

2012-2013

Transportation Fuels Infobook

Fact sheets and suggested activities to educate students about the economic, environmental, and societal impacts of using conventional and alternative transportation fuels.



Grade Level:

- Intermediate
- Secondary

Subject Areas:

- Science
- Language Arts
- Technology



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Teacher Advisory Board Statement

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

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Energy Data Used in NEED Materials

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



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Transportation Fuels Infobook

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- U.S. Department of Energy *Transportation Energy Data Book, 30th Edition*
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Correlations to National Science Education Standards: Grades 5-8

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

Content Standard B | *PHYSICAL SCIENCE*

▪ **Properties and Changes of Properties in Matter**

- A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.
- Chemical elements do not break down during normal laboratory reactions involving such treatments as heating, exposure to electric current, or reaction with acids. There are more than 100 known elements that combine in a multitude of ways to produce compounds, which account for the living and nonliving substances that we encounter.

▪ **Transfer of Energy**

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
- In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light mechanical motion, or electricity might all be involved in such transfers.

Content Standard E | *SCIENCE AND TECHNOLOGY*

▪ **Understandings about Science and Technology**

- Scientific inquiry and technological design have similarities and differences. Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations. Technological solutions are temporary; technologies exist within nature and so they cannot contravene physical or biological principles; technological solutions have side effects; and technologies cost, carry risks, and provide benefits.
- Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology.
- Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials, or effects of weather and friction; other constraints limit choices in the design, for example, environmental protection, human safety, and aesthetics.
- Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

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

▪ **Risks and Benefits**

- Students should understand the risks associated with natural hazards (fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions), with chemical hazards (pollutants in air, water, soil, and food), with biological hazards (pollen, viruses, bacterial, and parasites), social hazards (occupational safety and transportation), and with personal hazards (smoking, dieting, and drinking).
- Important personal and social decisions are made based on perceptions of benefits and risks.

▪ **Science and Technology in Society**

- Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.
- Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact. Technological changes are often accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and to society. Social needs, attitudes, and values influence the direction of technological development.



Correlations to National Science Education Standards: Grades 9-12

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

Content Standard B | *PHYSICAL SCIENCE*

▪ Structure and Properties of Matter

- Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element.
- Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically.
- The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.
- Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids, the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart.
- Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.

▪ Chemical Reactions

- Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies.
- Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.

Content Standard E | *SCIENCE AND TECHNOLOGY*

▪ Understandings about Science and Technology

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

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

▪ Science and Technology in Local, National, and Global Challenges

- Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science- and technology-related challenges. However, understanding science alone will not resolve local, national, or global challenges.
- Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology.



Teacher Guide

Fact sheets and suggested activities to educate students about the economic, environmental, and societal impacts of using conventional and alternative transportation fuels.

Grade Level

- Intermediate and Secondary
Grades 7-12

Time

- Two-five 45-minute class
periods

Need Resources

NEED has a many guides available to expand and extend your unit on transportation fuels. All guides are available to download free of charge from www.NEED.org:

- Biodiesel*
- Energy Expos*
- Ethanol*
- Exploring Hybrid Buses*
- Fossil Fuels to Products*
- H₂ Educate*
- Hybrid Buses*
- Transportation Fuels Debate*
- Transportation Fuels Enigma*
- Transportation Fuels Rock Performances*

Background

The *Transportation Fuels Infobook* provides the foundation for NEED's transportation curriculum of cooperative learning activities in which students evaluate the advantages and disadvantages of conventional and alternative transportation fuels for themselves and their communities.

Concepts

- All transportation fuels have economic, environmental, and societal advantages and disadvantages.
- Economic and environmental impacts are factors in determining the transportation fuels we use.
- Societal needs, personal beliefs, and changes to the quality of life are important considerations in determining the transportation fuels we use.

Skill Reinforcement

- Critical thinking
- Math—number manipulation
- Cooperative learning
- Comparison and contrast
- Negotiation and compromise
- Evaluation of multiple factors
- Presentation and persuasion

Preparation

- Familiarize yourself with the materials and activities in this booklet.
- Decide which activities your students will conduct.
- Reproduce materials the students will need (glossary, acronyms list, etc.) to conduct the activities. These materials may contain items not covered in-depth within the guide; however, students and teachers may find them useful during research and questioning.
- Find experts in the community to supplement the information in this booklet.

Suggested Activities

1. **LEARNING ABOUT TRANSPORTATION FUELS**

Have your students learn about transportation fuels by reading the background information in this booklet. Brainstorm with students to develop a list of questions they have about alternative fuels and alternative fuel vehicles.

2. **CONDUCTING RESEARCH ON TRANSPORTATION FUELS**

Using the *Web Resources* listed on page 24 and experts in the community, have the students answer the questions they have developed and learn about transportation fuels and vehicles available in their area. Experts might include fuel producers, consumers, distributors, and retailers.

3. **SYNTHESIS ACTIVITY ONE**

Have the students write one-page persuasive or expository papers explaining which alternative fuel vehicle (AFV) would buy or persuade someone to buy for personal use and why.

4. **SYNTHESIS ACTIVITY TWO**

The mayor of a large city in your area has asked your class to develop a plan to reduce emissions from city vehicles—including school buses, public buses, sanitation trucks, police and emergency vehicles, and the city fleet of automobiles. Divide the students into six groups and have each group develop a plan to present to the mayor, listing recommendations and costs for each type of vehicle and the rationale for each recommendation. Invite area experts to visit the classroom to discuss alternative fuel vehicles.

On the board, list the recommendations of each group by vehicle category. Where there are several recommendations, have representative students debate and defend their recommendations until a consensus is reached by the class or by majority vote.

5. **TEACHING OTHERS ABOUT TRANSPORTATION FUELS—TECHNOLOGY CONNECTION**

Using the Student Guides in *Energy Expos*, have students in groups prepare exhibits or multimedia presentations on transportation fuels to teach others. *Energy Expos* is available to download at www.NEED.org.

6. **CALCULATING FUEL SAVINGS**

Have your students compare the fuel costs for a Ford Fusion and Ford Fusion Hybrid over five years using the following figures:

	2011 FORD FUSION	2011 FORD FUSION HYBRID
Initial Cost:	\$25,300	\$28,600
Average Miles per Gallon:	26 mpg	39 mpg
Miles per Year:	15,000	15,000
Cost per Gallon:	\$ 3.31	\$ 3.31



Petroleum

For more than a century, petroleum has been the lifeblood of our transportation system. In the United States alone, we use 13.5 million barrels of oil each day to keep us on the move. It's no wonder that petroleum is often referred to as "black gold."

No one can argue the importance of the automobile in modern society. Driving has become an important part of our daily lives. In fact, Americans drive their personal vehicles about 2.5 trillion miles a year. Commercial trucks drive 288 billion miles, public transit buses drive 2.3 billion, and school buses drive nearly 6 billion miles. There are a lot of vehicles racking up that kind of mileage—246 million personal vehicles, 11 million commercial trucks, 65,400 public transit buses, and 683,700 school buses.

Petroleum Challenges

These vehicles require fuels that are economical and convenient. Today, over 99 percent of the vehicles in the U.S. are powered by gasoline or diesel fuels. America's vast transportation network of refineries, pipelines, and service stations has been designed for **petroleum fuels**. But there are problems with using petroleum.

Today, the United States imports 49 percent of its petroleum from other countries, about twice as much as during the oil embargoes of the 1970s, when American drivers waited in lines for hours to buy gasoline. These oil shocks and the Persian Gulf War made Americans painfully aware of the dangers of depending on foreign oil, a danger that still exists today. Though our oil supply might seem stable today, the unrest in the Middle East could cause shortages or much higher prices at any time.

Auto manufacturers have done a good job of reducing emissions from vehicles. Since the 1960s, when controls were first introduced, **emissions** from vehicles have been reduced by more than 95 percent. Even though pollutants represent less than one percent of the fuel consumed, the large number of cars and growing quantities of fuel they use result in emissions that constitute major health and environmental concerns. Although per-vehicle emissions continue to decrease and average vehicle mileage increases, people keep driving more miles in more vehicles.

The millions of cars, trucks, and buses on the road today contribute half or more of the air pollution in many metropolitan areas. According to the **U.S. Environmental Protection Agency**, almost one-half of all people in the U.S. live in areas that are not in compliance with federal air quality standards (**non-attainment areas**). This has led to a concerted effort to develop alternatives to petroleum fuels.

Taking an Alternative Route

On and off-road motor vehicles can be powered by fuels other than gasoline and diesel. **Alternative fuels**—such as propane, natural gas, ethanol, biodiesel, and electricity—all can help reduce our nation's oil consumption and dependence on foreign oil, as well as reduce

OIL PUMP JACK



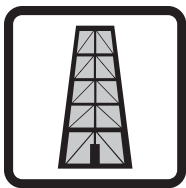
OIL TANKER



Image courtesy of BP

The United States uses 13.5 million barrels of oil each day to meet transportation needs. Approximately 49 percent of the oil we consume is produced by foreign sources and much is shipped to the United States in tankers.

the transportation sector's impact on the environment. Each of these alternative fuels has advantages and disadvantages and may be better suited to some regions and transportation needs than others. Every year, the role of these fuels expands considerably and people have the choice of a larger variety of **alternative fuel vehicles**.



Gasoline

Gasoline is a petroleum-based **hydrocarbon** fuel that contain energy. It is used as a fuel in most U.S. passenger vehicles with **internal combustion engines**. Today, about 42 percent of the crude oil in the U.S. is refined into gasoline. To meet transportation needs, Americans use 13.5 million barrels of crude oil, or 256.6 million gallons of gasoline, every day. With the U.S. population over 309 million people, that is almost one gallon of gasoline every day for each man, woman, and child.

History of Gasoline

Edwin Drake dug the first oil well in 1859 and distilled the petroleum to produce kerosene for lighting. He had no use for the gasoline or other products, so he discarded them. It wasn't until 1892 with the invention of the automobile that gasoline was recognized as a valuable fuel. By 1920, there were nine million vehicles on the road powered by gasoline and service stations were popping up everywhere.

The early distillation process converted only a small percentage of crude oil into gasoline. As the demand for gasoline increased, processes were developed to increase the yield. Heavy hydrocarbon molecules were 'cracked' using heat and pressure. In the 1960s, catalytic cracking began being used to produce much higher yields. A typical U.S. refinery may produce twice as much gasoline from each barrel of crude oil as a European refinery.

During the 1950s, cars were becoming bigger and faster. **Octane ratings** increased and so did lead levels, as lead compounds were added to gasoline to reduce knocking and improve engine performance. Unleaded gasoline was introduced in the 1970s, when the health implications of lead became clear. Leaded gasoline was completely phased out in the 1980s with the introduction of catalytic converters to enhance fuel combustion.

Gasoline as a Transportation Fuel

Today, gasoline is the fuel used by a vast majority of passenger vehicles in the U.S. There are about 246 million vehicles that use gasoline to travel an average of 12,000 miles per year. There are 159,000 fueling stations that provide convenient accessibility for consumers. The production and distribution infrastructures are in place. Most Americans consider gasoline the most sensible transportation fuel for today, even if it is not an ideal fuel.

Consumers are concerned about price fluctuations. During World War I, the cost of gasoline was about \$0.25 a gallon. The price of gasoline has averaged about \$2.00 a gallon in inflation-adjusted dollars for the last 80 years, until the shortages caused by Hurricanes Katrina and Rita, and the unrest in many oil producing areas, such as Iraq, Iran, and Nigeria. In 2008, the highest ever average cost for a gallon of gasoline was \$3.27. However, in 2010, the average cost for a gallon of gasoline has only \$2.79.



More than 246 million passenger vehicles take to the roads every day in the United States. Gasoline fuels 99 percent of these vehicles.

Characteristics and Environmental Impacts of Gasoline

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 criteria air pollutants—carbon monoxide, lead, nitrogen dioxide, **ozone**, particulate matter, and sulfur dioxide—when it is burned. Since the 1960s, stricter environmental standards have led to gasoline formulations and vehicle designs that have reduced vehicle exhaust emissions by 95 percent.

The **Clean Air Act** Amendments of 1990 mandated that **reformulated gasoline** be used in areas of the country that do not meet air quality standards, as well as reductions in nitrogen compounds (**NO_x**) and **volatile organic compounds** (VOCs). More than a dozen different formulations of gasoline are now required by law in the U.S.

Even with reductions in toxic and non-toxic **emissions**, the impact of gasoline on the environment is immense because there are so many vehicles in the United States driving so many miles. It will take the concerted efforts of consumers, industry, and government to make significant changes to our transportation system.



Diesel

Diesel is a petroleum-based fuel made of hydrocarbons that contain energy. At refineries, crude oil is separated into different fuels including gasoline, jet fuel/kerosene, lubricating oil, and diesel. There are five million diesel cars, pickups, and sport utility vehicles (SUVs) on the road today.

Approximately 10 gallons of diesel are produced 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.

History of Diesel

Rudolf Diesel originally designed the diesel engine to use coal dust as fuel, but petroleum proved more effective. The first diesel-engine automobile trip was completed on January 6, 1930. The trip was from Indianapolis to New York City, a distance of nearly 800 miles. This feat helped prove the usefulness of the diesel engine design. It has been used in millions of vehicles since that time.

Diesel as a Transportation Fuel

Diesel fuel plays a vital role in America's economy, quality of life, and national security. As a transportation fuel, it offers a wide range of performance, efficiency, and safety features. Diesel fuel contains between 18 and 30 percent more energy per gallon than gasoline. Diesel technology also offers a greater power density than other fuels, so it packs more power per volume.

Diesel fuel has a wide range of applications. In agriculture, diesel powers more than two-thirds of all farm equipment in the U.S. because diesel engines are uniquely qualified to perform demanding work. In addition, it is the predominant fuel for public transit buses, school buses, and intercity buses throughout the U.S.

America's construction industry depends upon diesel's power. Diesel engines are able to do demanding construction work, like lifting steel beams, digging foundations, drilling wells, digging trenches for utilities, grading and paving new roads, and moving soil—safely and efficiently. Diesel power dominates the movement of America's freight in trucks, trains, boats, and barges; 94 percent of our goods are shipped using diesel-powered vehicles. No other fuel can match diesel in its ability to move freight economically.

A new generation of clean diesel cars, light trucks, and SUVs is now available and offers consumers a new choice in fuel-efficient and low-emissions technology. Clean diesel is a proven technology that is clean, quiet, and fun to drive. Many new diesel options are available for car consumers in every state. Thanks to their inherent fuel efficiency, diesel engines also offer a viable and readily available strategy for reducing greenhouse gas emissions as they produce 25 percent fewer carbon dioxide emissions than gasoline vehicles. American drivers who purchase cleaner-burning diesel cars, trucks, and SUVs are eligible for similar **tax incentives** as purchasers, of gasoline-hybrid electric

DIESEL TRUCK



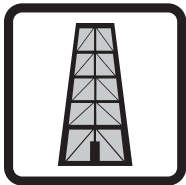
vehicles.

Characteristics and Environmental Impacts of Diesel

Diesel-powered cars achieve 30-35 percent better fuel economy than gasoline powered equivalents, especially in popular SUVs and light trucks, which now make up more than half of all new vehicle sales. Safety is another advantage of diesel fuel; it is safer than gasoline and other alternatives because it is less flammable.

Significant progress has been made in reducing emissions from diesel engines. As of 2010, new trucks and buses have near zero emission levels. Ultra low sulfur diesel (ULSD) fuel is highly refined for clean, complete combustion and low emissions, enabling the use of emission treatment systems. In 2006 the EPA lowered the legal limit of sulfur in diesel from 500 parts per million (ppm) to 15 ppm. Today, refiners reduce the sulfur content in diesel fuel by 97 percent. This new, ultra-clean fuel is important because sulfur tends to hamper exhaust-control devices in diesel engines, like lead once impeded the catalytic converters on gasoline cars. Removing the sulfur from diesel has helped usher in a new generation of clean diesel technology.

Advanced technologies such as electronic controls, high-pressure fuel injection, variable injection timing, improved combustion chamber configuration, and turbo-charging have made diesel engines cleaner, quieter, and more powerful. Using low sulfur diesel fuel and exhaust control systems, such as particulate traps and diesel specific catalytic converters, can reduce particulate emissions by up to 90 percent and nitrogen oxides (NO_x) by 25-50 percent.



Biodiesel

Biodiesel is a fuel made by chemically reacting alcohol with vegetable oils, fats, or greases, such as recycled restaurant greases. It is most often used in blends of two percent or 20 percent (B20) biodiesel. It can also be used as neat biodiesel (B100). Biodiesel fuels are compatible with and can be used in unmodified diesel engines with the existing fueling infrastructure. It is the fastest growing alternative transportation fuel in the U.S.

Biodiesel contains virtually no sulfur, so it can reduce sulfur levels in the nation's diesel fuel supply. Removing sulfur from petroleum-based diesel results in poor lubrication. Biodiesel is a superior lubricant and can restore the lubricity of diesel fuel in blends of only one or two percent. Biodiesel can also improve the smell of diesel fuel, sometimes smelling like french fries.

B100 and biodiesel blends are sensitive to cold weather and may require special anti-freeze, as petroleum-based diesel fuel does. Biodiesel acts like a detergent **additive**, loosening and dissolving sediments in storage tanks. Because biodiesel is a solvent, B100 may cause rubber and other components to fail in vehicles manufactured before 1994. Using B20 minimizes these problems.

Environmental Impacts

Biodiesel is renewable, safe, and biodegradable, and reduces serious air pollutants such as particulates, carbon monoxide, hydrocarbons, and air toxics. Emissions of nitrogen oxide (NO_x), however, increase slightly with the concentration of biodiesel in the blend. The industry is developing additives that will decrease NO_x emissions, and if used with clean diesel technology, NO_x emissions will not increase.

Biodiesel's fuel characteristics exceed those of petroleum-based diesel in **cetane number**, resulting in superior ignition. Therefore, biodiesel has a higher flash point, making it more versatile where safety is concerned. Horsepower, torque, and fuel economy are comparable to diesel.

Distribution of Biodiesel

Currently, biodiesel is available mainly through bulk suppliers; there are 618 public biodiesel refueling stations in the United States. Biodiesel, therefore, is more practical for fleets with their own fueling facilities. Biodiesel is delivered by distributors directly to fleet operators. Currently there are almost 650 biodiesel filling stations. Availability is increasing as the market expands.

Today, the national average of B100 costs about \$4.20 a gallon, depending on purchase volume and delivery costs. Biodiesel is taxed as a diesel fuel, so taxes are added to the purchase price. At today's prices, B20 costs slightly more per gallon than diesel. However, because it is stored in existing infrastructure and can fuel vehicles without modification, biodiesel has emerged as the fastest growing and lowest cost alternative fuel for fleets regulated by the **Energy Policy Act**

BIODIESEL GARBAGE TRUCK



Biodiesel is more practical for fleets with their own fueling facilities, like these garbage trucks from Denver.

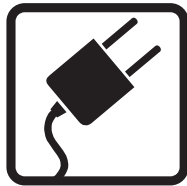
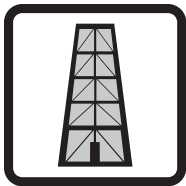
BIODIESEL SCHOOL BUS



Images courtesy of NREL

Used vegetable oil can be used in modified diesel engines, making the exhaust smell like the food that was fried in the oil.

(EPACT). The cost difference will continue to decrease due to projected petroleum price increases, EPA rules requiring a 97 percent reduction of sulfur in diesel, and production improvements in the biodiesel industry. Minnesota and Washington were the first states to mandate the addition of at least two percent biodiesel in every gallon of diesel fuel and many other states are considering mandates as well.



Hybrid Electric Vehicles

Hybrid Electric Vehicles (HEVs) are powered by two energy sources—an energy conversion unit (such as a combustion engine or fuel cell) and an energy storage device (such as a battery, flywheel, or ultra capacitor). The energy conversion unit can be powered by gasoline, compressed natural gas, hydrogen, or other alternative fuels.

HEVs can have either a parallel or series design. In a parallel design, the energy conversion unit and electric propulsion system are both connected directly to the vehicle's wheels. The electric propulsion system never drives the wheels alone, unlike a series design. The primary engine is used for highway driving; the electric motor provides added power during hill climbs, acceleration, and other periods of high demand. In a series design, the primary engine is connected to a generator that produces electricity. The electricity charges the batteries and drives an electric motor that powers the wheels.

Hybrid power systems were designed as a way to compensate for the limitations of **dedicated** EVs. Because batteries can only supply power for short trips, a generator powered by an internal combustion engine was added to increase range. An HEV can function as a purely electric vehicle for short trips, only using the internal combustion engine when longer range is required.

HEVs on the market today combine an internal combustion engine with a battery and electric motor, resulting in vehicles with 1.5 times the fuel economy of comparable conventional vehicles. Depending on driving conditions, one or both are used to maximize fuel efficiency and minimize emissions, without sacrificing performance.

An HEV battery is continually 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 used to recharge the batteries.

Environmental Impacts

The HEV provides extended range and rapid refueling compared to conventional vehicles, as well as significant environmental benefits, reducing emissions by one-third. Their range and fuel economy make them attractive to consumers.

Hybrids Today and Tomorrow

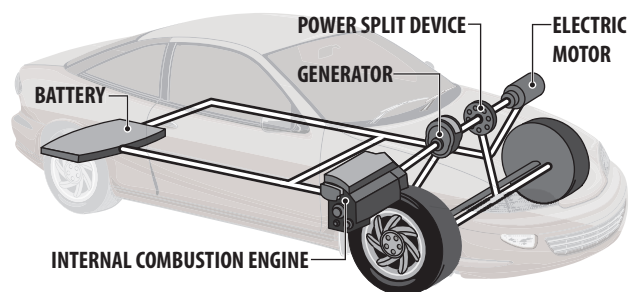
In 2006, there were eight hybrid models available to the general public. In 2012, there are over 30 hybrid models available from almost every manufacturer. Today's hybrid vehicles include two seat passenger cars, four and five seat sedans, SUVs, and even full size pick up trucks capable of towing.

TOYOTA PRIUS



Image courtesy of NREL

How a Hybrid Electric Vehicle Works



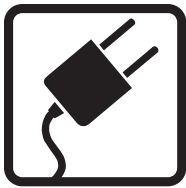
Hybrid electric vehicles combine the benefits of gasoline engines and electric motors. Typically, the wheels are powered by an electric motor, and in some cases, the internal combustion engine assists. Hybrid electric vehicles do not need to be plugged in to charge the battery because they are charged by an onboard generator.

Plug-In Hybrid Vehicles (PHEVs)

PHEVs are very similar to HEVs. They have an internal combustion engine, an electric motor and a large battery pack. The larger battery pack in the PHEV gives it a range of 10-40 miles on an electric only range. When the battery is depleted the car continues to operate as a hybrid or gasoline vehicle.

The battery pack in a PHEV can be recharged by plugging it into a regular 120-volt electric outlet. People using a PHEV in an urban setting may be able to make their daily commute using all-electric power and then recharge the battery overnight to be ready for the next day's commute.

In 2012, there are only a few two PHEV models available on the market, but more are expected to be available soon.



Electric Vehicles

In 1891, William Morrison of Des Moines, Iowa, developed the first electric car. By the turn of the century, dedicated electric vehicles (EVs) outnumbered their gasoline-powered counterparts by two-to-one. Today, there are over 57,500 dedicated EVs in use in the United States, mostly in the West and South.

Rather than using gasoline, **electric vehicles** run solely on **electricity**. A battery stores the electrical energy that powers the motor. When a battery needs charging, EV owners can plug their cars into a charging station at home. A full charge can take four to eight hours, but there are options that allow for a faster charge, which only takes about 30 minutes. Fast charging stations will be public charging stations as they will be too expensive for home use. California currently has the most public charging stations available, but the number of public charging stations is quickly growing across the country. There are currently 9,980 electric charging units at public refueling stations.

The batteries limit the range of a dedicated EV, which is determined by the amount of energy stored in its battery pack. The more batteries a dedicated EV can carry, the more range it can attain, to a point. Too many batteries can weigh down a vehicle, reducing its load-carrying capacity and range, and causing it to use more energy. The typical dedicated EV can only travel 50 to 130 miles between charges. This driving range assumes perfect driving conditions and vehicle maintenance. Weather conditions, terrain, and some accessory use can significantly reduce the range.

Dedicated EVs, therefore, have found a niche market as neighborhood or low speed vehicles for consumers going short distances at speeds of 35 mph or less. However, this is changing. Tesla Motors has developed an electric sports car capable of accelerating 0-60 in 3.9 seconds and traveling 236 miles on one charge. The major car manufacturers have announced plans to put dedicated EVs on the market with a target range of 100 miles. By 2015, Nissan, Ford, Honda, Toyota, Chrysler, and Chevrolet all expect to have EVs available to consumers. Nissan's Leaf electric vehicle is one of the first to be mass produced and marketed in the United States.

The batteries most commonly used in new EVs are lithium-ion. Nickel-metal hydride batteries are also found in some electric vehicles. Extensive research is being conducted on advanced batteries such as lithium-polymer and lithium-air batteries. Such advanced batteries could double the current range of electric vehicles, reduce the cost of batteries, and hold promise for being longer lived.

Environmental Impacts

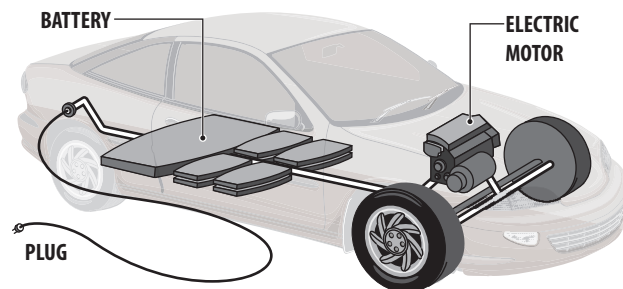
Dedicated electric vehicles produce no tailpipe emissions, but producing the electricity to charge them can produce emissions. EVs are really coal, nuclear, hydropower, oil, and natural gas cars, because these fuels produce most of the electricity in the U.S. Coal alone generates nearly half of our electricity. When fossil fuels are burned, pollutants are produced like those emitted from the tailpipe of a gasoline-powered automobile. Power plant emissions, however, are easier to control than

2011 NISSAN LEAF ELECTRIC VEHICLE



Image courtesy of Nissan

How an Electric Vehicle Works



Electric vehicles store electricity in large battery banks. They are plugged into a wall outlet (either a 240-volt or standard 120-volt) for several hours to charge. An electric motor powers the wheels, and acts as a generator when the brakes are applied, recharging the battery.

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. Using electricity generated from renewable energy produces near zero emissions.

Driving EVs in more populated cities will help decrease the emissions in that city and will help reduce petroleum consumption.

Maintenance

The low maintenance of dedicated electric vehicles is appealing to many consumers. Dedicated EVs require no tune-ups, oil changes, water pumps, radiators, injectors, or tailpipes, so no more trips to the service station.



Ethanol

Ethanol is a clear, colorless alcohol fuel made by **fermenting** the sugars found in grains, such as corn, grain sorghum, and wheat, as well as potato wastes, sugar cane, switchgrass, rice straw, urban wastes, and yard clippings.

There are several processes that can produce alcohol (ethanol) from **biomass**. The most commonly used processes today use yeast to ferment the sugars and starch in the **feedstock** to produce ethanol. Many cars in Brazil operate on ethanol made from sugar cane.

A new process, cellulosic conversion technology, uses enzymes to break down the cellulose in woody fibers, making it possible to produce ethanol from trees, grasses, and crop residues. Trees and grasses require less energy to produce than grain crops, because they use fewer pesticides and herbicides, which are produced from fossil fuels. Scientists have developed fast-growing, hybrid trees that can be harvested in ten years or less. Many perennial grasses can be established in one year and can produce two harvests a year for many years. The huge farms you drive by may not be producing food or animal feed, but fuel for ethanol.

History of Ethanol

Ethanol is not a new product. In 1908, Henry Ford designed his Model T to run on a mixture of gasoline and alcohol, calling it the fuel of the future. In 1919, the ethanol industry received a blow when Prohibition began. Since ethanol was considered a liquor, it could only be sold when it was denatured—rendered poisonous by the addition of petroleum components. With the end of Prohibition in 1933, interest in the use of ethanol increased, but with the end of World War II interest again declined as inexpensive oil became readily available.

Ethanol as a Transportation Fuel

In the 1970s, the oil embargoes revived interest in ethanol as an alternative fuel. In 2011, 193 ethanol plants produced over 13.6 billion gallons of ethanol. Gasoline containing ten percent ethanol—**E10**—is widely used across the United States. Since ethanol contains oxygen, using it as a fuel additive results in up to 25 percent fewer carbon monoxide emissions than conventional gasoline. Today, nearly all of the gasoline sold in the U.S. is E10.

Any vehicle can run on E10, but some vehicles, **flexible fuel vehicles (FFVs)**, are designed to use any combination of ethanol and gasoline up to 85 percent ethanol. **E85**, a fuel that is 85 percent ethanol and 15 percent gasoline, is used mainly in the Midwest and South. While eight million vehicles are capable of using this fuel, only 618,500 are taking advantage of the alternative fuel source. In part this is due to the limited availability of E85 fueling stations. Right now there are more than 2,500 E85 fueling stations in the country. The cost of E85 is a little more expensive than mid-grade gasoline.

The fueling process for E85 is the same as for gasoline; vehicle range, however, is about 15 percent less. With an octane rating of 100, power acceleration, payload capacity, and cruise speed are comparable to gasoline. Maintenance is also similar.

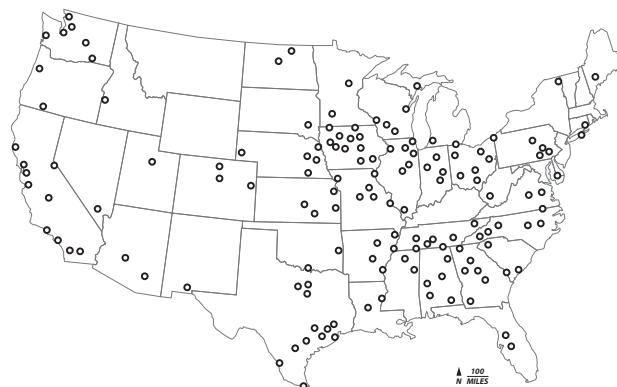
ETHANOL



Images courtesy of NREL

The city of Boulder, CO has set a goal to make 90 percent of its fleet vehicles run on some kind of alternative fuel. Many of them run on E85 Ethanol.

Major Ethanol Refineries



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.

Ethanol is made from crops that absorb **carbon dioxide** and give off oxygen. This carbon cycle maintains the balance of carbon dioxide in the atmosphere when using ethanol as a fuel. As new technologies for producing ethanol from all parts of plants and trees become economical, the production and use of ethanol should increase dramatically.



Propane

Propane is an energy-rich fossil fuel often called **liquefied petroleum gas (LPG)**. It is colorless and odorless; an odorant called mercaptan is added to serve as a warning agent. Propane is a by-product of petroleum refining and natural gas processing. And, like all fossil fuels, it is nonrenewable. The chemical formula for propane is C_3H_8 .

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.

Transporting Propane

Propane is moved from refineries through underground pipelines to distribution terminals across the nation. There are about 70,000 miles of pipeline in the United States, moving propane to 13,500 bulk storage and distribution terminals. It is then transported by railroad tank cars, transport trucks, barges, and tanker ships to bulk plants. A bulk plant is where local propane dealers fill their small tank trucks.

Propane as a Transportation Fuel

Propane has been used as a transportation fuel for more than 80 years. Taxicab companies, government agencies, and school districts often use propane instead of gasoline to fuel their fleets. Today about one percent of total propane consumption is used to fuel more than 143,000 vehicles, mostly in fleets. For fleet vehicles, the cost of using propane is 5 to 30 percent less than for gasoline.

Light- and medium-duty vehicles that run on propane are not directly available from manufacturers. However, certified installers can convert vehicles from gasoline to propane-fueled engines. Conversion costs range from \$4,000 to \$12,000 for light-duty vehicles. Federal and state tax incentives and lower fuel and maintenance costs make the payback period for fleet vehicles reasonable.

There are some interesting characteristics about propane that make it an ideal engine fuel. Propane is cleaner burning than gasoline. 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. Some fleets report two to three years longer service life and extended maintenance intervals.

Propane does not require the additives that are usually blended into gasoline. Even without additive boosters, propane's octane rating of 104 is equal to and, in most cases, higher than gasoline. Propane contains 91,000 Btu/gallon and provides slightly less range than gasoline. Power, acceleration, payload capacity, and cruise speed are comparable.

PROPANE-FUELED VAN



Images courtesy of NREL

Many fleet vehicles have been converted to run on propane.

Why is propane not more widely used as a transportation fuel? The infrastructure for distributing propane is in place across the country, but it is not as conveniently available as gasoline. In 2012, there were about 2,660 LPG vehicle-fueling stations in the U.S., which cost about the same to build as gasoline stations.

Environmental Impacts

Propane-fueled engines produce less air pollution than gasoline engines. Carbon monoxide emissions from engines using propane are 20 to 90 percent lower than emissions from gasoline-fueled engines. Nitrogen oxide emissions are 30 to 60 percent lower, and total hydrocarbon emissions are 40 to 80 percent lower in manufactured propane vehicles. **Converted vehicles**, however, may emit more emissions than manufactured propane vehicles if conversions are not properly designed or installed.



Natural Gas

The **natural gas** we use for heating, cooking, clothes drying, and water heating can also be a clean burning transportation fuel when compressed or liquefied. Natural gas vehicles burn so cleanly that they are used to carry TV cameras and reporters ahead of the runners in marathons. Natural gas is a nonrenewable fossil fuel with plentiful supplies in the United States. Its chemical formula is CH_4 .

CNG—Compressed Natural Gas

Natural gas is usually placed in pressurized tanks when used as a transportation fuel. Even compressed to 2,400–3,600 pounds per square inch (psi), it still has only about one-third as much energy per gallon as gasoline. As a result, natural gas vehicles typically have a shorter range, unless additional fuel tanks are added, which can reduce payload capacity. With an octane rating of 120+, power, acceleration, and cruise speed are comparable. Today, there are about 116,000 CNG vehicles in operation in the U.S., mostly in the South and West. About half are privately owned and half are vehicles owned by local, state, and federal government agencies.

In 2012, there were five models of light-duty CNG vehicles on the market. Honda's Civic GX NGV (natural gas vehicle) has won several awards for its clean emissions performance. However, the natural gas model costs around \$10,000 more than a comparable gasoline-powered Civic. A gasoline engine in several new or used vehicle models can also be converted to run on CNG at a cost of \$12,000–18,000. More commonly, CNG is found fueling heavy-duty vehicles. Tax incentives can help offset the conversion cost or the cost of buying a new light-duty or heavy-duty CNG vehicle.

Some people are concerned about the safety of using CNG as a fuel. CNG tanks are designed for high pressures; they are many times stronger than normal gasoline tanks. It is much less likely that CNG fuel tanks will be damaged in vehicle crashes than the typical gasoline tank. Additionally, if a fuel line is accidentally severed, the natural gas that is released rises and disperses, unlike gasoline, which forms puddles. Natural gas also ignites at a much higher temperature than gasoline (1,200° Fahrenheit compared to 800° Fahrenheit), making accidental combustion of natural gas less likely.

The production and distribution system for natural gas is in place, but the delivery system of stations is not extensive. Today, there are 1,014 natural gas refueling stations in the United States, considerably less than the multitude of gasoline stations. CNG refueling stations are not always at typical gasoline stations, may not be conveniently located, and some have limited operating hours. Natural gas vehicles are well suited to business and public agencies that have their own refueling stations, including public transit agencies. In 2009, 18 percent of new transit buses purchased were fueled by CNG or a natural gas blend. Many fleets report two to three years longer service life, because the fuel is so clean-burning.

Environmental Impacts

Compressed natural gas vehicles emit 60–90 percent less **smog**-producing pollutants and 30–40 percent less **greenhouse gas** emissions than gasoline-powered vehicles. (Reactive hydrocarbon emissions produce ozone, one of the components of smog that causes respiratory problems.) These favorable emission characteristics result because natural gas is 25 percent hydrogen by weight; the only combustion product of hydrogen is water vapor.

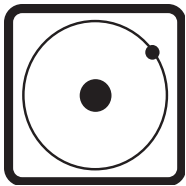
LNG—Liquefied Natural Gas

There are 3,354 vehicles in the U.S. that run on LNG—natural gas that is liquefied by cooling it to -259°F . Most LNG vehicles are government-owned; there are 53 LNG-fueling stations at this time. The advantage of LNG is that natural gas takes up much less space as a liquid than as a gas, so the tanks can be much smaller. The disadvantage is that the fuel tanks must be kept cold, which uses fuel.

NATURAL GAS BUS



Image courtesy of the United States Environmental Protection Agency
Many public buses are fueled by natural gas.



Road to the Future

The United States is geographically widespread; Americans travel more miles than the citizens of any other country to get where they want to go. And they use more petroleum than any other country—approximately 13.5 million barrels a day (MBD) to meet their transportation needs.

In many urban areas, this reliance on petroleum fuels is causing air pollution problems. Non-attainment areas that do not meet **National Ambient Air Quality Standards** stand to lose millions of dollars in federal funds if they do not reduce emissions.

There is no simple answer that can solve the problem, but using cleaner alternative fuels can make a significant difference. Alternative fuels emit fewer hydrocarbons and the hydrocarbons they do emit are less toxic and less reactive. Emissions from electricity, natural gas, and ethanol can be much lower in toxins and ozone-forming hydrocarbons than gasoline.

Use of alternative fuels can also reduce emissions of carbon dioxide, a greenhouse gas. Combustion of any carbon-based fuel produces carbon dioxide, but the overall impact of a fuel depends on how the fuel is made. Fuels produced from biomass and from natural gas result in less carbon dioxide than fuels from petroleum.

There are almost one million dedicated alternative fuel vehicles on the road today that can meet the needs of individual consumers and fleets. Most **dedicated vehicles**—those that use only one fuel (hydrogen, LNG, electric, CNG, LPG, or E85)—are better suited to fleets with their own fueling stations, since availability is not yet widespread. Flexible-fuel and hybrid vehicles can meet the needs of most consumers and provide environmental benefits without burdensome restrictions.

Hydrogen Fuel Cells

In the future, hydrogen may provide a significant contribution to the alternative fuel mix. The space shuttles used hydrogen for fuel. **Fuel cells** use hydrogen and oxygen to produce electricity without harmful emissions; water is the main by-product. Hydrogen is a gas at normal temperatures and pressures, which presents greater transportation and storage hurdles than liquid fuels. No distribution system currently exists.

Hydrogen is the most abundant element in the universe, but it doesn't exist on Earth as a gas. Hydrogen is produced by several methods—electrolysis and synthesis gas production from steam reforming or partial oxidation. Electrolysis uses electricity to split water molecules into hydrogen and oxygen. The photolytic process uses sunlight to illuminate a semiconductor immersed in water splitting the water. Photobiological systems use natural photosynthetic activity of bacteria and green algae to produce hydrogen.

Today, the predominant method of producing hydrogen is steam reforming of natural gas, although biomass and coal can also be used as feedstocks. The fact that hydrogen can be produced using so many different domestic resources is an important reason why it is a promising energy carrier.

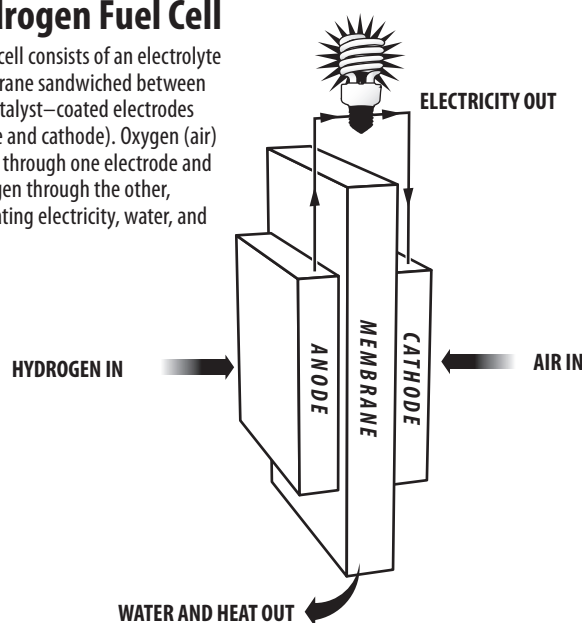
CAR FUELED BY A HYDROGEN FUEL CELL



Image courtesy of DOE-NREL, Keith Wipke

Hydrogen Fuel Cell

A fuel cell consists of an electrolyte membrane sandwiched between two catalyst-coated electrodes (anode and cathode). Oxygen (air) passes through one electrode and hydrogen through the other, generating electricity, water, and heat.



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

While there are no commercially available hydrogen fueled vehicles on the market for consumers, there are 56 hydrogen refueling stations available for 421 hydrogen test vehicles in use today. The **U.S. Department of Energy** is leading government and industry efforts to make hydrogen fuel cell vehicles a viable transportation option in the future.



National Ambient Air Quality Standards

The U.S. Environmental Protection Agency (EPA) uses six pollutants as indicators of air quality and has established maximum threshold concentrations for each. When areas do not meet the standard for one of these pollutants, they may be designated as non-attainment areas and required to implement plans to reach acceptable levels within certain time frames or be subject to penalties.

Ozone

Ozone (O_3) is a photochemical oxidant and the major component of smog. Ozone in the upper atmosphere is beneficial because it helps shield the Earth from ultraviolet radiation, but high concentrations of ozone in the lower atmosphere is detrimental to public health and the environment. Ozone can damage lung tissue, reduce lung function, and sensitize the lungs to other irritants.

Ozone is formed through a chemical reaction between volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of sunlight, especially in warm seasons. Both VOCs and NO_x are emitted by transportation and industrial sources.

The ozone threshold value is 0.075 parts per million (ppm), measured over eight hours. Attainment is met by the annual fourth-highest daily maximum eight-hour concentration, averaged over three years.

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, poisonous gas produced by incomplete combustion of carbon in fuels. When CO enters the bloodstream, it reduces the delivery of oxygen to the body's organs and tissues.

Seventy-seven percent of CO emissions nationwide are from transportation sources, especially highway motor vehicles. Major urban areas have, therefore, been the focus of CO monitoring.

The NAAQS for carbon monoxide is 9.0 ppm, measured as an eight-hour nonoverlapping average concentration. An area meets the standard if no more than one eight-hour value exceeds the threshold per year.

Nitrogen Dioxide

Nitrogen dioxide (NO_2) is a brownish, highly reactive gas present in all urban atmospheres. The three major emissions sources are transportation, electric utilities, and industrial boilers. Oxides of nitrogen are important precursors of ozone and acid rain and can affect aquatic and terrestrial ecosystems. They are formed when fuels are burned at high temperatures. Nitrogen dioxide can irritate the lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections.

The NAAQS for NO_2 is 0.053 ppm, measured as an average annual concentration. An area meets the standards when the mean concentration in a calendar year is below the threshold.

Sulfur Dioxide

Sulfur dioxide (SO_2) is mainly produced by stationary sources of coal and oil combustion, steel mills, refineries, pulp and paper mills, and non-ferrous smelters. SO_2 is a primary contributor to acid rain and can impair visibility. High concentrations of SO_2 can affect breathing and aggravate existing respiratory and cardiovascular disease.

The NAAQS for SO_2 are:

- a one-hour level of 0.075 ppm met by the 99th percentile of one-hour daily maximum concentrations averaged over three years.
- a 3-hour level of 0.50 ppm, not to be exceeded more than once per year.

Particulate Matter

Air pollutants designated as particulate matter (PM) include dust, dirt, soot, smoke, and liquid droplets emitted directly into the air by factories, power plants, cars, construction, fires, and natural windblown dust. Particles formed in the atmosphere by condensation or transformation of emitted gases such as SO_2 and VOCs are also considered particulate matter.

Particulate matter can have major effects on human health, including breathing and respiratory symptoms, damage to lung tissue, alteration of defense systems, carcinogenesis, and premature death. Particulate matter also soils and damages materials and is a major cause of visibility impairment.

The NAAQS for particulate matter are measured in several ways. The maximum annual level of 15 micrograms per cubic meter is measured as an annual mean, averaged over three years.

Lead

Lead is a heavy metal dangerous to human health. Exposure to lead (Pb) can occur through inhalation of lead-polluted air and ingestion of lead-polluted food, water, soil, or dust. Lead gasoline additives, non-ferrous smelters, and battery plants are the biggest contributors to atmospheric lead.

Regulations issued in the early 1970's required gradual reduction of the lead content of all gasoline over a period of years. These regulations have essentially eliminated violations of the lead standard in urban areas except those areas with lead point (localized) sources.

Programs are also in place to control lead emissions from stationary point sources. Significant and ambient problems still remain around some lead point sources, which are now the focus of new monitoring initiatives.

National primary and secondary ambient air quality standards for lead and its compounds, measured as elemental lead, are not to exceed 0.15 micrograms per cubic meter, measured as a rolling three month average.

Ozone Non-Attainment Areas





Glossary

additives	chemicals added to fuel to improve and maintain fuel quality; detergents and corrosion inhibitors are examples of gasoline additives
alternative fuel	as defined by the Energy Policy Act of 1992 (EPACT) - methanol, denatured ethanol and other alcohols (separately or in mixtures of 85% or more by volume with gasoline or other fuels), CNG, LNG, LPG, hydrogen, "coal-derived liquid fuels", fuels other than alcohols derived from biological materials, electricity, neat biodiesel, and any other fuel "substantially not petroleum" that yields substantial energy security benefits and substantial environmental benefits
alternative fuel vehicle (AFV)	as defined by EPACT, any dedicated, flexible-fueled, or dual-fueled vehicle designed to operate on at least one alternative fuel
biodiesel	a biodegradable transportation fuel for use in diesel engines that is produced using organically derived oils or fats as feedstock; biodiesel is used as a component of diesel fuel, and in the future it may be used as a replacement for diesel; B100 is 100 percent biodiesel, B20 is 20 percent biodiesel blended with diesel
biomass	renewable organic matter such as agricultural crops, crop-waste residues, wood, animal and municipal wastes, aquatic plants, fungal growth, etc., used for the production of energy
british thermal unit (Btu)	a standard unit for measuring heat energy; one Btu represents the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit (at sea level)
carbon dioxide	a product of combustion, a greenhouse gas
catalyst	a substance whose presence changes the rate of a chemical reaction without undergoing permanent changes in its composition
cetane number	the cetane number is a measure of the ignition quality of diesel fuel based on ignition delay in an engine; fuels with a higher cetane number have shorter ignition delay, better ignition quality, and less tendency to knock when burned in a compression-ignition engine
Clean Air Act (CAA)	originally enacted in 1963, the law set emissions standards for stationary sources, such as factories and power plants; the amendments of 1970 introduced motor vehicle emissions standards; in 1990, reformulated gasoline (RFG) and oxygenated gasoline provisions were added; the RFG provision requires the use of RFG all year in certain areas; the oxygenated gasoline provision requires the use of oxygenated gasoline during certain months, when CO and ozone pollution are most serious; the regulations also require certain fleet operators to use clean-fuel vehicles in certain cities
clean fuel vehicle (CFV)	any vehicle certified by the EPA as meeting federal emissions standards; there are three categories of CFV standards—LEV, ULEV, and ZEV
compressed natural gas (CNG)	natural gas that has been compressed under high pressures of 2000 to 3600 psi in a pressurized container
converted or conversion vehicle	a vehicle originally designed to operate on gasoline or diesel that has been modified to run on an alternative fuel
corporate average fuel economy (CAFE)	a law passed in 1975 that set federal fuel economy standards; CAFE values are an average of city and highway fuel economy
dedicated vehicle	an alternative fuel vehicle that operates on only one fuel; usually, dedicated vehicles have lower emissions and better performance than vehicles that can use more than one fuel
domestic fuel	domestic fuel is derived from resources within the United States, Canada, and Mexico
dual-fuel vehicle	vehicle designed to operate on a combination of an alternative and conventional fuel
CAA	vehicle with two separate fuel systems designed to run on either an alternative fuel or conventional gasoline, using only one fuel at a time
E10 (gasohol)	ethanol/gasoline mixture containing 10% denatured ethanol and 90% gasoline, by volume
E85	ethanol/gasoline mixture containing 85% denatured ethanol and 15% gasoline, by volume
E95	ethanol/gasoline mixture containing 95% denatured ethanol and 5% gasoline, by volume

electricity	electric current used as a power source; in electric vehicles, on-board rechargeable batteries power an electric motor
electric vehicle	a vehicle powered by electricity, generally provided by storage batteries, but may also be provided by photovoltaic cells or fuel cells
emissions	gaseous products of combustion, some are pollutants
Energy Policy Act of 1992 (EPACT)	a broad-ranging act that deals with many aspects of alternative fuels and alternative fuel vehicles
ethanol (also known as ethyl alcohol, grain alcohol, CH₃CH₂OH)	an alcohol fuel produced from the fermentation of various sugars from carbohydrates found in agricultural crops and cellulosic residues from crops or wood; when used as a gasoline octane enhancer and oxygenate, it increases octane by 2.5 to 3 numbers at 10% concentration; ethanol can also be used in higher concentration in AFVs that have been designed or converted for its use
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
flexible fuel vehicles (FFV)	vehicles with a common fuel tank designed to run on varying blends of unleaded gasoline with either ethanol or methanol
fuel cell	an electrochemical engine (no moving parts) that converts the chemical energy of a fuel, such as hydrogen, and an oxidant, such as oxygen, directly into electricity
gasification	a chemical or thermal process used to convert a feedstock (such as coal) into a gaseous fuel
gasohol (E10)	gasoline that contains 10% ethanol by volume
global warming	the escalation of global temperatures caused by an increase in greenhouse gas emissions in the lower atmosphere
greenhouse effect	a warming of the Earth and its atmosphere as a result of the thermal trapping of incoming solar radiation
hybrid electric vehicle (HEV)	a vehicle that is powered by two or more fuels, one of which is electricity
hydrocarbon	a compound made up of hydrogen and carbon
inherently low emission vehicle (ILEV)	a vehicle that meets ILEV federal standards
internal combustion engine	an engine in which a fuel is burned within the chamber to create motion
knocking (pinging)	knocking in internal combustion engines occurs when fuel in the cylinder is ignited by the firing of the spark plug but burns too quickly, combusting completely before the optimum moment during the compression phase of the four-stroke cycle; the resulting shockwave collides with the rising piston, creating a characteristic metallic "pinging" sound
liquefied natural gas (LNG)	natural gas that has been condensed to a liquid by cooling
liquefied petroleum gas (LPG)	gaseous hydrocarbon mixture separated from natural gas and petroleum, commonly called propane
low emission vehicle (LEV)	vehicles that meet federal standards for LEVs
low speed vehicle (LSV)	small battery-powered electric vehicle with a 30 mph speed limit, sometimes referred to as a neighborhood vehicle
M85	fuel with 85% methanol and 15% gasoline by volume, no longer used as an alternative fuel
M100	neat (100%) methanol, no longer used as an alternative fuel
methane (CH₄)	the simplest hydrocarbon and principal constituent of natural gas
methanol (also known as methyl alcohol, wood alcohol, CH₃OH)	a liquid fuel usually manufactured from natural gas

methyl tertiary butyl ether (MTBE)	a high-octane ether used as a fuel oxygenate
National Ambient Air Quality Standards (NAAQS)	standards for air pollutants regulated under the Clean Air Act, including ozone, CO, NO ₂ , lead, particulate matter, and SO _x
natural gas	a mixture of gaseous hydrocarbons, primarily methane, occurring naturally in the earth and used as a fuel
neat fuel	fuel that is free from additives or dilution with other fuels; M100, for example, is 100% methanol and is called neat methanol
neighborhood electric vehicle (NEV)	battery-powered electric vehicle with top speed of 30 mph
nitrogen oxides (NO_x)	regulated air pollutants, primarily NO and NO ₂ , which are precursors of smog and acid rain
non-attainment area	a region of the country that exceeds minimum acceptable National Ambient Air Quality Standards (NAAQS) for one or more pollutants; such areas are required to seek modifications to their State Implementation Plans (SIPs), setting forth a reasonable timetable using EPA-approved means to achieve attainment; under the Clean Air Act, if a non-attainment area fails to meet NAAQS, the EPA may impose stricter requirements or impose fines, construction bans, and cutoffs in federal grant revenues until attainment is achieved
octane enhancer	a substance such as MTBE that is added to gasoline to increase octane and reduce engine knock
octane rating (octane number)	a measure of a fuel's resistance to self-ignition; a measure of the antiknock properties of the fuel
ozone	tropospheric ozone, or smog, at ground level is a respiratory irritant and considered a pollutant produced from the interaction of hydrocarbon fuel emissions and sunlight—this is different from the stratospheric ozone in the upper atmosphere that protects the Earth from ultraviolet radiation
particulate matter	diverse substances that exist as discrete particles and are considered pollutants according to NAAQS
petroleum fuels	gasoline and diesel fuels
propane	see Liquefied Petroleum Gas
reformulated gasoline (RFG)	gasolines that have been altered to reduce emissions of pollutants
regenerative braking	converts wasted energy from braking into electricity that can be stored in a battery
smog	a visible haze caused primarily by particulate matter and ozone in the lower atmosphere
State Implementation Plan (SIP)	every state must submit a plan to the EPA demonstrating compliance with NAAQS, according to the Clean Air Act
super ultra low emission vehicle (SULEV)	a California vehicle that produces fewer emissions than an ULEV; there is no federal standard for a SULEV
tax incentives	a reduction in taxes to encourage people and businesses to invest in socially desirable economic objectives, such as using alternative fuel vehicles
toxic emission	any pollutant emitted from a source that can negatively affect human health or the environment
transitional low emission vehicle (TLEV)	a vehicle that meets federal TLEV standards; TLEVs have fewer emissions than Tier 1 vehicles but are not eligible for the Clean-Fuel Fleet Program
ultra low emission vehicle (ulev)	vehicle that meets federal and California standards for ULEVs
U.S. Department of Energy (DOE)	department of the Federal Government that coordinates and manages energy conservation, supply, information dissemination, regulation, research, development, and demonstration
U.S. Department of Transportation (DOT)	department of the Federal Government that handles national transportation issues
U.S. Environmental Protection Agency (EPA)	government agency responsible for protection of the environment and public health, regulating air, water, and land pollution, as well as pollution from solid waste, radiation, pesticides, and toxic substances; EPA also controls emissions from motor vehicles, fuels, and fuel additives
volatile organic compounds (VOC)	reactive gases released during combustion or evaporation of fuel and regulated by EPA VOCs; react with nitrogen oxides (NO _x) in the presence of sunlight to form ozone
zero emission vehicle (ZEV)	vehicle meeting federal or California standards for ZEVs; ZEVs standards, usually met by electric vehicles, require zero vehicle emissions (though not zero power plant source emissions)

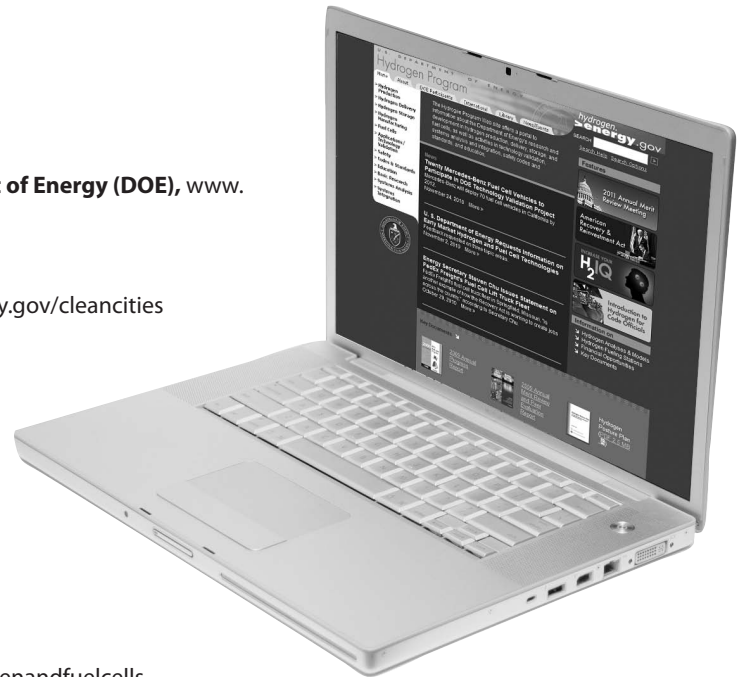


Transportation Fuel Acronyms

AFV	alternative fuel vehicle	LEV	low emission vehicle
B20	20% biodiesel/diesel blend	LNG	liquefied natural gas
Btu	British thermal unit	LPG	liquefied petroleum gas (propane)
CAA	Clean Air Act	LSV	low speed vehicle
CAAA	Clean Air Act Amendments of 1990	MSW	municipal solid waste
CAFE	corporate average fuel economy	MTBE	methyl tertiary butyl ether
CFV	clean fuel vehicle	NAAQS	National Ambient Air Quality Standards
CNG	Compressed Natural Gas	NEV	Neighborhood Electric Vehicle
CO	carbon monoxide	PM	particulate matter
CO₂	carbon dioxide	PPM	parts per million
DOE	U.S. Department of Energy	PSI	pounds per square inch
DOT	U.S. Department of Transportation	RFG	reformulated gasoline
E85	85% ethanol/gasoline blend	SULEV	super ultra low emission vehicle
EPA	U.S. Environmental Protection Agency	TLEV	transitional low emission vehicle
EPACT	Energy Policy Act of 1992	ULEV	ultra low emission vehicle
FFV	flexible fuel vehicle	ULSD	ultra low sulfur diesel
HEV	hybrid electric vehicle	VOC	volatile organic compound
HC	hydrocarbon	VFV	variable fuel vehicle
ILEV	inherently low emission vehicle	ZEV	zero emission vehicle



Web Resources



Alternative Fuels and Advanced Vehicles Data Center of Department of Energy (DOE), www.afdc.energy.gov/afdc

California Energy Commission, www.energy.ca.gov

Clean Cities Program of the Department of Energy, www1.eere.energy.gov/cleancities

Columbia Par Car, www.parcars.com

DaimlerChrysler, www.fleet.chrysler.com

Diesel Technology Forum, www.dieselforum.org

Electric Drive Transportation Association,
www.electricdrive.org

Energy Information Administration of the Department of Energy,
www.eia.gov

Ford, www.fleet.ford.com

Fuel Cell Technologies Program (DOE), www1.eere.energy.gov/hydrogenandfuelcells

Fuel Economy U.S. Department of Energy and Environmental Protection Agency,
www.fueleconomy.gov

General Motors, www.gmaltfuel.com

Governors' Biofuels Coalition, www.governorsbiofuelscoalition.org

Griffin Industries, www.biog3000.com

Honda, www.honda.com

Kentucky Clean Fuels Coalition, www.kentuckycleanfuels.org

Kentucky Division of Energy, www.energy.ky.gov

Kentucky Propane Gas Association, www.kypropane.org

Kentucky Soybean Board, www.kysoy.org

Kentucky Transportation Cabinet, www.transportation.ky.gov

Louisville Metro Air Pollution Control District, www.apcd.org

National Biodiesel Board, www.biodiesel.org

National Renewable Energy Laboratory, www.nrel.gov

Regional Ozone Coalition, www.oki.org/cleanair

Suburban Propane, www.suburbanpropane.com

Toyota, www.toyota.com

Transit Authority of River City, www.ridetarc.org

U.S. Environmental Protection Agency, www.epa.gov

Vehicle Technologies Program (DOE), www1.eere.energy.gov/vehiclesandfuels



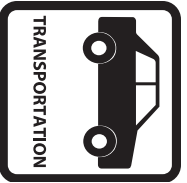
Selected Light Duty Vehicles, 2012

MODEL	FUEL	VEHICLE	EMISSION CLASS	FUEL ECONOMY
Buick LaCrosse FFV	Flex Fuel E85	Sedan	Tier 2 Bin 4	13 mpg city, 19 mpg highway
Cadillac Escalade ESV	Flex Fuel E85	SUV	Tier 2 Bin 5	10 mpg city, 15 mpg highway
Cadillac Escalade Hybrid	Hybrid Electric	SUV	Tier 2 Bin 5	20 mpg city, 23 mpg highway
Chevrolet Equinox	Flex Fuel E85	SUV	Tier 2 Bin 4	15 mpg city, 22 mpg highway
Chevrolet Malibu	Flex Fuel E85	Sedan	Tier 2 Bin 4	15 mpg city, 23 mpg highway
Chevrolet Silverado 1500 Hybrid	Hybrid Electric	Pickup Truck	Tier 2 Bin 5	20 mpg city, 23 mpg highway
Chevrolet Tahoe 1500 Hybrid	Hybrid Electric	SUV	Tier 2 Bin 5	20 mpg city, 23 mpg highway
Chevrolet Volt	Plug-in Hybrid Electric	Sedan	SULEV	95 mpg city, 93 mpg highway
Chrysler Town & Country	Flex Fuel E85	Minivan	Tier 2 Bin 4	12 mpg city, 18 mpg highway
Dodge Grand Caravan	Flex Fuel E85	Minivan	Tier 2 Bin 4	12 mpg city, 18 mpg highway
Ford Escape FFV	Flex Fuel E85	SUV	Tier 2 Bin 4	13 mpg city, 17 mpg highway
Ford Escape Hybrid	Hybrid Electric	SUV	SULEV, Tier 2 Bin 3	34 mpg city, 31 mpg highway
Ford F150	Flex Fuel E85	Pickup Truck	Tier 2 Bin 4	12 mpg city, 17 mpg highway
Ford Focus EV	Electric (Dedicated)	Sedan	ZEV, Tier 2 Bin 1	100 mile range city
Ford Fusion Hybrid	Hybrid Electric	Sedan	SULEV, Tier 2 Bin 3	41 mpg city, 36 mpg highway
GMC Yukon 1500 Hybrid	Hybrid Electric	SUV	Tier 2 Bin 5	20 mpg city, 23 mpg highway
Honda Civic NGV	Natural Gas (Dedicated)	Sedan	LEV II AT-PZEV, Tier 2 Bin 2	24 mpg city/ 36 mpg highway
Honda Fit EV	Electric (Dedicated)	Two-Seater	CARB ZEV, Tier 2 Bin 1	100 mile range city
Honda Insight	Hybrid Electric	Two-Seater	LEV II AT-PZEV, Tier 2 Bin 2	40 mpg city, 43 mpg highway
Jeep Grand Cherokee	Flex Fuel E85	SUV	Tier 2 Bin 4	13 mpg city, 17 mpg highway
Kia Optima Hybrid	Hybrid Electric	Sedan	LEV II SULEV	35 mpg city, 40 mpg highway
Lexus CT 200h	Hybrid Electric	Sedan	LEV II SULEV, Tier 2 Bin 3	43 mpg city, 40 mpg highway
Nissan Altima Hybrid	Hybrid Electric	Sedan	LEV II SULEV, Tier 2 Bin 5	33 mpg city, 33 mpg highway
Nissan Leaf	Electric (Dedicated)	Sedan	CARB ZEV, Tier 2 Bin 1	100 mile range city
Porsche Cayenne S Hybrid	Hybrid Electric	SUV	LEV II ULEV, Tier 2 Bin 5	20 mpg city, 24 mpg highway
Tesla Motors Model S	Electric (Dedicated)	Sedan	CARB ZEV, Tier 2 Bin 1	300 mile range city
Toyota Highlander Hybrid	Hybrid Electric Flexible Fuel	SUV	LEV II SULEV, Tier 2 Bin 3	28 mpg city, 28 mpg highway
Toyota Prius Hybrid	Hybrid Electric	Sedan	LEV II AT-PZEV, Tier 2 Bin 3	51 mpg city, 48 mpg highway
Toyota Prius Plug-in Hybrid	Plug-in Hybrid Electric	Sedan	LEV II AT-PZEV, Tier 2 Bin 3	95 mpg city
Toyota RAV4 EV	Electric (Dedicated)	SUV	CARB ZEV, Tier 2 Bin 1	100 mile range city

mpgge = miles per gallon gasoline equivalent

mpkg = miles per kilogram

For a complete list, visit www.fueleconomy.gov.



Transportation Fuel Comparison

	GASOLINE	DIESEL	PROPANE	CNG	LNG	ETHANOL	ELECTRICITY	BIODIESEL	HYDROGEN
Chemical Formula	C ₄ to C ₁₂	C ₈ to C ₂₅	C ₃ H ₈	CH ₄	CH ₄	C ₂ H ₅ OH	N/A	C ₁₂ TO C ₂₂	H ₂
Energy Content (Btu/gallon)	116,090	128,450	84,950	20,268 Btu/lb	74,720	E85 – 80,460 E100 – 76,330	3,414 Btu./kWh	B20 – 126,000 B100 – 119,550	51,585 Btu/lb
Octane	84-93	Cetane: 40-55	105	120+	120+	110	N/A	Cetane: 48-65	130+
Number of Vehicles (2010)	239,700,000	4,800,000	143,037	115,863	3,354	618,506	57,462	N/A	421
Number of Fuel Stations	159,000	68,880	2,661	1,014	52	2,499	9,980 electric changing units	618	56
Advantages	Many fuel stations; vehicles designed to use gasoline; familiarity.	Many fuel stations; vehicles designed to use diesel fuel; familiarity; more fuel-efficient than gasoline; near zero emissions.	Inexpensive fuel; most widely available clean fuel; lower emissions of ozone-forming hydrocarbons and toxics; very good for fleets.	Very low emissions of ozone-forming hydrocarbons, toxics, and carbon monoxide. Very good fuel for fleets; can be made from renewables.	Very low emissions of ozone-forming hydrocarbons, toxics, and carbon monoxide. Very good fuel for fleets; can be made from renewables.	From renewable feedstocks; very low emissions of ozone-forming hydrocarbons and toxics; can be domestically produced.	Zero vehicle emissions; power plant emissions easier to control; can recharge at night when power cost and demand is low.	Reduces sulfur emissions; increases lubricity; uses renewable waste products; no vehicle changes required.	Near zero emissions; can be produced domestically from renewable sources
Challenges	Polluting emissions; unpredictable price; nonrenewable; limited and possibly unreliable supply.	Unpredictable price; nonrenewable; limited and possibly unreliable supply.	Nonrenewable; cost may rise with increasing demand; limited supply; no energy security or trade balance benefits.	Higher vehicle cost; lower vehicle range; limited fueling stations; nonrenewable at present.	Higher vehicle cost; lower vehicle range; limited fueling stations; nonrenewable at present.	Variable fuel cost; somewhat lower vehicle range; not widely available.	Current technology is limited; higher vehicle cost; lower range and performance; less convenient refueling.	Limited availability; higher cost.	Production is still in research stage; distribution infrastructure is not in place.



Transportation Fuels Infobook Evaluation Form

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

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

Please explain any 'no' statement below.

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

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

What would make the unit more useful to you?

Other Comments:

Please fax or mail to: **The NEED Project**
P.O. Box 10101
Manassas, VA 20108
FAX: 1-800-847-1820

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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
New Orleans Solar Schools Initiative
New York Power Authority
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