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ENERGY EFFICIENCY AND RENEWABLE ENERGY CLEARINGHOUSE

Advanced Technology and Alternative Fuel Vehicles

Surveys show that Americans are concerned about the environment, global warming, and related issues. Yet many don't realize that the cars and trucks they drive are a major source of these problems, and that there are alternative choices they can make today.

Most of us drive or ride in vehicles that are powered by petroleum-based fossil fuels — gasoline or diesel. Some people, however, are choosing to drive vehicles that run on smaller amounts of fuel, and/or partially or completely on fuels other than diesel or gasoline. These advanced and alternative fuel vehicles (AFVs) help reduce our dependence on foreign oil imports, save us money on fuel costs, and improve our air quality.

Why Drive an Advanced or Alternative Fuel Vehicle?

Transportation accounts for more than 67 percent of the oil we consume in the United States—more than we produce. Today, our country imports more than 54 percent of its oil supply, and it's estimated that this could increase to 75 percent by 2010.

According to the U.S. Federal Highway Administration, the average vehicle (car or light truck) on the road today emits more than 600 pounds of air pollution each year. These pollutants (such as carbon monoxide, sulfur dioxide, nitrogen dioxide, and particulate matter) contribute to smog and to many health problems. For example, smog can cause eye and respiratory tract irritation, and carbon monoxide can inhibit the ability of a person's blood to carry oxygen to vital organs.

The average vehicle, through its combustion of fossil fuels, also emits greenhouse gases. Greenhouse gases—such as carbon

Warren Gretz, NREL/PIX07070

Advanced and alternative fuel vehicles help reduce emissions that cause air pollution, smog, and global warming.

Warren Gretz, NREL/PIX00246

This snowplow in Minnesota runs on ethanol.

Alternative fuels not only burn cleaner, but some are even renewable.

dioxide, methane, nitrous oxide, hydrocarbons, and chlorofluorocarbons—surround the Earth's atmosphere like a clear thermal blanket, allowing the sun's warming rays in and trapping the heat close to the Earth's surface. This natural greenhouse effect keeps the average surface temperature at around 60˚F (33˚C).

However, the increased use of fossil fuels during the last century has created an enhanced greenhouse effect, known as global warming. And transportation has played a large role in this increase.

During the 1990s, the annual growth rate of U.S. greenhouse gas emissions from transportation averaged 1.6 percent. In 1999, some 82 percent of U.S. greenhouse gas emissions consisted of carbon dioxide released by the combustion of energy fuels. The U.S. Environmental Protection Agency (EPA) estimates that each year the average light vehicle in the United States releases 10,000 pounds of carbon dioxide into the air. Motor gasoline contributed close to 300 million metric tons of carbon dioxide, making it the largest single source of U.S. carbon dioxide emissions.

By reducing vehicle emissions, AFVs and advanced vehicle technologies help combat both air pollution and global climate change.

Today's Alternative Fuel Choices

Alternative fuels not only burn cleaner—producing lower emissions—but some are even renewable, unlike fossil fuels, which means we could develop a continuous supply of them. The alternative fuels in use today include ethanol, biodiesel, methanol, natural gas, propane, electricity, and hydrogen.

Biofuels

Biofuels are renewable since they are produced from biomass—organic matter, such as plants. They generate about the same amount of carbon dioxide (a greenhouse gas) from the tailpipe as fossil fuels, but the plants that are grown to produce the biofuels actually remove carbon dioxide from the atmosphere. Therefore, the net emission of carbon dioxide will be close to zero.

Ethanol

The most widely used alternative transportation fuel is ethanol. Ethanol is an alcohol typically made from corn or corn byproducts, using a process similar to brewing beer. Vehicles that run on ethanol have lower carbon monoxide and carbon dioxide emissions than traditional vehicles.

In the United States, we blend more than 1.5 billion gallons of ethanol with gasoline each year to produce E10 (10 percent ethanol and 90 percent gasoline.) E10 can be used in most of the vehicles we're driving on the roads today. As a result, we're already using E10 across the country to improve vehicle performance and reduce air pollution.

Today we also have some vehicles that can use a higher blend of ethanol – up to 85 percent – called E85. These vehicles, known as flexible-fuel vehicles, can use E85, gasoline, or any mixture of the two. E85 is available in many parts of the country but primarily in the Midwest.

There are about 100,000 natural gas vehicles in the United States.

Biodiesel

Biodiesel is an ester (similar to vinegar) that can be made from several types of oils, such as vegetable oils and animal fats. Each year about 30 million gallons of biodiesel are produced in the United States from recycled cooking oils and soybean oil.

Biodiesel is currently not available to the general public. Some federal, state, and transit fleets, as well as tourist boats and launches, use biodiesel either alone or blended with another fuel.

Biodiesel is typically used as a blend—20 percent biodiesel and 80 percent petroleum diesel—called B20. B20 can be used in a conventional diesel engine with essentially no engine modifications.

There is also a growing interest in using biodiesel where workers are exposed to diesel exhaust, in aircraft to control local pollution near airports, and in locomotives that face restricted use unless emissions can be reduced.

Methanol

Methanol, another alcohol-based fuel, is usually produced from natural gas, but it can also be produced from biomass. Therefore, it has the potential to help reduce petroleum imports.

Methanol-powered vehicles emit smaller amounts of air pollutants, such as hydrocarbons, particulate matter, and nitrogen oxides, than do similar gasoline-fueled vehicles. Some buses and fleet vehicles currently run on M85, which contains 85 percent methanol and 15 percent gasoline.

Warren Gretz, NREL/PIX03830

There are approximately 600 public, CNG refueling stations across the country.

Natural Gas

Natural gas is a mixture of hydrocarbons, mainly methane. It can be produced either from gas wells or in conjunction with crude oil production.

Natural gas is a clean burning, domestically produced fuel that generates significantly less carbon monoxide, carbon dioxide, particulate matter, and nitrous oxide compared to similar fossil fuel vehicles. It is used in vehicles as compressed natural gas (CNG) or liquefied natural gas (LNG).

There are about 100,000 natural gas vehicles in the United States. Nearly one of every five new transit buses in the United States runs on natural gas.

Propane

Liquefied petroleum gas (LPG), commonly called propane, is a mixture of at least 90 percent propane, 2.5 percent butane and higher hydrocarbons, and ethane and propylene make up the remaining balance. It is a byproduct of natural gas processing and/or petroleum refining.

Nebraska Soybean Board/PIX04231

Soybean oil can be used to make biodiesel, which powers this bus.

Warren Gretz, NREL/PIX06167

The sun's energy, via a photovoltaic module, is used to recharge this electric vehicle.

Propane is a publicly accessible alternative fuel.

A propane-powered vehicle can't run as far on a tank of gas as a comparable gasoline-powered vehicle, but propane generates lower vehicle emissions. Propane emits 64 percent less reactive organic compounds, 20 percent less nitrogen oxide, and 20 percent less carbon monoxide than a similar gasoline vehicle.

Propane is a publicly accessible alternative fuel. There are fueling stations in all states. Today there are more than 270,000 on- and off-road, propane-powered vehicles in the United States.

Electricity

Electricity is considered a fuel when used in vehicles. Electric vehicles use various types of batteries and other energy storage mechanisms to store the electricity used to run a vehicle. While the electricity production process for vehicles may contribute somewhat to air pollution, an electric vehicle (EV) itself does not, resulting in much lower emissions per mile traveled.

In 2000, close to 7,600 on-road EVs in the United States consumed electricity at an amount equivalent to about 1.7 million gallons of gasoline.

Hydrogen

Hydrogen is a simple, abundant element found in organic matter, notably in the hydrocarbons that make up many of our fuels, such as gasoline, natural gas, methanol, and propane. As an energy carrier like electricity (not an energy source), it must be manufactured. Hydrogen can be made by using heat to separate it from the hydrocarbons. Currently, most hydrogen is made this way from natural gas.

Hydrogen can be combined with gasoline, ethanol, methanol, or natural gas to reduce nitrogen oxide emissions. Because the only byproduct of hydrogen is water, only the engine lubricants from a hydrogen-fueled vehicle emit small amounts of air pollutants.

Hydrogen is already the fuel of choice for propelling space shuttles. It is also being explored for use in internal combustion engines. Although hydrogen can be burned in an internal combustion engine, or serve as a fuel additive, there's more interest in using hydrogen to supply fuel cells that power EVs (see "Fuel Cell Vehicle" on page 6).

P-Series

P-Series is a relatively new alternative fuel. It is a blend of ethanol, methyltetrahydrofuran (MTHF), and pentanes, with butane added for blends used in severe cold weather.

Because both the ethanol and the MTHF can be produced from renewable biomass resources, emissions from producing and using P-Series are substantially less than those from gasoline.

P-Series was initially designed as a fuel to help fleets meet the U.S. Energy Policy Act 's requirement to purchase more AFVs. Therefore, P-Series will initially be sold to fleets. Eventually it will be available to the general public too.

Warren Gretz, NREL/PIX08394

This engine runs on gasoline and electricity.

You may already be driving around in an alternative fuel-capable vehicle and not even know it.

Alternative Fuel Vehicles

Most major automakers produce and sell AFVs—cars, light- and heavy-duty trucks, shuttle buses, transit buses, off-road vehicles, and even boats. Many AFVs are sold as fleet vehicles, but some are now available to the public. In fact, you may already be driving around in an alternative fuel-capable vehicle and not even know it. Look in your owner's manual or on the inside of the fuel compartment door for information on what fuels are appropriate for your vehicle.

There are three basic types of AFVs: flex-fuel, bifuel or dual-fuel, and dedicated vehicles.

Flex-Fuel Vehicles

A flex-fuel vehicle (FFV) has one tank and can accept any mixture of gasoline and either methanol or ethanol. P-Series fuel is designed to run in FFVs also.

It's estimated that 1 to 2 million FFVs are already on American roads.

Bifuel or Dual-Fuel Vehicles

Bifuel vehicles have two tanks—one for gasoline and one for either natural gas or propane, depending on the vehicle. The vehicles can switch between the two fuels.

Dedicated vehicles

Dedicated vehicles are designed to be fueled only by an alternative fuel.

EVs are a special type of dedicated vehicle. EVs—like small cars and bicycles—are perfect for driving short distances and where low top speeds aren't an issue, such as in small neighborhoods. Some EVs today though can break most highway speeds. Some large shuttle buses are also EVs.

High-Efficiency Advanced Vehicles

No matter what the fuel, the higher the fuel economy of a car or truck, the less it pollutes. (The "Fuel Economy Guide" Web site listed on page 8 can help consumers choose the most fuel efficient vehicle models.)

Fuel economy becomes even more important when you consider the growing popularity of sport utility vehicles (SUVs). According to *Automotive News*, General Motors expects SUVs to outsell every other car and truck by 2005. If we could double the fuel economy of SUVs, we could save more than 5000 gallons of fuel per vehicle over its lifetime.

Some new cars on the market now offer really impressive improvements in fuel economy. Other advanced technologies are under development and will soon be available in new vehicles.

Warren Gretz, NREL/PIX08392

This HEV, made by Toyota and available today, averages about 50 miles-per-gallon.

Researchers are working on making fuel cell components competitve with internal combustion engines.

Hybrid Electric Vehicles

In 2000, two automakers — Honda and Toyota — began selling hybrid electric vehicles (HEV). Additional models from other automakers are expected to follow.

HEVs, which combine the internal combustion engine of a conventional vehicle with an electric motor, can achieve about twice the fuel economy of conventional vehicles. An energy storage system stores the power to run the electric motor. Batteries are by far the most common energy storage choice. But researchers are still exploring other energy storage options.

HEVs reduce smog-forming pollutants by running more efficiently. But because of their internal combustion engines, they are not zero-emission vehicles. However, the first HEVs on the market emit a third to one half the amount of greenhouse gases emitted by standard gasoline vehicles. Later models may cut emissions even more.

Advanced Drive Trains

The drive train is the system within the vehicle that transmits power from the engine and directs it toward the wheels, and varies the amount of force (torque) that rotates the wheels.

Compression-Ignition Direct-Injection (CIDI) Engines

CIDI engines are the most efficient internal combustion engines available today. Vehicles with CIDI engines have the ability to directly inject fuel into the combustion chamber of an engine to ignite the fuel by compressing it.

Turbocharged Direct-Injection (TDI) Diesel Engines

This is the turbocharged version of the CIDI engine, which is popular in Europe and now available in automobiles sold in the United States. The TDI engine's fuel economy is 20 percent greater than conventional diesel engines.

Spark-Ignition Direct-Injection (SIDI) Engines

Standard gasoline engines use a spark to ignite the fuel. Like CIDI engines, SIDI engines inject fuel directly into the combustion chamber. However, SIDI engines have the advantage of burning gasoline and different types of alternative fuels.

Fuel Cell Vehicle

The fuel cell is one of the hottest advanced vehicle technologies. Many researchers expect this technology to be used in vehicles by 2010.

Fuel cells, which convert hydrogen and oxygen into electricity, have been researched for use in vehicles for many years, and their development and performance have progressed. Because they produce only water vapor as emissions, fuel cells are ideal power sources for transportation. They can be used as the main power for an electric vehicle, or in conjunction with an internal combustion engine in a hybrid vehicle.

Fuel cells convert the chemical energy of a fuel into usable electricity and heat without combustion as an intermediate step. Fuel cells are similar to batteries in that they produce a direct current by means of an electrochemical process. Unlike batteries, however, they store their reactants (hydrogen and oxygen) externally and operate continuously as long as they are supplied with these reactants.

Today, researchers are working on making fuel cell components—considering their size, weight, and cost—competitive with internal combustion engines. Although researchers still have several obstacles to overcome, fuel-cell technology has the potential to provide us with another energy-efficient, cost-competitive transportation option that will help lower emissions and reduce dependance on petroleum.

Steering Toward the Future

Automakers and researchers will continue to develop and improve on the transportation technologies we've discussed. They're exploring better ways to use fuel cells, alternative fuels, and EV and HEV systems. They are also working on new ways to store energy, and creating lightweight advanced materials to make vehicles that run cleaner and use less fuel.

In addition to the technologies available now, researchers across the United States are developing new advanced technologies—for use in cars, minivans, pickup trucks, sport utility vehicles, buses, and heavy-duty trucks—that will steer us toward an even cleaner future with more available, domestic fuel resources.

Resources

The following are sources of additional information on alternative fuels, AFVs, and advanced technology vehicles. The list is not exhaustive, nor does the mention of any resource constitute a recommendation or endorsement.

Ask an Energy Expert
DOE's Energy Efficiency and Renewable Energy Clearinghouse (EREC)
P.O. Box 3048
Merrifield, VA 22116
Phone: 1-800-DOE-EREC (1-800-363-3732)
Fax: (703) 893-0400
E-mail: doe.erec@nciinc.com
Online submittal form:
www.eren.doe.gov/menus/energyex.html
Consumer Energy Information Web site:
www.eren.doe.gov/consumerinfo/

Energy experts at EREC provide free general and technical information to the public on many topics and technologies pertaining to energy efficiency and renewable energy.

DOE's Energy Efficiency and Renewable Energy Network (EREN)
Web site: www.eren.doe.gov/

Your comprehensive online resource for DOE's energy efficiency and renewable energy information.

Organizations

DOE Alternative Fuels Data Center
National Alternative Fuels Hotline: 1-800-423-1363
Web site: www.afdc.doe.gov

Provides detailed information and contacts on alternative fuels.

American Coalition for Ethanol (ACE)
P.O. Box 85102
Sioux Falls, SD 57104
Phone: (605) 334-3381
Fax: (605) 344-3389
Web site: www.ethanol.org/main.html

Promotes the increased production and use of ethanol

DOE Office of Transportation Technologies (OTT)
Web site: www.ott.doe.gov/

Partners with the domestic transportation industry to develop advanced transportation technologies and fuels for the general public.

Electrical Vehicle Association of the Americas (EVAA)
701 Pennsylvania Ave., NW
Third Floor – East Building
Washington, DC 20004
Phone: (202) 508-5995
Fax: (202) 508-5924
Web site: www.evaa.org/

Works to advance EV transportation technologies and supporting infrastructure through policy, information, and market development initiatives.

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Environmental Protection Agency (EPA)
Web site: www.epa.gov/
Global Warming Web site: www.epa.gov/globalwarming/

Provides more information on air pollution, vehicle emissions, greenhouse gas emissions, and global warming.

Partnership for a New Generation of Vehicles (PNGV)
Web site: www.ta.doc.gov/pngv/cover/pngvcover.htm

A partnership between the U.S. federal government and U.S. automakers that aims to strengthen the country's competitiveness by developing technologies for a new generation of vehicles.

Renewable Fuels Association (RFA)
One Massachusetts Ave., NW, Suite 820
Washington, D.C. 20001
Phone: (202) 289-3835
Fax: (202) 289-7519
E-mail: info@ethanolrfa.org
Web site: www.ethanolrfa.org

Striving to expand the production and consumer use of ethanol fuels.

United States Council for Automotive Research (USCAR)
Web site: www.uscar.org/

A group of U.S. automakers that strives to further strengthen the technology base of the domestic auto industry.

Research Laboratories

Center for Transportation Analysis
Oak Ridge National Laboratory
Web site: www-cta.ornl.gov/

Center for Transportation Technologies and Systems
National Renewable Energy Laboratory
Web site: www.ctts.nrel.gov/overview.html

Hybrid Electric Vehicle Laboratory
Idaho National Engineering and Environmental Laboratory
Web site: http://ev.inel.gov/dynamometer.html

National Vehicle and Fuel Emissions Laboratory
EPA
2000 Traverwood Drive
Ann Arbor, MI 48105
Phone: (734) 214-4200

Transportation Technology R&D Center
Argonne National Laboratories
Web site: www.transportation.anl.gov/

Web Sites

AFV Fleet Buyer's Guide
OTT
Web site: www.fleets.doe.gov/

Provides information on the AFVs available for fleets and how to acquire them.

Clean Cities Program
OTT
Web site: www.ccities.doe.gov

Encourages the use of AFVs and their supporting infrastructure throughout the nation.

DOE's Hydrogen Information Network
Web site: www.eren.doe.gov/hydrogen/

Provides a variety of information on hydrogen, including fuel cells.

EPAct Fleet Information & Regulations
OTT
Web site: www.ott.doe.gov/epact

Discusses the AFV acquisition requirements for fleets under the Energy Policy Act (EPAct) regulations.

EVWorld.Com
Web site: www.evworld.com/

Features information and news on the EV community, education, investments, and industry.

Fuel Economy Guide
DOE and EPA
Web site: www.fueleconomy.gov/

Helps consumers find and compare the fuel economies of many vehicle makes and models.

Hybrid Electric Vehicle Program
OTT
Web site: www.ott.doe.gov/hev

Features information on HEVs, their components, where to buy them, and on current HEV research and development.