

# TRANSPORTATION FUELS:

# THE FUTURE IS TODAY

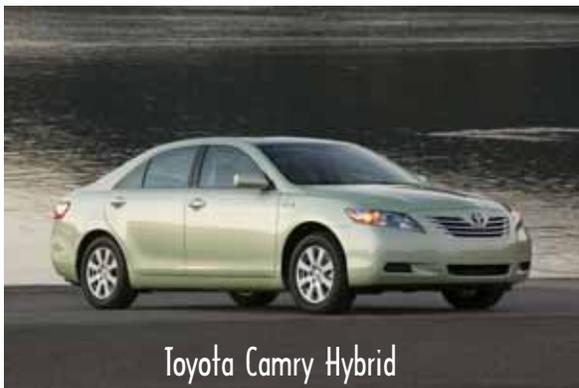
Students learn about conventional and alternative transportation fuels and participate in several activities to learn and teach others.



GRADE LEVEL  
7-12

SUBJECT AREAS  
Science  
Social Studies  
Math  
Language Arts  
Technology

Mercury Mariner Hybrid



Toyota Camry Hybrid



Ford Focus Fuel Cell Vehicle

NEED

2008-2009

Putting Energy into Education

NEED Project PO Box 10101 Manassas, VA 20108 1-800-875-5029 [www.NEED.org](http://www.NEED.org)

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## **Teacher Advisory Board Vision Statement**

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

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*This booklet was developed with funding from the Kentucky Clean Fuels Coalition.*



# Correlations to National Science Content Standards

*(Bolded standards are emphasized in the unit.)*

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

### 1. Abilities of Technological Design

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

### 2. Understandings about Science and Technology

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

## INTERMEDIATE–F: SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

### 3. Natural Hazards

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

### 4. Risks and Benefits

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

### 5. Science and Technology in Society

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

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

### **1. Abilities of Technological Design**

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

## **SECONDARY–F: SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES**

### **3. Natural Resources**

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

### **4. Environmental Quality**

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

### **5. Natural and Human-induced Hazards**

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

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

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

# Teacher Guide

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## TO EDUCATE STUDENTS ABOUT THE ECONOMIC, ENVIRONMENTAL, AND SOCIETAL IMPACTS OF USING CONVENTIONAL & ALTERNATIVE TRANSPORTATION FUELS.

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### BACKGROUND

*Transportation Fuels: The Future is Today* is a series of cooperative learning activities in which secondary 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.

### TIME

- Two–five 45-minute class periods.

### SKILL REINFORCEMENT

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

### MATERIALS & PREPARATION

- Familiarize yourself with the materials and activities in this booklet.
- Decide which activities your students will conduct.
- Reproduce materials the students will need to conduct the activities.
- 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 Resource List on page 28 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 papers explaining which alternative fuel vehicle (AFV) they would 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 Guide on page 29, have students in groups prepare exhibits on transportation fuels to teach others. Have the students prepare PowerPoint presentations instead of exhibits.

## 6. CALCULATING FUEL SAVINGS

Have your students compare the fuel costs for a Honda Civic Hybrid and a Jeep Wrangler over five years using the following figures:

	<b>2008 JEEP WRANGLER</b>	<b>2008 HONDA CIVIC HYBRID</b>
Initial Cost:	\$22,529	\$22,600
Average Miles per Gallon:	17 mpg	42 mpg
Miles per Year:	15,000	15,000
Cost per Gallon:	\$ 4.00	\$ 4.00

# PETROLEUM—BLACK GOLD

For more than a century, petroleum has been the lifeblood of our transportation system. In the United States alone, we use almost 21 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 4 trillion miles a year. Commercial trucks drive 183 billion miles and buses drive 6.5 billion. There are a lot of vehicles racking up that kind of mileage—203,000,000 personal vehicles, 7,000,000 commercial trucks and 700,000 buses.

## ALL THAT GLITTERS...

These vehicles require fuels that are economical and convenient. Today, about 98 percent of the vehicles in the U.S. are powered by petroleum 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.

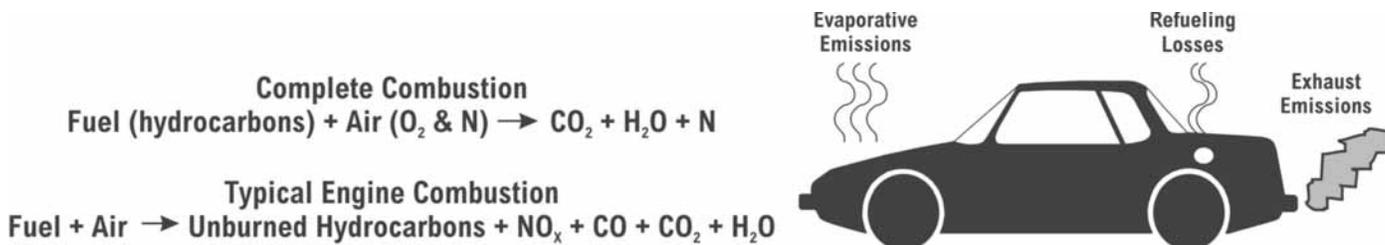
Today, the United States imports about two-thirds of its petroleum from other countries, about twice as much as during the oil embargoes of the 1970s, when American drivers waited in lines for hours to buy gasoline. These oil shocks and the Persian Gulf War made Americans painfully aware of the dangers 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 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, methanol, ethanol, biodiesel and electricity—all can help reduce our nation's oil consumption and dependence on foreign oil, as well as reduce 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.



## PETROLEUM - FUELED VEHICLE EMISSIONS

# GASOLINE

Gasoline is a petroleum-based fuel made of different hydrocarbons that contain energy. It is used as a fuel in most U.S. passenger vehicles with internal combustion engines. Today, 44 percent of the crude oil in the U.S. is refined into gasoline. Americans use almost 21 million barrels of crude oil, or more than 395 million gallons of gasoline, every day. With U.S. population at about 301 million people, that is more than a 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.

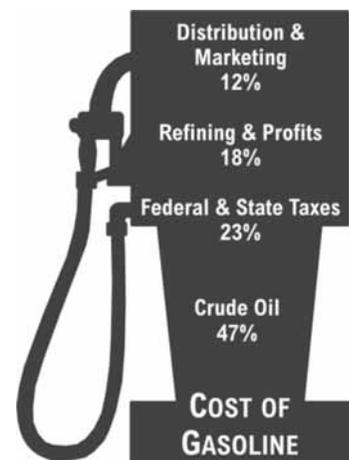
The early distillation process converted only a small percentage of crude oil into gasoline. As the demand for gasoline increased, processes were developed to increase the yield. Heavy hydrocarbon molecules were 'cracked' using heat and pressure. In the 1960s, catalytic cracking began being used to produce 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 levels 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 230 million vehicles that use gasoline to travel an average of 12,000 miles per year. There are 170,000 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 the spring of 2008, gasoline reached an all time high of nearly \$4.00 a gallon and experts believe the price will continue to rise.



## CHARACTERISTICS & ENVIRONMENTAL IMPACTS OF GASOLINE

Gasoline has a high energy content of about 114,000 Btu/gallon and octane ratings of 86-94. It is highly flammable and toxic—gasoline vapors can cause dizziness, vomiting and even death if inhaled in strong concentrations.

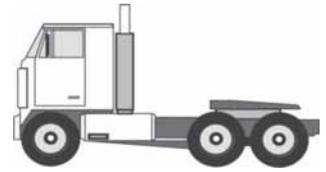
Gasoline is a nonrenewable fossil fuel that produces air pollutants when it is burned. Since the 1960s, stricter environmental standards have led to gasoline formulations and vehicle designs that have reduced vehicle exhaust emissions by 95 percent.

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 ( $\text{No}_x$ ) 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 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 hydrogen and carbon molecules (hydrocarbons) that contain energy. At refineries, crude oil is separated into different fuels including gasoline, jet fuel/kerosene, lubricating oil and diesel. 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.

Diesel automobiles are very popular in Europe, where nearly half the cars sold are diesel-powered. Advanced European diesel passenger vehicles exceed today's U.S. gasoline-electric hybrids in fuel efficiency by more than 25 percent. Combining the superior fuel efficiency of diesel engines with the efficiencies of hybrid electric vehicles can provide even greater fuel efficiency. A concept hybrid from Peugeot averages 70 miles per gallon.

## CHARACTERISTICS & ENVIRONMENTAL IMPACTS OF DIESEL

Diesel-powered cars achieve 20-40 percent better fuel economy than gasoline powered equivalents, especially in popular sport utility vehicles (SUVs) and light trucks, which now make up more than 55 percent 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.

The major disadvantage of diesel fuel is its harmful emissions. Pollutants associated with the burning of diesel fuel are gaseous emissions, including sulfur dioxide (SO<sub>2</sub>) and nitrogen oxide (NO<sub>x</sub>), and particulate matter. Significant progress has been made in reducing emissions from diesel engines. With new clean diesel technologies, today's trucks and buses are eight times cleaner than those built just a dozen years ago. New diesel fuels—some of which have lower sulfur content—can also help diesel vehicles achieve lower emissions. Ultra low sulfur diesel (ULSD) fuel is highly refined for clean, complete combustion and low emissions, enabling the use of emission treatment systems. The EPA has lowered the legal limit of sulfur in diesel from 500 parts per million (ppm) to 15 ppm effective October 15, 2006.

In addition, advanced technologies such as electronic controls, high-pressure fuel injection, variable injection timing, improved combustion chamber configuration and turbo-charging have made new 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 NO<sub>x</sub> by 25-50 percent.

# HYBRIDS—A GREAT COMBO

## HEVs—HYBRID ELECTRIC VEHICLES

Hybrid Electric Vehicles (HEVs) may be the best alternative vehicle for the near future, especially for the individual consumer. HEVs offer many of the energy and environmental advantages of the dedicated electric vehicle without the drawbacks.

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

HEVs can have either a parallel or series design. In a parallel design, the energy conversion unit and electric propulsion system are connected directly to the vehicle's wheels. 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. A 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 conventional vehicles. Depending on driving conditions, one or both are used to maximize fuel efficiency and minimize emissions, without sacrificing performance.

An HEV battery doesn't have to be recharged. It has a generator powered by the internal combustion engine to recharge the batteries whenever they are low. A regenerative braking system captures excess energy when the brakes are engaged. The recovered energy is also used to recharge the batteries.



*Toyota Highlander Hybrid*

## ENVIRONMENTAL IMPACTS

The HEV provides extended range and rapid refueling, as well as significant environmental benefits, reducing pollutants by one-third to one half. Their range and fuel economy will make them attractive to consumers as more models become available to meet their needs.

## HYBRIDS TODAY AND TOMORROW

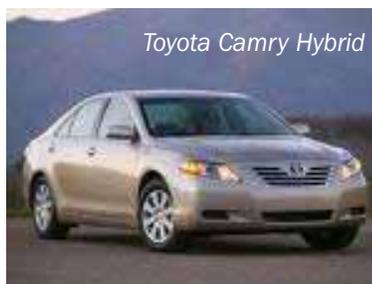
There are several hybrids on the market today. The Toyota Prius is a five-seat sedan that averages 60 mpg in city driving and 51 mpg on the highway driving. It can travel almost 600 miles before refilling. The Honda Civic is also available in a hybrid version that averages 50 miles per gallon. The Ford Escape is the first hybrid SUV on the market. The Escape averages 36 mpg in city driving and 31 mpg on the highway. It can go about 450 miles on a tank of fuel.

In 2006, there were eight hybrid models available to the general public. In 2008, there were 16 hybrid models, including the Toyota Camry and Highlander, the Saturn Vue and Aura, the Nissan Altima, the GMC Yukon, the Mazda Tribute, the Chevy Malibu, the Mercury Mariner, and three Lexus models.

*Ford Escape Hybrid*



*Toyota Camry Hybrid*



*Lexus Hybrid*

# PROPANE—NOT JUST FOR GRILLING

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 75 years and is the most widely used and most accessible alternative fuel. Taxicab companies, government agencies, and school districts often use propane instead of gasoline to fuel their fleets. Today about three percent of total propane consumption is used to fuel more than 200,000 vehicles, mostly in fleets. For fleet vehicles, the cost of using propane is 5 to 30 percent less than for gasoline.

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 2-3 years longer service life and extended maintenance intervals.

Propane doesn't 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.

## ENVIRONMENTAL IMPACTS

Propane-fueled engines produce less air pollution than gasoline engines. Carbon monoxide emissions from engines using propane are 50 to 92 percent lower than emissions from gasoline-fueled engines. Hydrocarbon emissions are 30 to 62 percent lower.

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 2004, there were about 3,000 LPG vehicle-fueling stations in the U.S., which cost about the same to build as gasoline stations. Second, a conventional automobile engine has to be converted to use propane fuel, at a cost of approximately \$2,500.



# ETHANOL—FROM FIELD TO FUEL

Ethanol is a clear, colorless alcohol fuel made by fermenting the sugars found in grains, such as corn, grain sorghum and wheat, as well as potato wastes, cheese whey, corn fiber, rice straw, urban wastes, and yard clippings. There are several processes that can produce alcohol (ethanol) from biomass. The most commonly used processes today use yeast to ferment the sugars and starch in the feedstock to produce ethanol. 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 convert than grain crops, which must be replanted every year. 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. Soon, you may find yourself driving by huge farms that are not producing food or animal feed, but fuel for ethanol.

## HISTORY OF ETHANOL

Ethanol is not a new product. It was widely used before the Civil War. 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. Today, 95 ethanol plants, mostly in the Midwest, produce over 7.8 billion gallons of ethanol. Gasoline containing ten percent ethanol—E10—is widely used in urban areas that fail to meet standards for carbon monoxide and ozone. Since ethanol contains oxygen, using it as a fuel additive results in up to 25 percent fewer carbon monoxide emissions than conventional gasoline. E10 is not considered an alternative fuel under EPACT, but a replacement fuel. Today, nearly half of the gasoline sold in the U.S. is E10.

Vehicles are not converted to run on E85, they are manufactured. Flexible fuel vehicles (FFVs) are designed to use any combination of ethanol and gasoline up to 85 percent ethanol. There are now more than four million flex-fuel vehicles on the road and one million more are produced each year. E85, a fuel that is 85 percent ethanol and 15 percent gasoline is used mainly in the Midwest and South. There are about six million vehicles using this fuel, serviced by ethanol fueling stations. Nearly half of these are private vehicles; the rest are federal, state and local government fleet vehicles. Right now there are over 1,400 E85 fueling stations in the country. The cost of E85 is equivalent to 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 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.



# BIODIESEL—FUEL FROM FRENCH FRIES?

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 oxides (NOx), however, increase slightly with the concentration of biodiesel in the blend. The industry is developing additives that will decrease NOx emissions, and if used with clean diesel technology, NOx 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 BIODESEL

Currently, biodiesel is available mainly through bulk suppliers; there are a growing number of 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, B100 costs about \$4.00 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 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 EPACT. The cost difference will continue to decrease due to projected petroleum price increases, new EPA rules requiring a 97 percent reduction sulfur in diesel, and production improvements in the biodiesel industry. Minnesota and Washington are 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.



*Biodiesel ferry at Mammoth Cave, KY*



*Biodiesel bus used by National Park Service*

# PLUGGING INTO 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 about 10,500 dedicated EVs in use in the United States, mostly in the West and South. Researchers are still working on the same problem that plagued those early dedicated EVs—an efficient battery.

## BATTERY LIMITATIONS

Dedicated electric vehicles must have batteries that can be discharged and recharged repeatedly. Since most batteries can't store large amounts of energy, a dedicated electric vehicle must carry as many batteries as possible. In some dedicated EVs, the batteries constitute almost half the weight of the car. The typical dedicated EV battery pack must be replaced every three to six years, a big expense in itself. Tax incentives can offset some of these costs.

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

Dedicated EVs, therefore, have found a niche market as neighborhood or low speed vehicles for consumers going short distances at speeds of 30 mph or less.

The batteries used in EVs today include lead-acid, NiCad, NiMH, Magnesium-Lithium, NaNiCl, nickel iron, and nickel zinc. Extensive research is being conducted on advanced batteries that will increase electric vehicle range. Some of these batteries are scaled-up versions of the batteries used in portable computers. Such advanced batteries could double the current range of electric vehicles, and hold promise for being longer lived.

## ENVIRONMENTAL IMPACTS

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

## 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. And no more trips to the service station.

*Plugging into an EV Refueling Station.*



Dedicated electric vehicles can be recharged at home at night, when electric rates are low, making the cost of fuel comparable to or lower than gasoline. There are also more than 600 refueling stations, mostly in California and Arkansas.



# CNG/LNG—A NATURAL FOR VEHICLES

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<sub>4</sub>.

## 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 140,000 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.

Vehicles manufactured to run on CNG are available from several manufacturers. A gasoline engine can also be converted to run on CNG at a cost of \$2,000-3,000, depending on the number of fuel tanks installed. Tax incentives can help offset the cost of conversion.

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 about 790 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. Many fleets report two to three years longer service life, because the fuel is so clean-burning.



CNG Refueling Pump



Louisville Metropolitan Sewer District Fleet CNG Vehicle

## ENVIRONMENTAL IMPACTS

Compressed natural gas (CNG) vehicles emit 85-90 percent less carbon monoxide, 10-20 percent less carbon dioxide, and 90 percent fewer reactive non-methane hydrocarbons than gasoline-powered vehicles. (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 also about 3,100 vehicles in the U.S. that run on LNG—natural gas that is liquefied by cooling to –259°F. Most LNG vehicles are government-owned; there are less than 40 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.

# METHANOL—MADE FOR POWER

Methanol, or wood alcohol, is a colorless, odorless, toxic liquid. Methanol is the simplest alcohol (CH<sub>3</sub>OH), produced by replacing one hydrogen atom of methane with a hydroxyl radical (OH). Methanol can be produced from natural gas, coal, residual oil, or biomass. Today, most of the methanol in the United States is produced by the steam reforming of natural gas (methane), a nonrenewable fossil fuel. Most methanol plants are located adjacent to ammonia plants, since both use the same synthesis gas in the production process.



## USES OF METHANOL

Methanol has been used in the chemical industry for many years and can be found in a number of household products, such as windshield washer fluid, antifreeze, and model airplane fuel. It's used for making plastics and is the principal feedstock for making formaldehyde, a chemical used in treating wood products. For a while, its main use was for production of methyl butyl ether (MTBE), a gasoline additive used to reduce emissions of carbon monoxide. The use of MTBE as an oxygenate is declining because of concerns that it can pollute ground water.

## METHANOL AS A VEHICLE FUEL

Although vehicles can operate on pure methanol fuel (M100), methanol blended with 15 percent unleaded gasoline—M85—is more practical for real world applications. Because methanol is a liquid fuel, it does not require major changes in the distribution system or in car engines, but no major auto manufacturers offer M85 compatible vehicles at this time. The cost of M85 is equal to or slightly higher than premium blends. M85 has a lower energy content per gallon, so mileage is lower; but power, acceleration and payload capacity are comparable to gasoline. Vehicles using methanol, however, must use a special, expensive lubricant.

Today, there are about 4,600 vehicles using M85. Most of these vehicles are in California, as are most of the methanol fueling stations. About half of the methanol vehicles are privately owned and half are owned by government agencies.

There is no distribution system for methanol in place at this time. In the future, it will probably be transferred from production facilities by barge, rail, or truck to reach retail outlets. It cannot easily be moved through the existing petroleum pipeline network.

## ENVIRONMENTAL IMPACTS

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

## RACING FUEL

Since it has a higher octane rating than gasoline (about 105), a methanol car can be a clean-burning muscle car. Methanol's exhaust contains 35 percent less smog-producing hydrocarbons that are less reactive (they produce less ozone in the atmosphere) and 30 to 40 percent less airborne toxics than gasoline.

The fuel's superior combustion means that engines designed for methanol typically develop more horsepower, which gives methanol cars faster acceleration than comparable gasoline-powered cars. As a matter of fact, methanol is used in several drag racing classes and has been the only fuel used in Indianapolis 500 races for 30 years.



# ROAD TO THE FUTURE—HYDROGEN FUEL CELLS

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 21 million barrels a day (MBD) to meet their transportation needs. In many urban areas, this reliance on petroleum fuels is causing air pollution problems. Nonattainment 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—slower to form ozone. Emissions from electricity, natural gas, and ethanol can be much lower in toxics and ozone-forming hydrocarbons than gasoline.

Use of alternative fuels can also reduce emission 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 more than 60 alternative fuel vehicles on the market today that can meet the needs of individual consumers and fleets. Most dedicated vehicles—those that use only one fuel—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.

Some alternative fuel vehicles are more expensive to purchase than their gasoline-powered counterparts, but tax incentives and, in some cases, lower fuel costs make them more competitive for both fleet-owners and the general public.

## HYDROGEN FUEL CELLS

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

Hydrogen is the most abundant element in the universe, but it doesn't exist on Earth as a gas; it is produced by four 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. The Department of Energy does not expect any of these methods to be the predominant method of producing large quantities of hydrogen fuel.

Today, the predominant method of producing hydrogen is steam reforming of natural gas, although biomass and coal can also be used as feedstocks.

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.

The Bush administration has launched a hydrogen fuel cell initiative to further research and development of this promising technology.



*Hydrogen fuel cell vehicles on the road today.*

# TRANSPORTATION FUEL ACRONYMS

<b>AFV:</b>	<b>alternative fuel vehicle</b>
<b>B20:</b>	<b>20% biodiesel/diesel blend</b>
<b>Btu:</b>	<b>British thermal unit</b>
<b>CAA:</b>	<b>Clean Air Act</b>
<b>CAAA:</b>	<b>Clean Air Act Amendments of 1990</b>
<b>CAFE:</b>	<b>corporate average fuel economy</b>
<b>CFV:</b>	<b>clean fuel vehicle</b>
<b>CNG:</b>	<b>Compressed Natural Gas</b>
<b>CO:</b>	<b>carbon monoxide</b>
<b>CO<sub>2</sub>:</b>	<b>carbon dioxide</b>
<b>DOE:</b>	<b>U. S. Department of Energy</b>
<b>DOT:</b>	<b>U. S. Department of Transportation</b>
<b>E85:</b>	<b>85% ethanol/gasoline blend</b>
<b>EPA:</b>	<b>U. S. Environmental Protection Agency</b>
<b>EPACT:</b>	<b>Energy Policy Act of 1992</b>
<b>FFV:</b>	<b>flexible fuel vehicle</b>
<b>HEV:</b>	<b>hybrid electric vehicle</b>
<b>HC:</b>	<b>hydrocarbon</b>
<b>ILEV:</b>	<b>inherently low emission vehicle</b>
<b>LEV:</b>	<b>low emission vehicle</b>
<b>LNG:</b>	<b>liquefied natural gas</b>
<b>LPG:</b>	<b>liquefied natural gas (propane)</b>
<b>LSV:</b>	<b>low speed vehicle</b>
<b>MSW:</b>	<b>municipal solid waste</b>
<b>MTBE:</b>	<b>methyl tertiary butyl ether</b>
<b>NAAQS:</b>	<b>National Ambient Air Quality Standards</b>
<b>NEV:</b>	<b>Neighborhood Electric Vehicle</b>
<b>PM:</b>	<b>particulate matter</b>
<b>PPM:</b>	<b>parts per million</b>
<b>PSI:</b>	<b>pounds per square inch</b>
<b>RFG:</b>	<b>reformulated gasoline</b>
<b>SULEV:</b>	<b>super ultra low emission vehicle</b>
<b>TLEV:</b>	<b>transitional low emission vehicle</b>
<b>ULEV:</b>	<b>ultra low emission vehicle</b>
<b>ULSD:</b>	<b>ultra low sulfur diesel</b>
<b>VOC:</b>	<b>volatile organic compound</b>
<b>VFV:</b>	<b>variable fuel vehicle</b>
<b>ZEV:</b>	<b>zero emission vehicle</b>

# TRANSPORTATION FUEL 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 (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. 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 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. The 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:**

**EPACT:** Vehicle designed to operate on 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.

**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,  $\text{CH}_3\text{CH}_2\text{OH}$ ):** 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.

**Inherently Low Emission Vehicle (ILEV):** A vehicle that meets ILEV Federal standards.

**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 Speed Vehicle (LSV):** Battery-powered electric vehicle, sometimes referred to as a neighborhood vehicle.

**Low Emission Vehicle (LEV):** Vehicles that meet federal standards for LEVs.

**M85:** Fuel with 85% methanol and 15% gasoline by volume, used as a fuel in FFVs.

**M100:** Neat (100%) methanol.

**Methane ( $\text{CH}_4$ ):** The simplest hydrocarbon and principal constituent of natural gas.

**Methanol (also known as Methyl Alcohol, Wood Alcohol,  $\text{CH}_3\text{OH}$ ):** 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 (CAA), including ozone, CO,  $\text{NO}_2$ , lead, particulate matter, and  $\text{SO}_x$ .

**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<sub>x</sub>):** Regulated air pollutants, primarily NO and NO<sub>2</sub>, which are precursors of smog and acid rain.

**Non-attainment Area:** A region of the country that exceed 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 (CAA), 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.

**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 EPA demonstrating compliance with NAAQS, according to the Clean Air Act (CAA).

**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<sub>x</sub>) 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).

# 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 nonattainment 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 0.12 parts per million (ppm), measured as a 1-hour average concentration. An area meets the ozone NAAQS if there is not more than one day per year when the highest hourly value exceeds the standard for three consecutive 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 9 ppm, measured as an 8-hour nonoverlapping average concentration. An area meets the standard if no more than one 8-hour value per year exceeds the threshold for two consecutive years.

## **NITROGEN DIOXIDE**

Nitrogen dioxide ( $NO_2$ ) is a brownish, highly reactive gas present in all urban atmospheres. The two 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, and are formed when fuels are burned at high temperatures by oxidation of the primary pollutant nitric oxide (NO).  $NO_2$  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 a 1-hour average 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.

There are three NAAQS for  $SO_2$ :

- an annual mean concentration of 0.03 ppm,
- a 24-hour level of 0.14 ppm, and
- a 3-hour level of 0.50 ppm.

The annual mean standard cannot be exceeded for attainment, while the short-term standards cannot 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<sub>2</sub> 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 is an annual average concentration of 150 micrograms per cubic meter over a 24-hour period. Areas are in attainment when they exceed the standard less than one day per year.

## **LEAD**

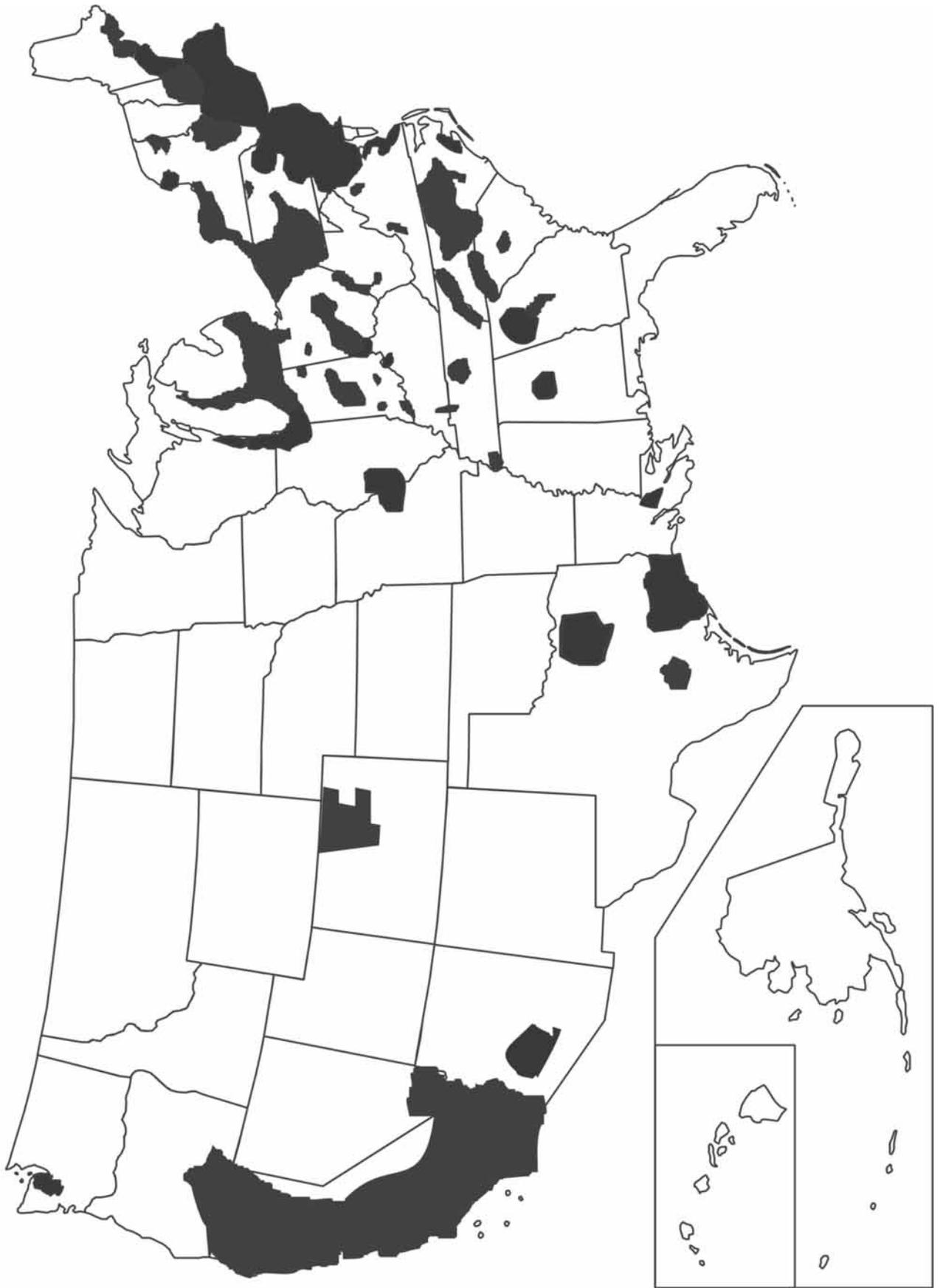
Lead is a heavy metal dangerous to human health. Exposure to lead (Pb) can occur through inhalation of lead-polluted air and ingestion of lead-polluted food, water, soil, or dust. Lead gasoline additives, non-ferrous smelters, and battery plants are the biggest contributors to atmospheric lead.

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 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 1.5 micrograms per cubic meter, as a maximum arithmetic mean averaged over a calendar quarter.

# OZONE NON-ATTAINMENT AREAS



# Transportation Fuel Comparison

	GASOLINE	DIESEL	PROPANE	CNG	LNG	ETHANOL	METHANOL	ELECTRICITY	BIODIESEL
<b>Chemical Formula</b>	$C_8H_{15-18}$	$C_{16}H_{34}$	$C_3H_8$	$CH_4$	$CH_4$	$C_2H_5OH$	$CH_3OH$		$C_{14}$ to $C_{24}$
<b>Energy Content (Btu/gallon)</b>	114,000	128,000	84,000	114,000 <i>gal equiv.</i>	76,000	E85 - 80,460 E100 - 75,000	M85 - 65,000 M100 - 57,000		B20 - 126,000 B100 - 115,000
<b>Octane</b>	86-94	Cetane: 40-55	104	120+		100	100		Cetane: 40-55
<b>Number of Vehicles</b>	220,000,000	800,000	195,000	144,000	3,100	E85-146,000 E10-3,000,000	4,600	55,000	
<b>Number of Fuel Stations</b>	180,000		3,500	1,300	50	E85-200	40	600	
<b>Advantages</b>	Many fuel stations; vehicles designed to use gasoline; familiarity.	Many fuel stations; vehicles designed to use diesel fuel; familiarity.	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 made from renewable feedstocks.	Very low emissions of ozone-forming hydrocarbons and toxics; can be made from renewable feedstocks.	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.
<b>Disadvantages</b>	Polluting emissions; unpredictable price; nonrenewable; limited and possibly unreliable supply.	Polluting emissions; 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.	Limited supplies; lower range; not widely available; currently made from nonrenewables.	Current technology is limited; higher vehicle cost; lower range and performance; less convenient refueling.	Limited availability; higher cost.

# LIGHT DUTY VEHICLES

MODEL	FUEL	VEHICLE	EMISSION CLASS	RANGE
American Honda Civic GX	Dedicated CNG	Compact Sedan	ILEV	200 mi
American Honda Civic	Hybrid Gas/Electric	Compact Sedan	LEV	400 mi
American Honda Insight	Hybrid Gas/Electric	Compact 2-seater	LEV	700 mi
Dodge Ram Van/Wagon	Dedicated CNG	Van/Wagon	ILEV/ULEV	230/210 mi
Chrysler Town & Country				
Dodge Caravan	E85 FFV	Minivan	LEV	320 E85/400 Gas
Chrysler Voyager				
Ford Escape	Hybrid Gas/Electric	SUV	LEV	300 mi
Ford F-150	CNG Bi-Fuel	Light Duty Truck	LEV	120CNG/320 Gas
Ford E Van/Wagon	CNG Dedicated	Van/Wagon	ILEV/ULEV	TBD
Ford F150	CNG Dedicated	Light Duty Truck	ILEV/SULEV	290 mi
Ford Crown Victoria	CNG Dedicated	Sedan	ULEV	200 mi
Ford Taurus	E85 FFV	Sedan/Wagon	LEV	250-350 mi
Ford Explorer	E85 FFV	SUV	LEV	290 mi E85
Ford Ranger FFV	E85 FFV	Light Duty Truck	LEV	TBD
Ford Ranger EV	Electric (Lead Acid)	Light Duty Truck	ZEV	73 mi
Ford F-150	LPG Bi-Fuel	Light Duty Truck	ULEV	250 LPG/390 Gas
Ford Think City	Electric(NiCad)	Two-seater	ZEV	53 mi
GM Chevy Silverado				
GMC Sierra	CNG Bi-Fuel	Light Duty Truck	LEV	TBD
GM Chevy Silverado				
GMC Sierra	CNG Dedicated	Light Duty Truck	ULEV	TBD
GM Chevy Express				
GMC Savana	CNG Bi-Fuel	Van	LEV	TBD
GM Chevy Cavalier	CNG Bi-Fuel	Sub-compact	LEV	110 CNG/360 Gas
GM Chevy Tahoe				290 mi E85
GMC Yukon	E85 FFV	SUV	LEV	340 mi Gas
GM Chevy Suburban				290 mi E85
GMC Yukon XL	E85 FFV	SUV	LEV	340 mi Gas
GM Chevy S-10				
GMC Sonoma	E85 FFV	Light Duty Truck	LEV	400 mi
Mazda B3000	E85 FFV	Light Duty Truck	LEV	230-300 mi
Nissan Altra-EV	Electric (Lithium)	Mid-size Wagon	ZEV	80 mi
Quantum/ProCon:				
Express G2500/3500	LPG Dedicated	Van	ILEV	250 mi
Savana G2500/3500				
Solectria Citivan	Electric (Lead Acid)	Van	ZEV	40 mi
Toyota Camry	CNG Dedicated	Fleet Only Compact	ULEV	270 mi
Toyota RAV4-EV	Electric (Lead Acid)	CA Fleet Only SUV	ZEV	126 mi
Toyota RAV4-EV	Electric (NiMH)	Fleet Only Lease	ZEV	80 mi
Toyota Prius	Hybrid Gas/Electric	5-seat Sedan	LEV	500 mi

# WEB RESOURCES

[www.kentuckycleanfuels.org](http://www.kentuckycleanfuels.org) - Kentucky Clean Fuels Coalition

[www.afdc.doe.gov](http://www.afdc.doe.gov) - Alternative Fuels Data Center of Department of Energy (DOE)

[www.ott.doe.gov](http://www.ott.doe.gov) - Office of Transportation Technologies of Department of Energy (DOE)

[www.eere.energy.gov/hydrogenandfuelcells](http://www.eere.energy.gov/hydrogenandfuelcells) - Office of Energy Efficiency and Renewable Energy (DOE)

[www.ccities.doe.gov](http://www.ccities.doe.gov) - Clean Cities Program of the Department of Energy

[www.eia.doe.gov](http://www.eia.doe.gov) - Energy Information Administration of the Department of Energy

[www.epa.gov](http://www.epa.gov) - U.S. Environmental Protection Agency

[www.nrel.gov](http://www.nrel.gov) - National Renewable Energy Laboratory - Department of Energy

[www.energy.ky.gov](http://www.energy.ky.gov) - Kentucky Division of Energy

[www.doyourshare.org](http://www.doyourshare.org) - Regional Ozone Coalition

[www.evaa.org](http://www.evaa.org) - Electric Electric Drive Transportation Association

[www.energy.ca.gov](http://www.energy.ca.gov) - California Energy Commission

[www.biodiesel.org](http://www.biodiesel.org) - National Biodiesel Board

[www.honda.com](http://www.honda.com) - Honda

[www.fleet.chrysler.com](http://www.fleet.chrysler.com) - DaimlerChrysler

[www.fleet.ford.com](http://www.fleet.ford.com) - Ford

[www.gmaltfuel.com](http://www.gmaltfuel.com) - General Motors

[www.toyota.com](http://www.toyota.com) - Toyota

[www.parcar.com](http://www.parcar.com) - Columbia Par Car

[www.kypropane.org](http://www.kypropane.org) - Kentucky Propane Council

[www.suburbanpropane.com](http://www.suburbanpropane.com) - Suburban Propane

[www.biog3000.com](http://www.biog3000.com) - Griffin Industries

[www.ridetarc.org](http://www.ridetarc.org) - Transit Authority of River City

[www.apcd.org](http://www.apcd.org) - Jefferson County Air Pollution Control District

[www.transportation.ky.gov](http://www.transportation.ky.gov) - Ky Transportation Cabinet

[www.kysoy.org](http://www.kysoy.org) - Kentucky Soybean Council

[www.ethanol-gec.org](http://www.ethanol-gec.org) - Governors' Ethanol Coalition

[www.fueleconomy.gov](http://www.fueleconomy.gov) - Fuel Economy U.S. Department of Energy and Environmental Protection Agency

[www.dieselforum.org](http://www.dieselforum.org) - Diesel Technology Forum

# STUDENT GUIDE—FUEL EXHIBIT

## STEP 1—LEARN ABOUT YOUR TRANSPORTATION FUEL.

- Read about your topic in your backgrounder and in other resources. Underline the main ideas. Put a star (\*) by the most important facts.
- As a group, make a list of the facts you want to teach others. Make sure you answer these questions:
  - What is the chemical composition of your fuel?
  - Is your fuel renewable or nonrenewable?
  - How is your fuel made?
  - Is your fuel available in your area?
  - What types of vehicles can use your fuel?
  - What are the costs associated with your fuel?
  - What are the advantages and disadvantages of your fuel?
  - What are the challenges to developing a widespread market for your fuel?
  - Would you buy a vehicle that uses your fuel? Why or why not?

## STEP 2—PLAN YOUR EXHIBIT.

- As a group, make a list of the displays you can use to make your exhibit interesting. Here are some suggestions:**
  - Display pictures of vehicles that use your fuel.
  - Make a diagram listing the advantages and disadvantages of your fuel.
  - Show a cost analysis of your fuel, including cost of vehicles, fuel, and tax incentives.
  - Show an environmental analysis of your fuel.

## STEP 3—USE YOUR TALENT.

- As a group, decide who will do which jobs. Write down the name of each person in the group. Next to each name, write the person's jobs. You can have more than one person helping on each job.**
  - Who will write the script?
  - Who will make the displays?
  - Who will collect the materials we need?
  - Who will learn the script and teach the others?

## STEP 4—CREATE YOUR EXHIBIT AND WRITE YOUR SCRIPT.

- Write a two minute script using the list of important facts.**
- Create an interesting display with posters and hands-on materials. Make sure the display and the script cover the same information.**
- Practice the script so that you don't have to read it. Use notecards with the important facts listed on them.**

## STEP 5—TEACH OTHERS!

- Give a presentation of your exhibit to others.**



# THE FUTURE IS TODAY

## Evaluation Form

**State:** \_\_\_\_\_ **Grade Level:** \_\_\_\_\_ **Number of Students:** \_\_\_\_\_

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

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

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

What would make the activity more useful to you?

Other Comments:

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

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Kentucky Oil and Gas Association  
Kentucky Propane Education and Research  
Council  
Kentucky River Properties LLC  
Keyspan  
KidWind  
Llano Land and Exploration  
Long Island Power Authority–NY  
Maine Energy Education Project  
Maine Public Service Company  
Marianas Islands Energy Office  
Maryland Energy Administration  
Massachusetts Division of Energy  
Resources  
Michigan Energy Office  
Michigan Oil and Gas Producers Education  
Foundation  
Minerals Management Service–  
U.S. Department of the Interior  
Mississippi Development Authority–Energy  
Division  
Montana Energy Education Council  
Narragansett Electric–  
A National Grid Company  
NASA Educator Resource Center–WV  
National Alternative Fuels Training Center–  
West Virginia University  
National Association of State Energy  
Officials  
National Association of State Universities  
and Land Grant Colleges  
National Hydropower Association  
National Ocean Industries Association

National Renewable Energy Laboratory  
New Jersey Department of Environmental  
Protection  
New York Power Authority  
North Carolina Department of  
Administration–State Energy Office  
Nebraska Public Power District  
New Mexico Oil Corporation  
New Mexico Landman's Association  
New York State Energy Research and  
Development Authority  
Offshore Energy Center/Ocean Star/  
OEC Society  
Offshore Technology Conference  
Ohio Energy Project  
Pacific Gas and Electric Company  
Petroleum Equipment Suppliers  
Association  
Poudre School District–CO  
Puerto Rico Energy Affairs Administration  
Puget Sound Energy  
Roswell Desk and Derrick Club  
Roswell Geological Society  
Rhode Island State Energy Office  
Sacramento Municipal Utility District  
Saudi Aramco  
Schlumberger  
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Snohomish County Public Utility District–  
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U.S. Department of Energy  
U.S. Department of Energy–Hydrogen,  
Fuel Cells and Infrastructure Technologies  
Virgin Islands Energy Office  
Virginia Department of Mines, Minerals  
and Energy  
Virginia Department of Education  
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