG retail stations in the U.S.

Natural gas is a clean-burning vehicle fuel. It is not toxic and does not catch on fire easily. Since it is lighter than air, if there is a leak, methane rises and dissipates quickly. Surrounding ecosystems and ground water won't be contaminated. CNG and LNG vehicles slightly reduce life cycle greenhouse gas emissions compared to gasoline and diesel-powered vehicles.

Although natural gas is a nonrenewable resource, the U.S. has a large supply, so using CNG and LNG as transportation fuels may help reduce the amount of petroleum we need to import from other countries, increasing our energy security.

Propane Autogas

Propane, C₃H₈, is an energy-rich fossil fuel product often called **liquefied petroleum gas (LPG)**. 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 many uses. When it's used for transportation, it's called autogas.

In the U.S., auto manufacturers build propane-powered trucks and buses, but they don't build any propane cars, vans, or pickup trucks. After purchasing a conventional vehicle, the engine must be converted to run on autogas. This is an added expense.

Autogas is an approved alternative fuel. Today, it powers 6,000 consumer owned vehicles and an estimated 14,500 fleet owned cars, pickup trucks, and SUVs. Fleets can build their own refueling stations on-site for their propane-powered police cars, taxis, school buses, and delivery trucks. autogas is also sold at 2,433 public LPG vehicle fueling stations in the U.S.

Propane is considered clean and environmentally friendly in its unused state. Propane is nontoxic. If released as a liquid or vapor, it doesn't harm soil, surface water, or ground water. It won't harm freshwater or saltwater ecosystems and won't harm birds or animals if they accidentally breathe it. Vehicles burning propane autogas may produce less air pollution and less greenhouse gas emissions than vehicles burning other petroleum fuels.

Since propane is portable and cleaner burning than other petroleum fuels, it is often used to power vehicles and equipment indoors, such as forklifts in a warehouse. Using autogas costs less than using gasoline or diesel. However, autogas contains less energy per gallon than gasoline. This means propane vehicles have less fuel economy. Our supply of propane depends on our supply of petroleum and natural gas. Since they are nonrenewable, we might run out someday.

Renewable Diesel

Renewable diesel is a biomass-based diesel fuel. It is a hydrocarbon, processed to be chemically the same as petroleum diesel fuel for use in diesel engines. It can be made from nearly any biomass **feedstock**, using several different technologies. Most commercial production facilities use a traditional **hydrotreating** process to make renewable diesel from animal fats, soybean oil, or canola oil. (Petroleum diesel is made the same way, but from crude oil instead of vegetable oil.) Hydrotreating reacts oil with hydrogen under high temperature and pressure in the presence of a **catalyst**. Renewable diesel fuel is manufactured domestically in the U.S. and imported from Singapore, the Netherlands, and Finland.

Renewable diesel is a direct replacement for petroleum diesel fuel. It can be used in its pure form, R100, or mixed and blended with petroleum diesel in any amount. The most common blends are R20 (up to 20 percent renewable diesel) and R5 (up to 5 percent renewable diesel). Since it is chemically the same as petroleum diesel, it can be used in existing petroleum pipelines and storage tanks without harming them. Renewable diesel works in newer and older diesel vehicles without any engine modifications.

Renewable diesel is an approved alternative transportation fuel. It is an important fuel for fleets trying to lower their carbon emissions. It can be used in any diesel vehicle, including school buses, trucks, and garbage haulers. Nearly all renewable diesel fuel is consumed in California to help meet state standards requiring the use of low-carbon fuels. There are about 647 retail gas stations selling renewable diesel, so drivers can fill their personal cars and trucks, too.

Renewable diesel is nontoxic and biodegradable. It releases lower levels of soot and fine particulate matter when burned, producing less air pollution than petroleum diesel. It produces less greenhouse gas emissions, too, including carbon dioxide and nitrogen oxide.

Manufacturing renewable diesel requires significantly more hydrogen than manufacturing petroleum diesel. How that hydrogen is made (typically using natural gas, a fossil fuel) can affect whether it meets certain state and national standards. Also, renewable diesel costs more to make than petroleum diesel, which means it costs more to buy, too. The supply of renewable diesel is slowly growing, and new production facilities are being built. Existing petroleum refineries can convert to produce renewable diesel with minor retrofits. One production facility in California makes sustainable aviation fuel (SAF), also called alternative jet fuel. The renewable jet fuel is used at Los Angeles International Airport and at San Francisco International Airport.

TRANSPORTATION FUELS *Enigma* DATA SHEET

FUEL: _____

1. **Type:** ____ Nonrenewable ____ Renewable
____ Neither
2. **Primary energy source:** ____ Fossil Fuel
____ Biomass ____ It's a Secondary Source
3. **How is it made?** _____
4. **Where is it produced?**
____ Domestic ____ Imported ____ Both
5. **Does it require a special car or engine conversion?** _____
6. **Fuel type:** ____ Conventional ____ Alternative
7. **Usage:** ____ Mostly Fleet ____ Mostly Personal
____ Both Fleet and Personal
8. **Fuel availability:** _____
9. **Environmental impacts:** _____

10. **Facts:** _____

TRANSPORTATION FUELS *Enigma* DATA SHEET

FUEL: _____

1. **Type:** ____ Nonrenewable ____ Renewable
____ Neither
2. **Primary energy source:** ____ Fossil Fuel
____ Biomass ____ It's a Secondary Source
3. **How is it made?** _____
4. **Where is it produced?**
____ Domestic ____ Imported ____ Both
5. **Does it require a special car or engine conversion?** _____
6. **Fuel type:** ____ Conventional ____ Alternative
7. **Usage:** ____ Mostly Fleet ____ Mostly Personal
____ Both Fleet and Personal
8. **Fuel availability:** _____
9. **Environmental impacts:** _____

10. **Facts:** _____

TRANSPORTATION FUELS *Enigma* DATA SHEET

FUEL: _____

1. **Type:** ____ Nonrenewable ____ Renewable
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2. **Primary energy source:** ____ Fossil Fuel
____ Biomass ____ It's a Secondary Source
3. **How is it made?** _____
4. **Where is it produced?**
____ Domestic ____ Imported ____ Both
5. **Does it require a special car or engine conversion?** _____
6. **Fuel type:** ____ Conventional ____ Alternative
7. **Usage:** ____ Mostly Fleet ____ Mostly Personal
____ Both Fleet and Personal
8. **Fuel availability:** _____
9. **Environmental impacts:** _____

10. **Facts:** _____

TRANSPORTATION FUELS *Enigma* DATA SHEET

FUEL: _____

1. **Type:** ____ Nonrenewable ____ Renewable
____ Neither
2. **Primary energy source:** ____ Fossil Fuel
____ Biomass ____ It's a Secondary Source
3. **How is it made?** _____
4. **Where is it produced?**
____ Domestic ____ Imported ____ Both
5. **Does it require a special car or engine conversion?** _____
6. **Fuel type:** ____ Conventional ____ Alternative
7. **Usage:** ____ Mostly Fleet ____ Mostly Personal
____ Both Fleet and Personal
8. **Fuel availability:** _____
9. **Environmental impacts:** _____

10. **Facts:** _____

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

_____ Diesel

_____ Electricity

_____ Ethanol

_____ Gasoline

_____ Hydrogen

_____ Natural Gas

_____ Propane

_____ Renewable Diesel

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

_____ Diesel

_____ Electricity

_____ Ethanol

_____ Gasoline

_____ Hydrogen

_____ Natural Gas

_____ Propane

_____ Renewable Diesel

Round Two 25 Points for each correct answer

_____ Biodiesel

_____ Diesel

_____ Electricity

_____ Ethanol

_____ Gasoline

_____ Hydrogen

_____ Natural Gas

_____ Propane

_____ Renewable Diesel

Round Three 15 Points for each correct answer

_____ Biodiesel

_____ Diesel

_____ Electricity

_____ Ethanol

_____ Gasoline

_____ Hydrogen

_____ Natural Gas

_____ Propane

_____ Renewable Diesel

Round Four 10 Points for each correct answer

_____ Biodiesel

_____ Diesel

_____ Electricity

_____ Ethanol

_____ Gasoline

_____ Hydrogen

_____ Natural Gas

_____ Propane

_____ Renewable Diesel



Transportation Fuels Enigma Clue Order Envelope

LETTER

1. _____ *Least revealing*

2. _____

3. _____

4. _____ *Most revealing*

Team Number: _____

Transportation Fuel: _____

Fold Here



Transportation Fuels Enigma Source Clues

1A It is often used by fleet vehicles.	1B It is blended with a petroleum-based fuel.
1C It is a replacement fuel used to meet the federal Renewable Fuel Standard.	1D It is produced domestically and imported from Brazil.
1E It requires a specially manufactured vehicle to use high level blends.	1F It is produced from biomass.
1G It reduces lifecycle greenhouse gas emissions.	1H It is a renewable fuel.

Team 1 Ethanol



Transportation Fuels Enigma Source Clues

2A It is used in diesel engines.	2B It can be blended with a petroleum-based fuel.
2C It is a cleaner-burning fuel.	2D It is produced domestically and imported from Singapore, the Netherlands, and Finland.
2E It is a hydrocarbon.	2F It is produced from biomass.
2G It is mostly consumed in California which requires the use of low-carbon fuels.	2H It is an alternative fuel.

Team 2 Renewable Diesel



Transportation Fuels Enigma Source Clues

3A It is made from a fossil fuel.	3B It is called autogas when used by vehicles for transportation.
3C It requires conventional vehicles to get an after-market engine conversion.	3D It is an alternative fuel.
3E It is a portable fuel.	3F It is often used to fuel vehicles and equipment used indoors.
3G It is used by more fleet vehicles than personal vehicles.	3H It is a cleaner-burning fuel.

Team 3 Propane



Transportation Fuels Enigma Source Clues

4A It fuels most U.S. passenger vehicles.	4B It produces air pollutants when burned.
4C It is produced domestically.	4D It is a hydrocarbon.
4E Its high energy content makes it an efficient transportation fuel.	4F It is not biodegradable.
4G It is highly flammable.	4H It is used in an internal combustion engine.

Team 4 Gasoline



Transportation Fuels Enigma Source Clues

5A

It is often used by fleet vehicles.

5B

It is a superior lubricant.

5C

It can be blended with a petroleum-based fuel.

5D

It is sensitive to cold weather.

5E

It is produced domestically.

5F

It is biodegradable.

5G

It is produced by chemically reacting alcohol with vegetable oils, fats, or grease.

5H

It is a cleaner-burning fuel.

Team 5 Biodiesel



Transportation Fuels Enigma Source Clues

6A It is possible to refuel your vehicle at home.	6B It requires a specially manufactured vehicle.
6C It is produced domestically.	6D It is a secondary energy source that often requires fossil fuels to produce.
6E It is an alternative fuel.	6F It can fuel heavy-duty vehicles like city transit buses and school buses.
6G It produces zero tailpipe emissions.	6H It can fuel a vehicle slowly using AC power, or rapidly using DC power.

Team 6 Electricity



Transportation Fuels Enigma Source Clues

7A It is produced domestically and imported from Canada.	7B It is possible to refuel your vehicle at home.
7C It is an alternative fuel.	7D It requires a specially manufactured vehicle or after-market engine conversion.
7E It is a cleaner-burning fuel.	7F It is compressed or liquefied to fuel vehicles.
7G It is a hydrocarbon.	7H It can fuel heavy-duty vehicles like school buses and garbage trucks.

Team 7 Natural Gas



Transportation Fuels Enigma Source Clues

8A It is a hydrocarbon.	8B It provides passenger vehicles with better fuel economy.
8C It is refined from crude oil.	8D It is used in vehicles with a diesel engine.
8E It is the main fuel for school buses and public transit buses.	8F It produces air pollutants when burned.
8G It is the predominant fuel for shipping goods in the U.S.	8H It is produced domestically and imported from Canada.

Team 8 Diesel



Transportation Fuels Enigma Source Clues

9A It is a secondary energy source that often requires fossil fuels to produce.	9B It has a very limited infrastructure to produce, deliver, and dispense it.
9C It is produced domestically.	9D It is the most abundant element in the universe.
9E It requires a specially manufactured vehicle.	9F It is an alternative fuel.
9G It produces no harmful tailpipe emissions.	9H It is usually produced by steam reforming.

Team 9 Hydrogen



Glossary

all-electric vehicle	a vehicle that receives power by plugging into an electric power source and storing the power in a battery pack; does not use any petroleum-based or other liquid- or gas-based fuel during operation; does not produce tailpipe emissions
alternative fuel	transportation fuels that are not petroleum-based, including methanol, denatured ethanol, natural gas, liquefied petroleum gas (propane), hydrogen, coal-derived liquid fuels, fuels derived from biological materials (biofuels such as soy diesel fuel), and electricity
biodegradable	capable of being decomposed by bacteria or other living organisms
biodiesel	a fuel typically made from soybean, canola, or other vegetable oils, animal fats, and recycled grease; it can serve as a substitute for petroleum-derived diesel or distillate fuel
biomass	organic nonfossil material of biological origin constituting a renewable energy source
biomass-based diesel fuel	biodiesel and other renewable diesel fuel or diesel fuel blending components derived from biomass, but excluding renewable diesel fuel coprocessed with petroleum feedstocks
carbon dioxide	a colorless, odorless, noncombustible gas with the formula CO ₂ that is present in the atmosphere; it is formed by combustion and by respiration
cold flow improver	a chemical added to biodiesel sold in the winter that reduces friction and increases performance
compressed natural gas (CNG)	natural gas compressed to a pressure at or above 200-248 bar (i.e., 2900-3600 pounds per square inch) and stored in high-pressure containers, used as a fuel for natural gas-powered vehicles
conventional fuels	petroleum-based fuels such as motor gasoline or diesel fuel
diesel fuel	a fuel composed of distillates obtained in petroleum refining operation or blends of such distillates with residual oil used in motor vehicles; the boiling point and specific gravity are higher for diesel fuels than for gasoline
direct current (DC)	an electric current that flows in only one direction through a circuit, as from a battery; typically abbreviated as DC
domestic	the United States
E85	a high-level gasoline-ethanol blend containing 51% to 83% ethanol, depending on geography and season
electric grid	an interconnected system that maintains an instantaneous balance between supply and demand (generation and load) while moving electricity from generation source to customer
electricity	a form of energy characterized by the presence and motion of elementary charged particles generated by friction, induction, or chemical change; electricity is electrons in motion
electric vehicle (EV)	a general term for any on-road licensed vehicle that can plug into an electric power source and uses electric power to move; EVs plug into a source of electricity and store power in a battery pack for all or part of their power needs; includes Battery Electric Vehicles (BEVs) and Plug-in Hybrid Vehicles (PHEVs)
electric vehicle supply equipment (EVSE)	infrastructure that supplies electric energy to recharge electric vehicles
electrolysis	the process of splitting a water molecule into its basic elements
electromagnetic	having to do with magnetism produced by an electric current
emission	discharges into the air or releases of gases into the atmosphere from some type of human activity (cooking, driving a car, etc.); in the context of global climate change, emissions consist of greenhouse gases (e.g., the release of carbon dioxide during fuel combustion)
energy	the ability to do work, produce change, or move an object; electrical energy is usually measured in kilowatt-hours (kWh), while heat energy is usually measured in British thermal units (Btu)
ethanol (C₂H₅OH)	a clear, colorless, flammable alcohol; ethanol is typically produced biologically from biomass feedstocks such as agricultural crops and cellulosic residues from agricultural crops or wood; can also be produced chemically from ethylene
exports	shipments of goods from within the 50 States and the District of Columbia to U.S. possessions and territories or to foreign countries
feedstock	a raw material that can be used as a fuel or processed into a different fuel or product
fermentation	the changing of a sugar into an acid, gas, or alcohol with the presence of bacteria or yeast

fleet vehicle	any motor vehicle a company owns or leases that is in the normal operations of a company; fleet vehicles include gasoline/diesel powered vehicles and alternative-fuel vehicles
flexible fuel vehicle (FFV)	has a single fuel system to handle alternative and petroleum-based fuels, can operate on alternative fuels (such as M85 or E85), or 100-percent petroleum-based fuels, or any mixture of an alternative fuel (or fuels) and a petroleum-based fuel
fossil fuels	fuels (coal, oil, natural gas, etc.) that result from the compression of ancient plant and animal life formed over hundreds of millions of years
freight	any type of goods, items, or commodities that are transported in bulk by air transport, surface transport, or sea/ocean transport
fuel cell	a device capable of generating an electrical current by converting the chemical energy of a fuel (e.g., hydrogen) directly into electrical energy
fuel cell electric vehicle (FCEV)	An electric vehicle that generates on-board electricity with a fuel cell powered by hydrogen rather than relying on electricity from a high capacity battery
fuel cell stack	an assembly of individual membrane electrodes that use hydrogen and oxygen to produce electricity
fuel economy	distance travelled by a vehicle compared to volume of fuel consumed
gasification	a method for converting coal, petroleum, biomass, wastes, or other carbon-containing materials into a gas that can be burned to generate power or processed into chemicals and fuels
gasoline	a complex mixture of relatively volatile hydrocarbons with or without small quantities of additives, blended to form a fuel suitable for use in spark-ignition engines
generator	a device that turns mechanical or motion energy into electrical energy; the motion energy is sometimes provided by an engine or turbine
greenhouse gases	gases that trap the heat of the sun in the Earth's atmosphere, producing the greenhouse effect; the two major greenhouse gases are water vapor and carbon dioxide; lesser greenhouse gases include methane, ozone, chlorofluorocarbons, and nitrogen oxides
hydrocarbon	an organic compound made entirely of hydrogen and carbon; hydrocarbons are found in crude oil, natural gas, and other fossil fuel
hydrogen	a colorless, odorless, highly flammable gaseous element; it is the lightest of all gases and the most abundant element in the universe, occurring chiefly in combination with oxygen in water and also in acids, bases, alcohols, petroleum, and other hydrocarbons
hydrotreating	a refining process for treating petroleum in the presence of catalysts and substantial quantities of hydrogen
imports	receipts of goods into the 50 States and the District of Columbia from U.S. possessions and territories or from foreign countries
infrastructure	the basic physical structures, facilities, and systems needed to operate a society or business, for example: roads, buildings, power supplies
internal combustion engine	type of engine that has one or more cylinders in which the process of combustion takes place, converting energy released from the rapid burning of a fuel-air mixture into mechanical energy
light-duty vehicles	vehicles weighing less than 8,500 lbs, including automobiles, motorcycles, and light trucks
liquefied natural gas (LNG)	natural gas (primarily methane) that has been liquefied by reducing its temperature to -260 degrees Fahrenheit at atmospheric pressure
liquefied petroleum gases (LPG)	a group of hydrocarbon gases, primarily propane, normal butane and isobutane, derived from crude oil refining or natural gas processing
lubricants	substances used to reduce friction between bearing surfaces
lubricity	ability to reduce friction
methane (CH₄)	a colorless, flammable, odorless hydrocarbon gas which is the major component of natural gas; also an important source of hydrogen in various industrial processes; methane is a greenhouse gas
motor gasoline (finished)	a complex mixture of relatively volatile hydrocarbons with or without small quantities of additives, blended to form a fuel suitable for use in spark-ignition engines; includes conventional gasoline, all types of oxygenated gasoline including gasohol, and reformulated gasoline, but excludes aviation gasoline
natural gas	a gaseous mixture of hydrocarbon compounds, the primary one being methane
natural gas processing plant	facilities designed to recover natural gas liquids from a stream of natural gas that may or may not have passed through lease separators and/or field separation facilities; these facilities control the quality of the natural gas to be marketed
nitrogen oxides (NOx)	compounds of nitrogen and oxygen produced by the burning of fossil fuels
nonrenewable	fuels that cannot be easily made or replenished; we can use up nonrenewable fuels; oil, natural gas, and coal are examples of nonrenewable fuels

nontoxic	not poisonous
ozone	a molecule made up of three atoms of oxygen; occurs naturally in the stratosphere and provides a protective layer shielding the Earth from harmful ultraviolet radiation; in the troposphere, it is a chemical oxidant, a greenhouse gas, and a major component of photochemical smog
particulate matter	also called particle pollution, a mixture of solid particles or liquid droplets found in the air, for example dust, dirt, soot, or smoke
petroleum	generally refers to crude oil or the refined products obtained from the processing of crude oil (gasoline, diesel fuel, heating oil, etc.); petroleum also includes lease condensate, unfinished oils, and natural gas plant liquids
pipeline	a length of pipe that carries petroleum and natural gas from a refinery to the consumer
plug-in hybrid electric vehicle (PHEV)	a vehicle that can both (1) plug into an electric power source and store power in a battery pack and (2) use petroleum-based or other liquid- or gas-based fuel to power an internal combustion engine
pollutant	determined to be hazardous to human health and regulated under EPA's National Ambient Air Quality Standards
power plant	a facility where power is generated
propane (C₃H₈)	a straight-chain saturated (paraffinic) hydrocarbon extracted from natural gas or refinery gas streams, which is gaseous at standard temperature and pressure; a colorless gas that boils at a temperature of -44 degrees Fahrenheit
refinery	an industrial plant that heats crude oil (petroleum) so that it separates into chemical components, which are then made into more useful substances
regenerative braking	a feature of hybrid and plug-in electric vehicles that captures energy normally lost during braking by using the electric motor as a generator and storing the captured energy in the battery
renewable	fuels that can be easily made or replenished; we can never use up renewable fuels; types of renewable fuels are hydropower (water), solar, wind, geothermal, and biomass
renewable diesel fuel	diesel fuel and diesel fuel blending components produced from renewable sources that are coprocessed with petroleum feedstocks and meet requirements of advanced biofuels
Renewable Fuel Standard (RFS)	a regulation created under the Energy Policy Act of 2005 and implemented by the U.S. Environmental Protection Agency to ensure transportation fuel sold in the United States contains a minimum volume of renewable fuels and for these fuels to be blended into transportation fuel in increasing amounts each year
retail fueling station	location where the public can purchase fuel from a retailer (a firm that carries on the trade or business of purchasing refined petroleum products and reselling them to ultimate consumers without substantially changing their form)
secondary source of energy	also known as energy carriers, these sources require another source of energy to be created; electricity is an example of a secondary source of energy
steam reforming	a process that combines high-temperature steam with natural gas to extract hydrogen
smog	a form of air pollution
tailpipe emissions	emissions produced through fuel combustion during a vehicle's operation
toxic	poisonous
transportation	moving people and/or goods from one physical location to another
transportation sector	the part of the economy having to do with how people and goods are transported (moved) from place to place; the transportation sector is made up of automobiles, airplanes, trucks, ships, trains, etc.
turbine	a machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas); turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two
ultra-low sulfur diesel (ULSD) fuel	diesel fuel containing a maximum 15 parts per million (ppm) sulfur

AWESOME EXTRAS!

Our Awesome Extras page contains PowerPoints, energy graphics, and other great resources to compliment what you are teaching!

www.need.org/educators/awesome-extras/

BIOMASS AT A GLANCE

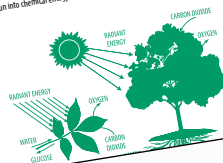


WHAT IS BIOMASS?

Biomass is any organic matter—wood, crops, livestock, animal wastes—that can be used as an energy source. Biomass is probably our oldest source of energy after the sun. For thousands of years, people have burned wood to heat their homes and cook their food. Biomass gets its energy from the sun. All organic matter contains stored energy from the sun. During a process called photosynthesis, sunlight gives plants the energy they need to convert water and carbon dioxide into oxygen and sugar. These sugars, called carbohydrates, supply plants and the animals that eat them with energy. Foods rich in carbohydrates are a good source of energy for the human body. Biomass is a renewable energy source because its supplies are not limited. We can always grow trees and crops, and waste will always exist.

PHOTOSYNTHESIS

In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose (or sugar).



TYPES OF BIOMASS

1 WOOD AND AGRICULTURAL PRODUCTS

Most biomass used today is home grown energy. Wood—logs, chips, bark, and sawdust—accounts for just under half of biomass energy. But any organic matter can produce biomass energy. Other biomass sources can include agricultural waste products like fruit pits and corn cobs. Wood and wood wastes are used to generate electricity. Much of the electricity is used by the industries making the waste: it is not distributed by utilities. It is a process called cogeneration. Paper mills and saw mills use much of their waste products to generate steam and electricity for their use. However, since they use so much energy, they need to buy additional electricity from utilities.

2 SOLID WASTE

Burning trash turns waste into a usable form of energy. One ton (2,000 pounds) of garbage contains about as much heat energy as 500 pounds of coal. Garbage is not all biomass; perhaps half of its energy content comes from plastics, which are made from biomass, perhaps half of its energy content comes from garbage for energy are called petroleum and natural gas. Power plants that burn garbage for energy are called waste-to-energy plants. These plants generate electricity much as coal-fired plants do, except that combustible garbage—and coal—is the fuel used to fire the boilers.

3 LANDFILL GAS AND BIOGAS

Solid waste and fungi are not only trash. They are dead plants and animals, waiting them to rot or decay. A fungus can be used in converting cellulose to sugars to feed itself. Although this process is slow in a landfill, a substance called methane gas is still produced as the waste decays. Many regulations require landfills to collect methane gas for safety and environmental reasons. Methane gas is colorless and odorless, but it is a fuel. The gas can close fires or explosions. It's kept into nearby homes and is

4 ETHANOL

Ethanol is an alcohol fuel (ethyl alcohol) made by fermenting the sugars and starches found in plants and then distilling them. Any organic material containing cellulose, starch, or sugar can be made into ethanol. The majority of the ethanol produced in the United States comes from corn. New technologies are producing ethanol from cellulose in woody forest from trees, grasses, and crop residues. Today nearly all of the gasoline sold in the U.S. contains around 10 percent ethanol and is known as E10. In 2015, the U.S. Environmental Protection Agency (EPA) approved the introduction of E15 (15 percent ethanol, 85 percent gasoline) for use in passenger vehicles from model year 2001 and newer. Fuel containing 85 percent ethanol and 15 percent gasoline (E85) qualifies as an alternative fuel. There are about 20 million flexible fuel vehicles (FFV) on the road that can run efficiently on E85 or E10. However, a small percentage of these vehicles use E85 regularly.

BIODIESEL

Biodiesel is a fuel made by chemically reacting alcohol with vegetable oils, animal fats, or greases, such as recycled restaurant grease. Most biodiesel today is made from soybean oil. Biodiesel is most often blended with petroleum diesel in ratios of two percent (B2), five percent (B5), or 20 percent (B20). It can also be used as neat (pure) biodiesel (B100). Biodiesel fuels are compatible with and can be used in most (petrol) diesel engines with the existing fueling infrastructure. It is a renewable fueling infrastructure. It is a supply, even compared to petroleum-based diesel. Biodiesel can reduce the life cycle



EL LIBRO PRIMARIO

Manual complementario para el Libro de Energía Primaria: actividades para reforzar la información básica de la energía y datos introductorios de las fuentes de energía.





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**

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