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Alternative Transportation Fuels and Vehicles: Energy, Environment, and Development Issues

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Summary

The sharp increase in petroleum prices beginning in mid-1999, and experiences with tighter supply, have renewed concern about our dependence on petroleum imports. One of the strategies for reducing this dependence is to produce vehicles that run on alternatives to gasoline and diesel fuel. These alternatives include alcohols, gaseous fuels, renewable fuels, electricity, and fuels derived from coal. The push to develop alternative fuels, although driven by energy security concerns, has been aided by concerns over the environment, because many alternative fuels lead to reductions in emissions of toxic chemicals, ozone-forming compounds, and other pollutants, as well as greenhouse gases.

Each fuel (and associated vehicle) has various advantages and drawbacks. The key drawback of all alternative fuels is that because of higher fuel and/or vehicle prices, the cost to own alternative fuel vehicles (AFVs) is generally higher than for conventional vehicles. And while most AFVs have superior environmental performance compared to conventional vehicles, their performance in terms of range, cargo capacity, and ease of fueling does not compare favorably with conventional vehicles. Furthermore, because there is little fueling infrastructure (as compared to gasoline and diesel fuel), fueling an AFV can be inconvenient.

Any policy to support AFVs must address the performance and cost concerns, as well as the issue of fueling infrastructure. Within this context, a “chicken and egg” dilemma stands out: The vehicles will not become popular without the fueling infrastructure, and the fueling infrastructure will not expand if there are no customers to serve.

Three key laws, the Alternative Motor Fuels Act of 1988 (P.L. 100-494), the Clean Air Act Amendments of 1990 (P.L. 101-549), and the Energy Policy Act of 1992 (P.L. 102-486), as well as three Executive Orders, support the development and commercialization of alternative fuels and alternative fuel vehicles. These legislative acts and administrative actions provide tax incentives to purchase AFVs, promote the expansion of alternative fueling infrastructure, and require the use of AFVs by various public and private entities.

Several bills in the 107th Congress propose to expand these programs or create further incentives for alternative fuel and vehicle use. Opponents argue that there are other, more cost-effective ways of promoting clean air and energy conservation. This report reviews these issues. It will be updated as events warrant.

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Alternative Transportation Fuels and Vehicles: Energy, Environment, and Development Issues

Introduction

Is there any practical replacement for gasoline and diesel fuel in automobiles? Since the oil crises of the 1970s and the rise in the awareness of environmental and security issues, policy makers have often considered this question. For many reasons, the United States has searched for alternatives to petroleum fuels. These reasons include limiting dependence on imported petroleum, controlling the emissions of pollutants into the air, and limiting the emissions of greenhouse gases.

Several fuels are considered alternative transportation fuels by the federal government. These fuels include electricity, natural gas, propane (liquefied petroleum gas, or LPG), ethanol, methanol, biodiesel, and hydrogen. Some of these fuels are similar to conventional fuels, and can be used in conventional vehicles with little or no modification to the engine and fuel system. However, some of these fuels are significantly different, and require the use of completely different engine, fuel, and drive systems. Consequently, cost as well as performance of the associated alternative fuel vehicles (AFVs) must be part of the discussion. Key factors in the ultimate success or failure of any alternative fuel include the relative cost of the fuel, the ability to develop and expand fueling stations, and the performance and safety of the fuel.

For various reasons—notably cost, performance, and availability—alternative fuels have yet to play a major transportation role in the United States. Many argue that the government must step in. Congress, recent Administrations, and state governments have instituted some key programs to promote the use of alternative fuels. These programs include tax incentives for the purchase of alternative fuels and alternative fuel vehicles (AFVs), purchase requirements for government and private fleets, and research grants for the study of alternative fuels. Despite these efforts, only 0.2% of motor fuel demand (125 billion gallons of gasoline and 38 billion gallons of diesel) is met by alternative fuels today.¹

Legislative Background

The three most important statutes concerning alternative fuels are the Alternative Motor Fuels Act of 1988 (AMFA, P.L. 100-494), the Clean Air Act Amendments of

¹U.S. Department of Energy, Energy Information Administration (EIA), *Alternatives to Traditional Transportation Fuels 1998*. January 2000.

1990 (CAAA, P.L. 101-549), and the Energy Policy Act of 1992 (EPAct, P.L. 102-486). AMFA promoted federal government use of alcohol- and natural gas-fueled vehicles. EPAct requires that federal and state agencies, as well as private firms that distribute alternative fuels, must purchase for their fleets a certain proportion of vehicles that are capable of being fueled by specific non-petroleum fuels. Furthermore, EPAct grants the Department of Energy (DOE) the authority to make similar requirements of local governments and private fleets. In addition, EPAct provides tax incentives for private purchases (both individual and commercial) of AFVs that are not required under the act. CAAA requires government and private fleets in cities with significant air quality problems to use low-emission, “clean-fuel” vehicles.

In addition to these laws, recent executive orders have also shaped alternative fuels policy in the United States. These include: E.O. 12844, which urged federal agencies to exceed EPAct purchase requirements; E.O. 13031, which required that federal agencies meet EPAct requirements regardless of budget; and E.O. 13149, which aims to drastically reduce federal government petroleum consumption through the use of AFVs and hybrid vehicles.

The major alternative fuels legislation and relevant Executive Orders are summarized in Table 1 and discussed further below.

Table 1. History of U.S. Alternative Fuel Vehicle Policies

Policy	Year	Key Provisions
Alternative Motor Fuels Act (42 U.S.C. 6374)	1988	<ul style="list-style-type: none"> Promoted Federal Government acquisition of AFVs Established commercial demonstration programs for alternative fuel heavy-duty trucks
Clean Air Act Amendments (42 U.S.C. 7581)	1990	<ul style="list-style-type: none"> Established Clean Fuel Fleet Program
Energy Policy Act (42 U.S.C. 6374)	1992	<ul style="list-style-type: none"> Established AFV purchase requirements for Federal, state, and fuel provider fleets Established tax incentives for the private purchase of AFVs
Executive Order 12844	1993	<ul style="list-style-type: none"> Urged agencies to exceed requirements set in EPAct
Executive Order 13031	1996	<ul style="list-style-type: none"> Required federal agencies to meet EPAct requirements regardless of budget Required yearly progress reports on EPAct purchases
Executive Order 13149	2000	<ul style="list-style-type: none"> Set goal of reducing federal government petroleum consumption Identified several strategies including the use of AFVs and hybrid vehicles

The Alternative Motor Fuels Act of 1988

Beginning in FY1990, the Alternative Motor Fuels Act called for the federal government to acquire the “maximum practicable” number of light-duty alcohol and natural gas vehicles. In addition, AMFA established an Interagency Commission on Alternative Motor Fuels to develop a national alternative fuels policy. Furthermore, the act established a commercial demonstration program to study the use of alcohol and natural gas in heavy duty trucks. Since 1991, DOE has supported projects in these areas, making the data publicly available through its Alternative Fuels Data Center (AFDC).²

The Clean Air Act Amendments of 1990

The Clean Air Act Amendments of 1990 established the Clean Fuel Fleet Program (CFFP).³ This program requires cities with significant air quality problems to promote vehicles that meet clean fuel emissions standards. In metropolitan areas in extreme, severe, or serious non-attainment for ozone⁴ or carbon monoxide, fleets of 10 light-duty vehicles or more face purchase requirements similar to those for EPAct (discussed below). However, under CFFP, conventional vehicles are admissible if they meet National Low Emission Vehicle (LEV) standards. Another key difference between the CFFP requirements and the EPAct requirements is that under CFFP, a vehicle must always be operated on the fuel for which it was certified. For example, if a dual-fuel ethanol vehicle is certified LEV using ethanol, but not using gasoline, the vehicle must be operated solely on ethanol. This provision avoids a perceived “loophole” in EPAct.

The Energy Policy Act of 1992

The Energy Policy Act of 1992 was enacted to promote energy efficiency and energy independence in the United States. It includes programs that require or promote alternative fuel vehicles, as well as commercial and domestic energy efficiency, natural gas imports, and nuclear power. Two key programs concerning alternative fuels are the AFV purchase requirements for federal, state, and alternative fuel provider⁵ fleets, and the AFV tax incentives.

Fleet Requirements. EPAct⁶ requires that a certain percentage of new light-duty vehicles (passenger cars and light trucks) purchased for certain fleets must be

²[<http://www.afdc.doe.gov/>.]

³P.L. 101-549, section 246.

⁴Ozone standards are maintained by limiting emissions of the three key components of ozone: nitrogen oxides (NOx), volatile organic compounds (VOCs), carbon monoxide.

⁵An alternative fuel provider fleet is a fleet of vehicles owned and operated by a private company that sells or distributes alternative fuels.

⁶P.L. 102-486, sections 303, 501, and 507.

fueled by an alternative fuel.⁷ Covered fleets are those that operate 50 or more light-duty vehicles, of which at least 20 operate primarily in a metropolitan area. Furthermore, the fleets must be capable of being fueled at a central location, such as the fleet motor pool. Law enforcement vehicles, emergency vehicles, non-road vehicles, and vehicles used for testing are exempted from the requirement. Federal, state, and alternative fuel provider fleets are currently mandated to purchase AFVs, and DOE is currently considering whether to include municipal and private fleets in the program.⁸ The purchase requirements are phased in between 1997 and 2001. (See Table 2.)

Table 2. Light-Duty Alternative Fuel Vehicle Purchase Requirements under the Energy Policy Act

Year	Percentage of all Acquisitions for Covered Fleets		
	Federal	State	Alternative Fuel Provider
1997	33%	10%	30%
1998	50%	15%	50%
1999	75%	25%	70%
2000	75%	50%	90%
2001 and beyond	75%	75%	90%

Source: National Alternative Fuels Hotline, Department of Energy, September 1998.

DOE currently recognizes the following as alternative fuels: methanol and denatured ethanol as alcohol fuels (mixtures that contain at least 70% alcohol), natural gas (compressed or liquefied), liquefied petroleum gas (LPG), hydrogen, coal-derived liquid fuels, fuels derived from biological materials, and electricity.⁹ Covered vehicles may be dedicated¹⁰ or dual fuel.¹¹

There have been mixed results from the program. According to DOE, some federal and state agencies are exceeding their mandates, while others are far below their quota. As a whole, the federal government is was compliance in 1998, mainly

⁷EPAAct defines an alternative fuel as “any fuel the Secretary [of Energy] determines, by rule, is substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits.”

⁸63 *Federal Register* 19372. April 17, 1998.

⁹Some fuels may actually be covered by more than one category. For example, most ethanol (an alcohol fuel) is derived from corn or other agricultural products (biological materials).

¹⁰Dedicated: operated solely on an alternative fuel.

¹¹ Dual-fuel: capable of being operated on both conventional and alternative fuel. There are two types of dual-fuel vehicles, bi-fuel and flexible fuel. Bi-fuel vehicles can only be operated on one fuel at a time, while flexible fuel vehicles can operate on any mixture of the two fuels.

due to large purchases such as 10,000 ethanol vehicles purchased by the U.S. Postal Service in that year.¹² However, according to a coalition of environmental groups, the government as a whole has failed to comply with EPAct since then. In a suit filed by Earthjustice¹³ in San Francisco federal court, 18 federal agencies are accused of failing to comply with the purchase requirements.¹⁴ In addition, questions have been raised about the success of the program since many covered fleets, especially fuel provider fleets, have not reported their purchases to DOE.¹⁵

A key concern over the fleet requirements is whether they actually support the goals of EPAct. This is because EPAct does not require the use of alternative fuels, only the purchase of AFVs. Fleets can purchase dual-fuel vehicles, operate them solely on gasoline or diesel fuel, and still meet the EPAct requirements. The fleet program has been criticized because this use of dual-fuel vehicles is seen by some as a “loophole.” This criticism is another element of the lawsuit filed by Earthjustice.

Tax Incentives. Another key provision of EPAct is a set of tax incentives for the purchase of new AFVs.¹⁶ The act provides an electric vehicle (EV) tax credit of 10% of the purchase price, up to a maximum of \$4,000. In addition, it provides a Clean Fuel Vehicle (any alternative fuel) tax deduction of \$2,000 for light-duty vehicles, \$5,000 for heavy-duty vehicles up to 26,000 pounds, and \$50,000 for heavier trucks and buses. Vehicles are not eligible for both incentives, and vehicles purchased to meet mandated fleet requirements are ineligible for either incentive. The EV tax credit is scheduled to be phased down starting in 2001, reaching zero in 2004; the Clean Fuel Vehicle tax deduction will be phased down starting in 2002, reaching zero in 2005.

Executive Orders

Three Executive Orders have also played a key role in developing alternative fuels policies. Executive Order 12844, issued on April 21, 1993, urged federal agencies to make every effort to exceed the mandatory purchase requirements set in EPAct. The order argued that the federal government could provide impetus for the development and manufacture of alternative fuel vehicles, and the expansion of fueling stations and other infrastructure to support privately-owned AFVs.

Executive Order 13031, issued December 13, 1996, expanded the Administration’s policy on EPAct fleets. The order required that federal agencies

¹²In 1998, the U.S. Postal Service placed an order with Ford for 10,000 specially-designed Ford Explorers. The redesigned sport-utility vehicles use flexible fuel ethanol/gasoline engines.

¹³Earthjustice is representing the Sierra Club, the Center for Biological Diversity, and the Bluewater Network.

¹⁴“U.S. Agencies Sued on Alternative Fuel Rule,” *San Francisco Chronicle*. January 3, 2002. p. A3.

¹⁵U.S. General Accounting Office (GAO), *Limited Progress in Acquiring Alternative Fuel Vehicles and Reaching Fuel Goals*. February 2000. p. 9.

¹⁶P.L. 102-486, section 1913.

must comply with EPAct regardless of their budgets. The order also required that agencies must submit a yearly progress report to the Office of Management and Budget (OMB) along with their yearly budgets. Further, it established penalties for failing to meet the EPAct requirements. If an agency reported to OMB that it did not meet its EPAct requirements, that agency must submit a detailed plan for meeting the requirements the next year. The Order also established credits for the use of medium- and heavy-duty vehicles and EVs to meet the requirements.

Most recently, the Administration issued Executive Order 13149 on April 21, 2000. This order presents the goal of reducing the federal fleet's annual petroleum consumption by 20% below the FY1999 level by the end of FY2005. The order suggests several strategies for attaining this goal, including using alternative fuel vehicles and high-efficiency hybrids. The order also requires that a majority of EPACT vehicles must be fueled with alternative fuels by FY2005. This helps fix the "loophole" that allows dual-fuel EPACT vehicles to operate solely on conventional fuel.

Alternative Fuels

As noted above, several fuels are considered alternative fuels. This report will address alternative fuels recognized by EPAct. Many technical and market factors affect the usability and ultimate success of these fuels as alternatives to petroleum-based fuels. Since many of these fuels require entirely new powertrains, or extensive modifications to conventional vehicles, the characteristics of both alternative fuels and alternative fuel vehicles must be discussed together. Fuel cost and fueling infrastructure, vehicle cost, fuel and vehicle performance, and other factors for each fuel will be addressed in turn in the discussion below. Table 3 presents a summary of the various alternative fuels.

Table 3. Summary of Alternative Fuels

Fuel	Fuel Consumption (million GEG) ^a	Vehicles in Use	Fueling Sites ^b	Incremental Vehicle Cost ^c
LPG	242.7	268,000	3,417	\$1,000-\$2,000
Natural Gas	104.4	103,000	1,278	\$4,000-\$6,000
Biodiesel ^d	33.5	N/A ^e	12	----
Ethanol	3.3 ^f	35,000 ^g	147	\$0
Methanol	1.4	18,000	0	\$500-\$2,000
Electricity	1.8	8,700	685	up to \$20,000
Hydrogen	----	----	----	----
Coal-Derived Fuels	----	----	----	----

Note: all data are for 2000, except fueling sites.

Source: Department of Energy and California Energy Commission.

^a GEG: Gasoline Equivalent Gallon. To compare various fuels, an equivalency factor is used. In this case, it is the amount of energy in one gallon of gasoline.

^b As of February 2, 2002.

^c This does not include additional infrastructure/fueling equipment costs or additional life-cycle vehicle costs (e.g. maintenance, resale).

^d Since biodiesel can be blended with conventional diesel, separate refueling sites are not necessary.

^e Biodiesel is used in conventional diesel engines.

^f 1,012 million GEG including ethanol in blended gasoline

^g This does not include flexible fuel ethanol/gasoline vehicles that operate primarily or exclusively on gasoline. There are approximately 725,000 of the vehicles in the United States (Energy Information Administration estimate).

Propane (LPG)

Liquefied petroleum gas (LPG) is produced as a by-product of natural gas processing and petroleum refining.¹⁷ Because the components of LPG are gases at normal temperatures and pressures, the mixture must be liquefied for use in vehicles. In addition to vehicles, propane is also used in home heating as well as recreational activities.¹⁸

Consumption. LPG is the most commonly used alternative fuel. Domestic consumption was approximately 243 million gasoline equivalent gallons (GEG)¹⁹ in 2000, or about 0.2% of gasoline demand.²⁰ This is greater than all other alternative fuels combined.²¹ Propane is used in both light- and medium-duty vehicles, and there were approximately 270,000 LPG vehicles on the road in 2000,²² or about 0.1% of the approximately 210 million gasoline and diesel-fueled vehicles.²³ In 1999, the federal government operated only 208 LPG vehicles.²⁴ LPG vehicles tend to be custom vehicles; in fact, the only light-duty production vehicles with an LPG option

¹⁷LPG is a mixture of hydrocarbons, mainly propane (C₃H₈), but also propylene (C₃H₆), butane (C₄H₁₀), and butylene (C₄H₈).

¹⁸Alternative Fuels Data Center (AFDC), *Propane (LPG) General Information*. [http://www.afdc.doe.gov/altfuel/lpg_general.html.] Updated My 31, 2000.

¹⁹Since all fuels have different energy contents, to compare performance factors (e.g. fuel economy and fuel cost) an equivalency factor is used. The most common factor is to determine the amount of alternative fuel needed to generate the energy in one gallon of gasoline. This amount is called a gasoline equivalent gallon (GEG). While some publications refer to this as a gasoline gallon equivalent (GGE), this report uses GEG throughout for clarity.

²⁰EIA, *Alternatives to Traditional Transportation Fuels*. Table 10.

²¹Excluding ethanol in gasoline. When used as a blending agent, ethanol does not qualify as an alternative fuel.

²²EIA, *Alternatives to Traditional Transportation Fuels*. Table 1.

²³U.S. Department of Transportation, Bureau of Transportation Statistics, *Pocket Guide to Transportation – 1998*. December 1998.

²⁴EIA, *Alternatives to Traditional Transportation Fuels*. Table 20.

are the Ford F150 pickup and the GM Express and Savanna vans (the latter two supplied by Quantum).²⁵

Cost. On a GEG basis, fuel costs for LPG are approximately equal to those of gasoline, and tend to fluctuate with gasoline prices. Between January 2000 and October 2001, the price for LPG averaged approximately \$1.38²⁶ to \$1.76²⁷ per GEG. While fuel costs are only slightly higher for LPG as compared to gasoline, there is an incremental purchase cost for an LPG vehicle, which ranges between \$1,000 and \$2,000.²⁸ This additional cost covers modifications to the fuel system and the addition of a high-pressure fuel tank. Some of this incremental cost currently may be defrayed by federal, state, local, or manufacturer incentives that promote the purchase of alternative fuel vehicles.

Infrastructure. Because of its many uses,²⁹ the refueling system for LPG is extensive. There are approximately 3,400 refueling sites in all 50 states,³⁰ which corresponds to 2.7% of the approximately 124,000 gasoline stations in the United States.³¹ Because of its wide use, if the demand for LPG as an alternative fuel were to expand, it is likely that the supply infrastructure could expand proportionally.

LPG is delivered to retailers through a pipeline and tanker truck system much like the gasoline delivery system. Therefore, an expansion of the LPG supply infrastructure would face few technical barriers. However, because the fuel must be kept under pressure, special equipment is required to transfer LPG to a vehicle. Addition of new refueling equipment would lead to additional capital costs for retailers.

Performance. In terms of environmental performance, LPG vehicles tend to produce significantly lower ozone-forming emissions, although it can be difficult to quantify the differences. According to the California Energy Commission, LPG vehicles emit up to 33% fewer VOCs, 20% less NO_x, and 60% less carbon monoxide.³²

²⁵National Alternative Fuels Hotline, *Model Year 2002: Alternative Fuel Vehicles*. November 2001.

²⁶GAO, *Limited Progress*. Appendix 1. (Data from U.S. Department of Energy.)

²⁷U.S. Department of Energy, Clean Cities Program, *The Alternative Fuel Price Report*. May 5, 2000, November 1, 2000, July 3, 2001, and December 17, 2001.

²⁸California Energy Commission, *Liquefied Petroleum Gas / Propane-Powered Vehicles* [<http://www.energy.ca.gov/afvs/lpg/propane.html>.] Updated March 10, 1999.

²⁹Including home heating and outdoor grills.

³⁰Department of Energy, Alternative Fuels Data Center (AFDC), *Refueling Sites*. [http://www.afdc.doe.gov/refuel/state_tot.shtml.] Updated July 30, 2001.

³¹Department of Commerce, Bureau of the Census, *County Business Patterns for the United States*. [<http://www.census.gov/epcd/cbp/view/cbpview.html>]

³²California Energy Commission, *Liquefied Petroleum Gas*.

A key performance drawback to LPG is the somewhat decreased range as compared to gasoline. However, because LPG has the highest energy content (by volume) of the alternative fuels, this range reduction is only about 26%. Further, larger LPG vehicles can carry a larger tank, and tend to maintain a range of between 300 and 400 miles. However, to allow longer range, payload is diminished due to the size and weight of the LPG tank.³³

Safety. LPG has a higher ignition temperature than gasoline, making it safer in that respect.³⁴ Furthermore, LPG must be present in greater concentrations than gasoline to ignite.³⁵ Because LPG is stored under pressure, it must be stored in heavy duty tanks. In order to prevent failure of the fuel tank, LPG tanks must undergo rigorous testing. Further, LPG is odorless, so an odorant is added to make it detectable in air.³⁶

Other Issues. There are few major issues involving LPG fuels and vehicles other than those issues relevant to all alternative fuel vehicles, such as the need to expand fueling infrastructure. However, because LPG is often derived from petroleum refining, it may do little to diminish petroleum dependence.

Natural Gas

Natural gas is a fossil fuel produced from gas wells or as a by-product of petroleum production. Natural gas is composed of hydrocarbons, mainly methane.³⁷ It is used extensively in residences and by industry, and is therefore widely available. Because of its gaseous nature, natural gas must be stored onboard a vehicle either as compressed natural gas (CNG) or as liquefied natural gas (LNG). CNG is generally preferred for light-duty applications such as passenger cars, while LNG is generally used in heavier applications, such as buses.

Consumption. Vehicles consumed 104 million GEG of natural gas in the United States in 2000 (mostly as CNG).³⁸ This was less than 0.1% of gasoline demand, although consumption has been rising steadily over the past ten years. After propane, CNG is the second most widely used pure alternative fuel.³⁹

³³In the case of a passenger car, the tank usually reduces available trunk space.

³⁴This is the range of concentrations in air that a fuel can ignite. Below the lower limit, the mixture is too “lean” to ignite; above the upper limit, the mixture is too “rich.”

³⁵In fact, propane can ignite through a slightly wider range of concentrations (in air) than gasoline. However, the lower flammability limit for LPG is higher than gasoline, making it generally more difficult to ignite. Below this concentration, the mixture is too “lean” to ignite. Source: Alternative Fuels Data Center, *Properties of Fuels*. August 28, 2000.

³⁶National Propane Gas Association, *Consumer Info*. [<http://www.npga.org/>.]

³⁷The chemical formula for methane is CH₄. Natural gas also contains minor amounts of ethane (C₂H₆), propane (C₃H₈), butane (C₄H₁₀) and pentane (C₅H₁₂).

³⁸EIA, *Alternatives to Traditional Transportation Fuels*. Table 10.

³⁹More ethanol is consumed, but most of this is blended with conventional gasoline.

Approximately 103,000 natural gas vehicles were in operation in the United States in 2000, and the number has been growing by approximately 20% per year.⁴⁰ These include CNG passenger cars such as the Honda Civic, Toyota Camry, and Chevrolet Cavalier, as well CNG light trucks natural gas transit buses.⁴¹ In 1999, the federal government operated approximately 15,000 CNG vehicles, and 7 LNG vehicles.⁴² In fact, the federal government operates more vehicles on than all other alternative fuels combined. Approximately half of the federal CNG vehicles are light duty vehicles, the rest being heavy trucks and buses.

Cost. Using natural gas can cut fuel costs significantly, since natural gas tends to be a relatively inexpensive fuel⁴³. The average price for one GEG of CNG ranged from \$0.58⁴⁴ to \$1.02,⁴⁵ between January and October 2000, and the price for LNG was comparable. In addition to the low cost of the fuel, natural gas is also subject to a much lower federal excise tax rate (5.4 cents per GEG⁴⁶) than the gasoline excise tax rate (18.3 cents per gallon). With recent fuel prices, natural gas vehicles can reduce annual fuel costs by \$200 for smaller cars and up to \$300 for larger vehicles.⁴⁷

While fuel costs tend to be lower for natural gas than for gasoline, equipment costs tend to be higher. Equipping a light-duty vehicle to operate on CNG typically costs between \$4,000 and \$6,000, though some of this incremental cost may be defrayed through federal and state incentives. In addition, although there are some public fueling stations, if in-home fueling is desired, a small slow-fill unit can be installed for approximately \$3,500.⁴⁸

Infrastructure. Refueling infrastructure for CNG is more broadly available than for most alternative fuels. There are approximately 1,200 public CNG refueling sites and 44 LNG refueling sites in 46 states.⁴⁹ Again, this number is small compared to the number of gasoline refueling stations. However, with the extensive natural gas system in the United States, the CNG refueling network could be greatly expanded. Furthermore, since slow-fill refueling systems are available for home installation,

⁴⁰EIA, *Alternatives to Traditional Transportation Fuels*. Table 1.

⁴¹National Alternative Fuels Hotline, *Model Year 2000*.

⁴²EIA, *Alternatives to Traditional Transportation Fuels*. Table 20.

⁴³Current high natural gas prices have made CNG less attractive as a fuel.

⁴⁴GAO, *Limited Progress*. Appendix 1.

⁴⁵Clean Cities Program, *Alternative Fuel Price Report*.

⁴⁶Based on a tax rate of 48.44 cents per 1000 cubic feet of natural gas and approximately 112 cubic feet per GEG. Source: ATA Foundation, Alternative Fuels Task Force, *1998-1999 Tax Guide for Alternative Fuels*. [<http://www.afdc.doe.gov/documents/taxindex.html>.]

⁴⁷This is based on a natural gas price of \$0.77 per GEG, and a gasoline price of \$1.20 per gallon. Source: John DeCicco, Jim Kleisch and Martin Thomas, *ACEEE's Green Book: The Environmental Guide to Cars and Trucks*, 2000.

⁴⁸California Energy Commission, *Frequently Asked Questions About Natural Gas Vehicles*. [<http://www.energy.ca.gov/afvs/ngv/ngvFAQs.html>.] Updated March 10, 1999.

⁴⁹AFDC, *Refueling Sites*.

consumers could fuel their vehicles overnight, and would only need to access public stations on longer trips. However, because the technology differs significantly from a gasoline pump, vehicle users or station operators would need to be trained in the use of natural gas pumps.

Performance. Compared to gasoline vehicles, the environmental performance of natural gas vehicles is exceptional. Particulate emissions are virtually eliminated, carbon monoxide emissions are reduced by as much as 65% to 95%, hydrocarbon emissions are reduced by up to 80%, and nitrogen oxide (NO_x) emissions by as much as 30%.⁵⁰ Furthermore, greenhouse gas emissions are also reduced compared with gasoline vehicles.⁵¹

The key performance drawback to natural gas vehicles is their significantly shorter range. Most natural gas passenger cars can only travel 100 to 200 miles on a full tank of fuel.⁵² This is significantly less than the range of 300 to 400 miles for most gasoline-powered passenger cars.⁵³ For this reason, natural gas vehicles have been popular for use as delivery trucks or other fleets that operate in cities or other localized areas.

Safety. Natural gas tends to be safer than gasoline for many reasons. First, the fuel is non-toxic, although in high gaseous concentrations it could lead to asphyxiation. Second, natural gas is more difficult to ignite than gasoline, and tends to dissipate more quickly due to its lower density. However, since natural gas is colorless and odorless, like LPG, an odorant is added to the fuel to make the fuel detectable in air.⁵⁴

A key safety concern with natural gas has to do with on-board storage. Because CNG is compressed under such high pressures, the rupture of a fuel tank would be extremely dangerous. For this reason, CNG tanks must undergo “severe abuse” tests such as collisions, fires, and even gunfire.⁵⁵

Other Issues. Besides the environmental benefits of natural gas, another benefit is the fact that over 80% of natural gas used in the United States comes from

⁵⁰Hydrocarbon and nitrogen oxide emissions contribute to the formation of ground-level ozone, the main component of urban “smog.”

⁵¹California Energy Commission, *Natural Gas Vehicles: Fuel and Vehicle History and Characteristics*. [<http://www.energy.ca.gov/afvs/ngv/ngvhistory.html>], updated March 10, 1999; James S. Cannon, *Paving the Way to Natural Gas Vehicles*, 1993.

⁵²Larger vehicles such as pickup trucks and vans can utilize larger fuel tanks by occupying some of the storage area of the vehicle.

⁵³National Alternative Fuels Hotline, *Model Year 2000*.

⁵⁴California Energy Commission, *Frequently Asked Questions About Natural Gas Vehicles*. [<http://www.energy.ca.gov/afvs/ngv/ngvFAQs.htm>.] Updated March 10, 1999.

⁵⁵The Natural Gas Vehicle Coalition, *Questions and Answers about Natural Gas Vehicles* [<http://www.ngvc.org/qa.html>.] Updated March 16, 2000.

domestic sources.⁵⁶ Therefore, it has been argued that natural gas vehicles can help promote energy security in this country by lowering our reliance on imported fuel. However, because natural gas is used extensively in electricity production, significant increases in its use for transportation could result in increased demand for other fuels for electricity.

Biodiesel

Biodiesel is a synthetic diesel fuel that is produced from fatty feedstocks such as soybean oil and recycled cooking oil.⁵⁷ Although more expensive than conventional diesel, it has some important advantages. The most notable advantage is that because biodiesel is very similar to conventional diesel, the fuel can be used in existing diesel engines.⁵⁸

Consumption. Currently, domestic production is between 30 and 60 million gallons per year,⁵⁹ as compared to approximately 31 billion gallons per year of conventional diesel.⁶⁰ Because biodiesel can be used in existing diesel engines, there are no vehicles designed specifically for its use.

Cost. The most significant drawback to biodiesel is its increased cost as compared to conventional diesel. Wholesale diesel prices have averaged between \$0.55 and \$0.67 per gallon over the past five years, although they are currently relatively high (generally between \$1.05 and \$1.10 per gallon⁶¹). Currently, wholesale prices for biodiesel range between \$1.33 and \$1.73 per gallon for biodiesel made from recycled oil, and between \$1.94 and \$2.26 for biodiesel made from virgin soy.⁶² Therefore, even current diesel prices are not yet high enough to make biodiesel competitive. However, wholesale biodiesel prices have been dropping due to process improvements and increases in production scale.

However, there is one key cost advantage of biodiesel relative to other alternative fuels. It can be used in existing diesel vehicles with little or no modification. Therefore, covered EPA fleets—and others interested in reducing their petroleum consumption and improving their environmental performance—may use biodiesel without the capital investments necessary for other alternative fuels.

⁵⁶Energy Information Administration, *Natural Gas Monthly*. October 2000.

⁵⁷Biodiesel is mixture of various compounds called mono alkyl esters.

⁵⁸National Biodiesel Board, *General Interest*. [<http://www.biodiesel.org>.] Updated November 10, 2000.

⁵⁹Personal conversation with Roy Truesdale, Director of Operations, National Biodiesel Board. September 25, 2000.

⁶⁰EIA, *Alternatives to Traditional Transportation Fuels*. Table 10.

⁶¹*Platt's Oligram Price Report*, September 21, 2000.

⁶²Roy Truesdale, personal conversation.

Infrastructure. Because biodiesel is chemically very similar to conventional diesel, it could be placed in the existing diesel distribution system with only a few modifications. Most importantly, since biodiesel is a more effective solvent than conventional diesel, it can cause deterioration of rubber and polyurethane materials (e.g. seals). Currently, most biodiesel supply involves purchase contracts by fleet owners, and delivery of biodiesel to fleet-owned dispensing sites. However, 12 biodiesel refueling stations have opened in 10 states in the past two years.⁶³

Performance. Biodiesel is generally mixed with conventional diesel at the 20% level. The resulting fuel, B20, can be used in existing diesel engines with few or no engine modifications. Higher concentrations can be used, however, especially with newer equipment. The use of biodiesel (B20 or higher concentrations) leads to substantial reductions in emissions of unburned hydrocarbons, carbon monoxide, and particulate matter.⁶⁴ Therefore, there are fewer public health concerns with biodiesel than with conventional diesel.

Other than the improvements in emissions, there seems to be little, if any, difference in performance between biodiesel and conventional diesel. Payload and range remain the same, and maintenance costs may actually be decreased due to the lower sulfur content of the fuel. Some minor modifications may be necessary with concentrations above 20%, due to fact that biodiesel is a very effective solvent and can corrode engine seals.⁶⁵

Safety. There seem to be few additional safety concerns for biodiesel. Its safety properties are consistent with conventional diesel. However, it does have one advantage over conventional diesel. Because biodiesel has a higher flash point⁶⁶ than conventional diesel, it is more difficult to ignite.⁶⁷

Other Issues. Biodiesel currently faces two key issues. The first has to do with the tax structure for biodiesel. Because biodiesel is a renewable fuel, there is interest in creating a tax incentive similar to the ethanol tax incentive. This incentive, supporters argue, would allow biodiesel to compete and play a larger role in our fuel supply. However, because of the cost disparity between biodiesel and conventional diesel, any incentive would have to be very large to be effective.

The second issue involves a 1998 amendment to EPAct. This amendment⁶⁸ grants credits to owners of covered fleets who purchase biodiesel. These credits count toward the purchase requirements for alternative fuel vehicles. Every 450

⁶³AFDC, *Refueling Sites*.

⁶⁴AFDC, *Biodiesel General Information*. [http://www.afdc.doe.gov/altfuel/bio_general.html.] Updated August 31, 1999.

⁶⁵Roy Truesdale, personal conversation.

⁶⁶The flash point is the minimum temperature at which chemical can ignite under normal conditions.

⁶⁷National Biodiesel Board, *General Interest*.

⁶⁸P.L. 105-388, section 312.

gallons of biodiesel purchased earns one credit. This allows fleet owners to meet their EPA requirements without purchasing new vehicles and without modifying their existing fueling infrastructure. Environmentalists have charged that because the fuel is then blended at the 20% level, there is little impact on oil consumption or vehicle emissions.⁶⁹

Ethanol⁷⁰

Ethanol, or ethyl alcohol, is an alcohol made by fermenting and distilling simple sugars.⁷¹ Ethyl alcohol is in alcoholic beverages, and it is denatured (made unfit for human consumption) when used for fuel or industrial purposes. Although the broadest current use of fuel ethanol in the United States is as an additive in gasoline, in purer forms it can also be used as an alternative to gasoline. It is produced and consumed mostly in the Midwest, where corn—the main feedstock for ethanol production—is produced. When used as an alternative fuel, ethanol is usually blended with gasoline at a ratio of 85% ethanol to make E85. As with other alternative fuels, there are many benefits but also drawbacks associated with its use.

Consumption. Ethanol is the most commonly used alternative fuel, although most of this is blended at the 10% level with 90% gasoline to make E10, or “gasohol.” Including its use in gasohol, 2000 ethanol consumption was approximately 1.6 billion gallons, or 1.0 billion GEG. This corresponds to approximately 1% of annual gasoline consumption. However, E10 is not recognized by EPA as an alternative fuel because its widespread use does not significantly diminish gasoline consumption. Consumption of E85—which is recognized by EPA—is relatively low. Only about 3.3 million GEG of E85 were consumed in 2000, although consumption has steadily increased since 1992.⁷²

As of 2000, there were approximately 35,000 E85 vehicles being fueled primarily by ethanol in use in the United States.⁷³ This number has been growing, but is still negligible against the total number of conventional vehicles on the road. However, many E85 vehicles can be fueled with E85, gasoline, or any mixture of the two. There are many more of these flexible fuel vehicles (FFV) than dedicated ethanol vehicles. Models of some popular production vehicles, including the Ford Ranger and Ford Taurus now have E85/gasoline flexible fuel capability standard. Other vehicles with the option of FFV capability include the Dodge Caravan, Chevrolet S-10 pickup, and Mazda B3000 pickup.⁷⁴ The Energy Information Administration estimates that approximately 725,000 ethanol FFVs were on the road in 1999. In 1998, the federal government operated approximately 4,300 ethanol FFVs. It is expected that the vast

⁶⁹“Committee Backs Biodiesel,” *The Oil Daily*. August 6, 1998.

⁷⁰For more information on ethanol fuel, see CRS Report RL30369, *Fuel Ethanol: Background and Public Policy Issues*.

⁷¹Its chemical formula is C₂H₅OH.

⁷²EIA, *Alternatives to Traditional Transportation Fuels*. Table 10.

⁷³EIA, *Alternatives to Traditional Transportation Fuels*. Table 1.

⁷⁴National Alternative Fuels Hotline, *Model Year 2000*.

majority of these vehicles will be fueled with gasoline. However, it is possible that the greater availability of FFVs will spur the market for ethanol fuel.

Cost. One of the key drawbacks to the use of ethanol is its cost. Per gallon, E85 prices ranged from approximately \$0.90⁷⁵ to \$1.80⁷⁶ between January 2000 and October 2001. In terms of GEG, ethanol costs ranged between \$1.30 and \$2.70.⁷⁷ When blended with gasoline, ethanol benefits from an exemption to the motor fuels excise tax.⁷⁸ This benefit makes ethanol competitive with gasoline as a blending agent. In fact, when used to make E10, the exemption is a nominal 53 cents per gallon of pure ethanol. However, for neat fuels, the exemption is much less—only a nominal 6.4 cents per gallon of pure ethanol for E85.

While fuel costs are higher for E85, there is little, if any, incremental vehicle cost.⁷⁹ Further, ownership and maintenance costs tend to be equal for ethanol and gasoline vehicles.

Infrastructure. Most of the current infrastructure for the delivery of ethanol is in the form of tanker trucks used to deliver ethanol to terminals for blending with gasoline. However, there were 147 E85 refueling sites nationally as of February 21, 2002, mostly in the Midwest, where ethanol is produced.⁸⁰ Since there is experience in storing and delivering ethanol, and since the fueling systems are similar to gasoline, the refueling infrastructure could expand to meet increased demand if the delivery costs were reduced.

Performance. Because of its lower energy content, the key performance drawback of ethanol is lower fuel economy. Fuel economy is reduced by approximately 29%, resulting in reduced range. However, this reduction in range can be mitigated somewhat by increasing fuel tank size (with the associated drawbacks of a larger tank). Another problem with ethanol is that in cold weather, an ethanol-powered vehicle may be difficult to start. For this reason, most ethanol that is used in purer forms is E85. The 15% gasoline allows for easier ignition under cold-start conditions. There are few other technical concerns over the performance of ethanol because of the relatively few modifications necessary to operate a vehicle on ethanol.

There are key environmental advantages to ethanol, as well as some drawbacks. Ethanol-powered vehicles tend to emit 30 to 50 percent less ozone-forming compounds than similar gasoline-powered vehicles, including significant reductions

⁷⁵GAO, *Limited Progress*. Appendix 1.

⁷⁶Clean Cities Program, *Alternative Fuel Price Report*.

⁷⁷Based on 1.41 gallons of ethanol per GEG.

⁷⁸26 U.S.C. 40.

⁷⁹Because ethanol is more corrosive than gasoline, some components (e.g. seals) must be replaced.

⁸⁰AFDC, *Refueling Sites*.

in carbon monoxide emissions.⁸¹ In addition, ethanol tends to have a much lower content of toxic compounds such as benzene and toluene, leading to lower emissions of most toxic compounds. However, ethanol-powered vehicles tend to emit more formaldehyde and acetaldehyde,⁸² although these emissions can be largely controlled through the use of catalytic converters.⁸³

Another key environmental advantage with ethanol is its relatively low life-cycle greenhouse gas emissions.⁸⁴ Ethanol-powered vehicles tend to emit lower levels of greenhouse gases than gasoline vehicles. Also, the growth process of the ethanol feedstock results in uptake of carbon dioxide, further reducing net greenhouse gas emissions. Conversely, when the raw materials and practices used to produce the feedstock and the fuel are taken into account, emissions for both fuels are increased. According to a study by Argonne National Laboratory, the use of E85 results in a 14% to 19% reduction in life-cycle greenhouse gas emissions, and with advances in technology, this reduction could be as high as 70% to 90% by 2010.⁸⁵ However, other studies cite lower efficiency in the ethanol production process, leading to smaller reductions in greenhouse gas emissions.⁸⁶

Safety. Fuel ethanol tends to be safer than gasoline. At normal temperatures, E85 is less flammable than gasoline, and tends to dissipate more quickly. While an ethanol flame is less visible than a gasoline flame, it is still easily visible in daylight.⁸⁷

Other Issues. The most significant issue surrounding ethanol is the exemption from the motor fuels excise tax. Because a few producers control a majority of ethanol production capacity in the United States, the exemption has been called “corporate welfare” by its opponents. Proponents of the exemption argue that it helps support farmers (through increased demand for their product), and helps compensate for added economic value from benefits to the environment, and to energy security because ethanol is produced from domestic crops.⁸⁸ Outside of the tax debate, concerns have been raised over using crops for fuel because the effects on soil, water, and the food supply have not been fully assessed.

⁸¹California Energy Commission, *Ethanol Powered Vehicles*.

[<http://www.energy.ca.gov/afvs/ethanol/ethanolhistory.html>.] Updated November 3, 1998.

⁸²Formaldehyde and acetaldehyde are toxic compounds that, in air, can irritate tissues and mucous membranes in humans, and are characterized by EPA as possible carcinogens.

⁸³California Energy Commission, *Ethanol Powered*.

⁸⁴Although most greenhouse gases are not regulated pollutants, environmentalists are concerned that the accumulation of these gases (such as carbon dioxide) in the atmosphere will lead to global warming.

⁸⁵M. Wang, C. Saricks, and D. Santini, *Effects of Fuel Ethanol on Fuel-Cycle Energy and Greenhouse Gas Emissions*, January 1999. Argonne National Laboratory.

⁸⁶Alan Kovski, “Study Defends Fuel Efficiency of Ethanol, While Another Notes Emissions of Pollutants,” *The Oil Daily*, March 9, 1998. p. 6.

⁸⁷Center for Transportation Research, Argonne National Laboratory, *Guidebook for Handling, Dispensing, & Storing Fuel Ethanol*.

⁸⁸For more information, see CRS Report 98-435E, *Alcohol Fuels Tax Incentives*.

Methanol

Methanol, the simplest alcohol, is also called “wood alcohol.”⁸⁹ It is usually derived from natural gas, but can also be derived from coal or biomass. As a fuel, methanol is most often used as a blend with gasoline called M85 (85% methanol, 15% gasoline), although the fuel can also be used in an almost pure (neat) form called M100. In addition to general transportation, Indianapolis-type race cars use methanol exclusively. As a motor fuel it has many benefits, but also many drawbacks.

Consumption. Because of its drawbacks, methanol consumption is relatively low. In 2000, 1.4 million GEG of M85 were consumed, along with 0.45 million GEG of M100.⁹⁰ This corresponds to roughly 1/1000th of 1% of the approximately 125 billion gallons of gasoline demand. Methanol consumption peaked in 1996 and has decreased since.

There are few methanol-powered vehicles operating in the United States. Consistent with the decline in methanol consumption, after a peak in 1996, the number of M85 and M100 vehicles has declined. There were approximately 18,000 M85 vehicles (both dedicated and dual-fuel) and approximately 200 M100 vehicles in 2000. The federal government operated 206 light-duty dual-fuel M85 vehicles in the same year, and zero M100 vehicles.⁹¹ The major automobile manufacturers did not sell methanol-powered production cars in model year 2002.⁹²

Cost. A notable concern with methanol is its cost. Per GEG, methanol tends to be more expensive than gasoline. As of January 1, 2000, the price for methanol was between \$0.95 and \$1.20 per gallon.⁹³ However, due to the lower energy content of methanol, the fuel costs roughly \$1.73 to \$2.10 per GEG.⁹⁴ In the future, the California Energy Commission predicts that as production facilities are introduced, M85 price could decline to \$1.27 per GEG by the year 2010, as compared to gasoline at \$1.48 per gallon.⁹⁵

In addition to the fuel cost, incremental vehicle cost is higher with the use of methanol. The incremental cost for the purchase of a methanol-fueled vehicle (or the conversion of an existing gasoline-fueled vehicle) can range from \$500 to \$2,000, though some of this incremental cost currently may be defrayed by purchase incentives. The most notable part of the incremental cost is replacing parts (such as certain seals) that may be corroded by alcohol.

⁸⁹Its chemical formula is CH₃OH.

⁹⁰EIA, *Alternatives to Traditional Transportation Fuels*. Table 10.

⁹¹EIA, *Alternatives to Traditional Transportation Fuels*. Table 20.

⁹²National Alternative Fuels Hotline, *Model Year 2002*.

⁹³GAO, *Limited Progress*. Appendix 1.

⁹⁴Based on 1.77 gallons of M85 per GEG.

⁹⁵California Energy Commission, *Methanol Powered Flexible Fuel Vehicles*. [http://www.energy.ca.gov/afvs/m85/methanolhistory.html.] Updated December 14, 1998.

Infrastructure. Another barrier to the wide use of methanol as a motor fuel is the lack of fueling infrastructure. As of July 30, 2001, there were only two M85 refueling sites in California.⁹⁶ This lack of infrastructure makes it difficult for the methanol vehicle market to expand. In fact, due to lack of demand, methanol infrastructure has declined in the past few years. However, existing gasoline tanks and pumping equipment could be readily converted to store and deliver methanol, and vehicle users would experience little difference between a methanol pump and a gasoline pump.

Because methanol can be produced from natural gas and petroleum, a raw material shortage would be unlikely if methanol consumption increased. However, in terms of delivery to stations, most methanol is transported by tanker truck from the methanol plant.⁹⁷ This delivery method tends to be less flexible and more costly compared to the existing gasoline infrastructure, which relies primarily on pipeline delivery. Methanol cannot travel through pipelines due to its physical properties.

Performance. One of the key benefits of methanol vehicles is improved environmental performance over gasoline vehicles. M85 vehicles tend to emit 30% to 50% less ozone-forming compounds. And while formaldehyde emissions tend to be higher with methanol than gasoline, all M85 vehicles will be able to meet new emissions standards for formaldehyde.⁹⁸

A key performance drawback with methanol vehicles is a reduction in vehicle range. Since it requires 1.77 gallons of methanol to equal the energy in one gallon of gasoline, range per gallon is decreased by approximately 40%. By increasing the size of the fuel tank, the loss of range can be significantly improved or even eliminated. However, a larger fuel tank would decrease fuel economy and cargo space.

Safety. On the whole, methanol fuel is safer than gasoline. Since methanol vapor is only slightly heavier than air, vapors disperse quickly compared to gasoline. Furthermore, methanol vapors must be more concentrated than gasoline to ignite, and methanol fires release less heat. Since methanol burns with a light blue flame, one key drawback is that in bright daylight it may be difficult to see a methanol fire, although it may be possible to add colorants to the fuel.⁹⁹

Fuel Cells. Methanol has been touted as the most likely step from gasoline to hydrogen in fuel cell vehicles because the fueling infrastructure is similar to gasoline,

⁹⁶AFDC, *Refueling Sites*.

⁹⁷In contrast, gasoline is usually shipped in pipelines from the refinery to a distribution terminal, where tanker trucks transport the fuel to the fueling stations. This distribution network is considerably more cost effective than relying solely on tanker trucks.

⁹⁸California Energy Commission, *Questions and Answers About M85 and Flexible Fuel Vehicles* [<http://www.energy.ca.gov/afvs/m85/methanolq-a.html>], updated December 14, 1998.

⁹⁹Environmental Protection Agency, *Fact Sheet OMS-8: Methanol Fuels and Fire Safety*. August 1994.

while the fuel is much cleaner.¹⁰⁰ Fuel cells are a type of power source that generates electricity from hydrogen (or a hydrogen-bearing compound) without combustion. The chemical process is highly efficient and drastically reduces vehicle emissions.¹⁰¹ For more information on fuel cells, see CRS Report 30484, *Advanced Vehicle Technologies: Energy, Environment, and Development Issues*.

Another potential advantage of methanol is that it can be derived from biomass waste products. Research is ongoing, and there have been a few, small-scale demonstration projects at landfills.

Electricity¹⁰²

An electric vehicle (EV) is powered by an electric motor, as opposed to an internal combustion engine. Energy is supplied to the motor by a set of rechargeable batteries. When the vehicle is not being used, these batteries are recharged.

Because no fuel is burned, there are no emissions from the vehicle, making it a zero emissions vehicle (ZEV). However, there are emissions from electricity production associated with electric vehicles. When the entire fuel cycle is considered, pollutant emissions from EVs are still low relative to gasoline vehicles. Like other AFVs, however, there are key cost and performance drawbacks associated with these vehicles.

Consumption. Approximately 1.8 million GEG of electric fuel were consumed in the United States in 2000 by approximately 8,700 electric vehicles.^{103,104} Most of these vehicles are located in California, and several models are available exclusively in that state. One of the most popular EVs is the General Motors EV1. Others include the Dodge Caravan, Ford Ranger, Nissan Altra (fleet only), Solectria Force, and Toyota RAV4.¹⁰⁵ The federal government operated approximately 170 electric vehicles in 1999.¹⁰⁶

¹⁰⁰Vanessa Houlder, "Big push to reduce fuel emission problems," *Financial Times*, September 21, 2000. p. 5.

¹⁰¹If pure hydrogen is used, the only emissions would be water vapor.

¹⁰²For more information on electric vehicles, hybrid electric vehicles, and fuel cell vehicles, see CRS Report RL30484, *Advanced Vehicle Technologies: Energy, Environment, and Development Issues*.

¹⁰³EIA, *Alternatives to Traditional Transportation Fuels*. Tables 1 and 10.

¹⁰⁴These vehicles are light- and heavy-duty highway vehicles. Golf carts are another popular application for electric vehicles, and there are many of these in operation in the United States, especially in smaller communities.

¹⁰⁵National Alternative Fuels Hotline, *Model Year 2000*.

¹⁰⁶EIA, *Alternatives to Traditional Transportation Fuels*. Table 20.

Cost. Electric fuel is considerably less expensive than using gasoline, about 2.5 to 3.3 cents per mile, as opposed to 4 to 6 cents per mile for a gasoline vehicle.¹⁰⁷ Despite the fuel cost advantages, a major drawback with EVs is the incremental vehicle purchase cost, which can be as much as \$20,000. Most of this cost is related to the batteries, which are very expensive to produce.¹⁰⁸

Infrastructure. There are very few electric recharging sites in the United States. Currently, there are 685 recharging sites, mostly in California.¹⁰⁹ With the extensive nature of the electricity infrastructure in the United States, there are few technical barriers to expanding EV recharging sites. However, with existing technology, cost is a major factor because only a few vehicles can access a single charger in one day, as opposed to a gasoline pump which can serve a new vehicle every few minutes. While faster, “quick-charge” stations are being studied, none are currently in use.¹¹⁰

Performance. The environmental performance of EVs is very good. When the entire fuel cycle is considered, electric vehicles produce low overall levels of toxic and ozone-forming pollutants.¹¹¹ Depending on the fuel mix for local electric power generation, overall emissions can be decreased by 90% or more as compared to gasoline vehicles.¹¹²

A major performance drawback of EVs is their relatively short range. On a full charge, an electric vehicle can travel between 50 and 130 miles, as opposed to a range of 300 to 400 miles with a conventional vehicle.¹¹³ Another drawback is that fueling an electric vehicle takes between 3 and 8 hours, as opposed to a few minutes for a conventional vehicle.¹¹⁴

Safety. Few additional safety issues are associated with electric vehicles. Because no chemicals are transferred during fueling, there is no risk of spillage or inhalation, and with existing recharging systems, electric shocks are unlikely. In the

¹⁰⁷Because of the vast differences between electric and conventional vehicles, cents per mile are used to discuss fuel cost, as opposed to dollars per GEG. In this case, it was assumed that electricity was 10 cents per kilowatt-hour (kWh), an electric vehicle achieved between 3 and 4 miles per kWh, gasoline cost \$1.20 per gallon, and a gasoline vehicle achieved between 20 and 30 miles per gallon. Currently, electricity prices are somewhat lower than 10 cents per kWh, while gasoline prices are above \$1.20 per gallon.

¹⁰⁸This is based on suggested retail prices for the EV1 and the Chevrolet Cavalier, a similar gasoline vehicle.

¹⁰⁹AFDC, *Refueling Sites*.

¹¹⁰California Energy Commission, *Questions & Answers About Electric Vehicles*. [http://www.energy.ca.gov/afvs/ev/q_a.html.] Updated July 30, 1998.

¹¹¹The fuel mix plays a key role in the overall fuel-cycle emissions for electric vehicles because power plant emissions can vary greatly depending on the fuel used for generation.

¹¹²California Energy Commission, *Questions & Answers About Electric Vehicles*.

¹¹³Alternative Fuels Data Center, *Model Year 2000*.

¹¹⁴California Energy Commission, *Questions & Answers About Electric Vehicles*.

event of an accident, there is no combustible fuel so there is no danger of fire or explosion. However, because of the acid contained in some types of batteries, there could be concern over acid leaks if batteries were to rupture in a collision.

Fuel Cell and Hybrid Vehicles. While battery-powered electric vehicles tend to be very expensive, and have many other drawbacks, there is growing interest in fuel cell and hybrid electric vehicles. Research into batteries, electric drivetrains, and lightweight materials will play a key role in the development of EVs, as well as both hybrid and fuel cell vehicle technology. For a more detailed discussion of fuel cell and hybrid technologies, see CRS Report 30484, *Advanced Vehicle Technologies: Energy, Environment, and Development Issues*.

Fuel Cell Vehicles. Unlike a conventional vehicle, a fuel cell vehicle uses chemical reaction (as opposed to combustion) to produce electricity to power an electric motor. Unlike a battery-powered EV, fuel cell vehicles have a fuel tank, eliminating the long recharging time. These systems can be very efficient, although the technology is far from commercialization.

Hybrid Electric Vehicles. A hybrid electric vehicle combines an electric motor with a gasoline or diesel engine. This combination leads to very high fuel efficiency and low emissions while avoiding some of the problems associated with pure electric vehicles. Most hybrids operate solely on conventional fuel, with the engine providing power to the wheels and to an electric generator simultaneously. Therefore, hybrids can be fueled as quickly and conveniently as conventional vehicles, while achieving even longer ranges.

Two hybrid production vehicles are currently available, the Honda Insight and the Toyota Prius, and the three major American car companies plan to introduce hybrid vehicles in the next few years.¹¹⁵ Although hybrid electric vehicles are not considered AFVs (because they utilize conventional fuel), their environmental performance has led to legislation to promote their commercialization.¹¹⁶

Hydrogen

Due to its presence in water, hydrogen is the most common element on the planet, although it does not appear in pure form in any significant quantity.¹¹⁷ The hydrogen in water can be separated from oxygen through a process called hydrolysis.¹¹⁸ Other key hydrogen sources are fossil fuels and other hydrocarbons. Hydrogen fuel is of interest because it can be used in a zero-emission fuel cell. Because fuel can be continuously supplied, fuel cell-powered electric vehicles do not face some of the range and fueling limitations as battery-powered electric vehicles.

¹¹⁵Gregg Easterbrook, "Hybrid Vigor," *The Atlantic Monthly*. November 2000. p. 5.

¹¹⁶Several bills in the 106th Congress would have provided tax credits for the purchase of hybrids, although none of these bills passed their respective committees. See section below on Congressional Action.

¹¹⁷The chemical formula for hydrogen gas is H₂.

¹¹⁸The chemical formula for water is H₂O.

Currently, no production vehicles are powered by pure hydrogen, although all of the major domestic and foreign automobile manufacturers are researching hydrogen fuel cells, and several plan to introduce production vehicles by 2004. However, it is likely that the first commercially available fuel cell vehicles will be operated on a liquid fuel such as gasoline or methanol, because these fuels are much easier to deliver and are more readily available at present (see above section on methanol).

Key concerns about hydrogen include its extreme flammability and the potential cost of the fuel. Furthermore, while hydrogen fuel could be generated using electricity from solar cells to electrolyze water, thus making the fuel cycle emission-free, the most likely source for hydrogen in the near term is natural gas. Although not emission-free, the use of natural gas as a feedstock for hydrogen would still lead to much lower overall emissions compared to petroleum.

Coal-Derived Liquid Fuels

Although EPA recognizes coal-derived fuels as alternative fuels, these fuels have seen little commercial success. This is largely due to their high production costs and poor environmental performance.¹¹⁹ However, research to reduce costs and improve environmental performance is ongoing, mostly through support of the Department of Energy.¹²⁰ A potential advantage of coal-derived fuels is that the feedstock is an abundant domestic resource.

Conclusions

Alternative fuels have reached varying levels of commercial success, although currently none are able to compete with conventional fuels. LPG and natural gas fuels and vehicles have been successfully commercialized, and are widely used in both private and public fleets. Ethanol is a common additive in gasoline, but is used sparsely as an alternative fuel. Other fuels, such as methanol and electricity have had less commercial success, but may play a key role in the future of transportation.

The degree to which various alternative fuels have been used has been a result of economic factors, as well as government tax policies and regulatory mandates. Further, the performance characteristics of the fuels have also played a major role.

In general, there are potential energy security benefits to alternative fuels, as most alternative fuels can be derived from domestic sources. Further possible benefits include lower emissions of toxic pollutants, ozone-forming pollutants, and greenhouse gases. However, performance and cost are key barriers to consumer acceptance. Without considerable advances in alternative fuel and vehicle technology, or significant petroleum price increases, it is unlikely that any fuel or fuels will replace petroleum-based fuels in the near future.

¹¹⁹In fact, while the fuels themselves may result in lower vehicle emissions, the processes for converting coal to liquid fuel tends to lead to high pollutant emissions.

¹²⁰Nicholas P. Chowey, "Coal Conversion Keeps Itself Relevant," *Chemical Engineering*, September 1998. p. 35.

Congressional Action

Recent policy debate has focused on American energy security. Because of this, discussion has turned to alternative fuels. Proponents argue that expanding alternative fuel tax credits and other incentives would promote improved air quality and energy security. Opponents argue that alternative fuel programs could lead to “corporate welfare” and that there are less expensive ways to reduce pollution and cut fuel consumption, such as efficiency improvements and conservation. For example, an increase in fuel economy of one mile per gallon across all passenger vehicles in the United States would cut petroleum consumption more than all alternative fuels and replacement fuels¹²¹ combined.¹²²

The Bush Administration’s National Energy Policy supports an increased role for alternative fuels, as do several bills in the 107th Congress.¹²³ Provisions in various bills would provide tax credits for the purchase of alternative fuel and hybrid vehicles, and would expand the existing electric vehicle tax credit. Further, some bills would expand the existing tax credits and deductions for the installation of alternative fuel refueling infrastructure. Some bills would provide per gallon tax credits for the retail sale of alternative fuels, and some bills would allow states to exempt alternative fuel and/or hybrid vehicles from high occupancy vehicle (HOV) restrictions. Finally, some bills would provide grants to schools, municipalities, and/or transit systems for the purchase of alternative fuel vehicles, refueling infrastructure and/or fuel. These various bills are presented in Appendix 1.

Most notably, the Congress is considering comprehensive energy legislation. The House version (H.R. 4) which passed the House on August 2, 2001. The Senate version (S. 517)¹²⁴ was brought up for floor debate in early March, 2002. Both bills contain provisions for research and development funding, tax credits, and other incentives for alternative fuels.

¹²¹Replacement fuels include blending agents such as ethanol in E10, that are used in gasoline but do not qualify as alternative fuels.

¹²² Source: CRS analysis of data from the Department of Energy.

¹²³National Energy Policy Development Group, *National Energy Policy*. May 2001.

¹²⁴While S.517 is the vehicle for Senate floor debate, much of the language from S.1766 will be inserted into S.517 by S.Amdt. 2917.

Appendix 1. Alternative Fuel Vehicle Bills in the 107th Congress

Bill No.	Sponsor	Last Major Action	Key Provisions
H.R. 4	Tauzin	Passed House August 2, 2001; referred to Senate.	<ul style="list-style-type: none"> • Comprehensive energy policy bill including provisions for • Tax credits for alternative fuel, fuel cell, electric, and hybrid vehicles • Tax credits for alternative fuel refueling infrastructure • Grants for alternative fuel school buses • Exemptions of alternative fuel and hybrid vehicles from HOV restrictions
H.R. 377	Serrano	Referred to House Ways & Means	<ul style="list-style-type: none"> • Provides incentives for the use of clean-fuel vehicles by enterprise zone businesses within empowerment zones and enterprise communities.
H.R. 1864	Camp	Referred to House Ways & Means	<ul style="list-style-type: none"> • Provides tax credits for the purchase of alternative fuel, fuel cell, and hybrid vehicles; expands electric vehicle (EV) tax credit • Expands tax credits for the installation of alternative fuel infrastructure • Provides a tax credit of 50 cents per gasoline equivalent gallon (GEG) for the retail sale of alternative fuels
H.R. 2000	Nussle	Referred to House Ways & Means, Government Reform	<ul style="list-style-type: none"> • Provides a tax exemption of 3 cents per gallon for blends of 2% or more biodiesel • Requires the use of biodiesel by the Federal Government unless it is cost prohibitive
H.R. 2088	Shimkus	Referred to House Transportation and Infrastructure	<ul style="list-style-type: none"> • Allows funds from the Congestion Mitigation and Air Quality Improvement Program (CMAQ) to be used for alternative fuel purchases
H.R. 2263	Gilman	Referred to House Government Reform	<ul style="list-style-type: none"> • Requires 10% of Federal Government vehicle purchases to be alternative fuel or hybrid vehicles
H.R. 2326	Boehlert	Referred to House Science	<ul style="list-style-type: none"> • Authorizes \$200 million in grants for the installation of AFV refueling infrastructure
H.R. 2369	Issa	Referred to House Transportation and Infrastructure	<ul style="list-style-type: none"> • Allows states to exempt hybrid vehicles from HOV restrictions
H.R. 2392	Inslee	Referred to House Ways & Means	<ul style="list-style-type: none"> • Similar to H.R. 1864, except that it provides a 25 cent per gallon tax credit for the retail sale of alternative fuels (as opposed to 50 cents)

Bill No.	Sponsor	Last Major Action	Key Provisions
H.R. 2518	Boehlert	Referred to House Science	<ul style="list-style-type: none"> Creates a pilot program to provide grants for the purchase of alternative fuel school buses Authorizes \$40 million in FY2002, increasing to \$80 million in FY2006
S. 388	Murkowski	Referred to Senate Energy and Natural Resources; hearings held	<ul style="list-style-type: none"> Allows states to exempt hybrid vehicles from HOV restrictions Allows state and local fleets to coordinate alternative fuel procurement arrangements with federal fueling sites Requires that 50% of fuel used by federal agencies be alternative fuel by 2005, if cost-effective Authorizes \$100 million per year between FY2002 and FY2006 for grants to local governments for alternative fuel infrastructure
S. 389	Murkowski	Referred to Senate Finance	<ul style="list-style-type: none"> Same provisions as S. 388; contains tax provisions, as well Provides tax credits for the purchase of alternative fuel, fuel cell, and hybrid vehicle; expands the EV tax credit Expands tax credits for the installation of alternative fuel infrastructure Provides a tax credit of 25 cents per GEG for the retail sale of alternative fuels
S. 517	Bingaman	Considered by Senate, March 5, 2002	<ul style="list-style-type: none"> Vehicle for floor debate of S. 1766 S. Amdt. 2917 contains provisions for: <ul style="list-style-type: none"> Tax credits for alternative fuel, fuel cell, electric, and hybrid vehicles Tax credits for alternative fuel refueling infrastructure Grants for alternative fuel school buses Exemptions of alternative fuel and hybrid vehicles from HOV restrictions Provisions for biodiesel credits under EPAct Requires the use of renewable fuels in motor fuel Requires increased use of alternative fuel by the federal government
S. 597	Bingaman	Referred to Senate Energy and Natural Resources; markup held	<ul style="list-style-type: none"> Requires increased use of alternative fuels by federal vehicle Allows states to exempt AFVs from HOV restrictions
S. 760	Hatch	Referred to Senate Finance	<ul style="list-style-type: none"> Similar to H.R. 1864
S. 1058	Hutchinson	Referred to Senate Finance	<ul style="list-style-type: none"> Provides tax credits for the blending of biodiesel Provides a partial excise tax exemption for biodiesel mixtures

Bill No.	Sponsor	Last Major Action	Key Provisions
S. 1071	Bond	Referred to Senate Environment and Public Works	<ul style="list-style-type: none">• Allows funds from the Congestion Mitigation and Air Quality Improvement Program (CMAQ) to be used for alternative fuel purchases
S. 1766	Daschle	Placed on Senate Legislative Calendar, December 6, 2001	<ul style="list-style-type: none">• Grants for alternative fuel school buses• Exemptions of alternative fuel and hybrid vehicles from HOV restrictions• Provisions for biodiesel credits under EPAct• Requires the use of renewable fuels in motor fuel• Requires increased use of alternative fuel by the federal government