Final Report of the Interagency Commission on Alternative Motor Fuels

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This report is based on studies performed by:

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Contents

Executive Summary

This Final Report of the Interagency Commission on Alternative Motor Fuels describes progress to date in implementing the provisions of the Alternative Motor Fuels Act of 1988 (AMFA; Public Law 100–494). The purpose of AMFA, which was signed into law on October 14, 1988, is to help achieve energy security, improve air quality, and encourage the production of methanol-, ethanol-, and natural-gas-powered motor vehicles by encouraging the development and widespread consumer use of methanol, ethanol, and natural gas as transportation fuels. AMFA seeks to help alternative transportation fuels reach the threshold level of commercial application and consumer acceptability at which they can successfully compete with petroleum-based transportation fuels.

In only 3 years, AMFA has made significant progress. From an initial point of little industry activity in alternative-fuel-vehicle (AFV) research, development, and testing, a significant market for AFV's has begun to develop within government and business fleets.

If comprehensive National Energy Strategy (NES) energy legislation (described in Section 1.5 of this report) is passed, sales of AFV's are expected to increase dramatically. Sales of AFV's could exceed 1 million by the end of the decade. One million AFV's per year are expected to be sold to business fleets alone by the year 2010, and this level may be reached much sooner. The resulting oil displacement from the use of these vehicles is estimated to be on the order of 200,000 barrels per day by 2010.

Initiatives that could emerge from this energy legislation include:

- The purchase of new AFV's for Federal and non-Federal fleets
- Modification of the Clean Air Act Amendments (CAAA) clean-fuel-fleet concept to ensure the use of AFV's
- Increased Federal support to States and localities to advance the use of alternative fuels
- Increased research and development (R&D) on advanced biofuels technology
- Increased R&D on AFV's and electric vehicles
- Tax incentives to encourage the purchase of AFV's and installation of publicly available AFV refueling

The Administration has already begun implementing NES alternative-fuel measures that do not require new legislation. Achievements to date include the following:

- Executive Order 12759, *Federal Energy Management*, issued by the President in 1991, which requires the Federal Government to acquire the maximum number of AFV's as rapidly as practicable
- Purchases by the Federal Government of 3,267 AFV's through August 1992
- Plans for the additional acquisition of 5,000 AFV's in fiscal year 1993 and 20,000 by 1995, with a 1998 target of having half of all new Federal vehicles purchased be AFV's
- More than 200,000 miles of vehicle testing on alternative fuels through September 1991, including assessments of vehicle fuel economy and emissions characteristics
- The enhancement of the Nation's AFV research, development, and demonstration activities through initiation of programs such as the Truck Commercial Application Program and the Alternative-Fuels Bus Testing Program
- The President's October 1991 announcement of the signing of a cooperative agreement with

the U.S. Advanced Battery Consortium to undertake a 4-year, $260 million R&D program to develop a new generation of batteries for electric vehicles

Finally, other developments since the passage of AMFA have also served to encourage the production and sale of AFV's. These developments include the passage of the Clean Air Act Amendments of 1990, California's Low Emission Vehicles and Clean Fuels Program, and other State-level AFV programs. These programs are estimated to displace more than 100,000 barrels per day of oil in 2010, in addition to that expected from the NES legislation.

Role of AMFA

AMFA directed the Department of Energy (DOE) and other designated agencies to prepare several studies and reports to Congress, all of which have been completed in either final or draft form. AMFA also established the Interagency Commission on Alternative Motor Fuels to perform the following functions:

- Coordinate Federal agency efforts to develop and implement a national alternative-motor-fuels policy
- Ensure the development of a long-term plan for the commercialization of alcohols, natural gas, and other potential alternative motor fuels
- Ensure communication among representatives of all Federal agencies that are involved in alternative-motor-fuels programs or that have an interest in such programs
- Provide for the exchange of information among persons working with, or interested in working with, the commercialization of alternative motor fuels

AMFA also established the U.S. Alternative Fuels Council, which reported to the Commission. Both the Interagency Commission on Alternative Motor Fuels and the U.S. Alternative Fuels Council will be terminated upon submission of this Final Report.

Chapters 1 through 5 of this report address, respectively, current alternative-fuels policy; the status of the AMFA, Executive Order 12759, State and local government, and alternative-fuel school bus programs; activities of the U.S. Alternative Fuels Council; the possible effects of other environmental and energy legislation and State and local programs on AMFA goals; and R&D needs for alternative fuels. This report also presents a baseline estimate of year-2010 use of alternative fuels in the transportation sector.

Although DOE's two relatively new initiatives to implement Executive Order 12759 and to assist State and local governments in acquiring and operating AFV's are not a direct part of the AMFA program, they are included in this report because they are direct extensions of the AMFA initiative and experience.

Alternative-Fuels Policy

Major policies and legislation to encourage the use of alternative motor fuels include AMFA, the National Energy Strategy, Senate bill 2166 (the National Energy Security Act of 1992), House bill 776 (the Comprehensive National Energy Policy Act), and the Clean Air Act Amendments of 1990. (The Clean Air Act Amendments are discussed in "Effects of Other Legislation and Programs" later in this executive summary.)

Prompted by the Administration's submission of NES, omnibus legislation has been passed by both the House (H.R. 776) and the Senate (S. 2166). Both H.R. 776 and S. 2166 contain significant alternative-fuel provisions. If the House-Senate conference (scheduled for September 1992) goes smoothly, comprehensive energy legislation could be passed before the end of 1992. Table 1-1 in Chapter 1 compares the alternative-fuel provisions of the two bills.

The NES fleet requirements are projected to displace nearly twice as much oil as S. 2166 and more than twice as much oil as H.R. 776 in 2010; however, it is important to note that this comparison accounts only for the direct effects of the fleet provisions of the House and Senate bills, and not other portions of the bills. The Senate bill displaces approximately 14 percent more oil than H.R. 776. The cumulative, undiscounted program costs of the NES fleet requirements are projected to be nearly double the costs of the S. 2166 and H.R. 776 requirements; however, NES appears to displace oil at a lower cost per barrel because of its early comprehensive coverage of many different fleet types, which will more likely induce economies of scale.

Each bill would create a significant market for new AFV's by the year 2010, as follows: NES, 1.6 million AFV's; H.R. 776, 1.2 million; and S. 2166, 1 million. NES would generate the largest number because it covers more types of fleets and because it includes heavy-duty vehicles. In terms of the number of AFV's in operation, projections for the year 2010 are as follows: NES, 5.6 million; S. 2166, 3.3 million; and H.R. 776, 3.7 million.

AMFA Program Status

AMFA Program Plan

The initial *Alternative Motor Fuels Act of 1988 Program Plan* was developed and issued by DOE in January 1989. The program plan outlined the overall management organization, strategy, and approach to implement each element of the AMFA program and provided detailed activity descriptions, work breakdown structures, and an overall schedule to accomplish all work activities. The plan was subsequently updated in May 1989 and was again updated and reissued in August 1990 to reflect accomplishments to date. DOE's Office of Alternative Fuels, under the Deputy Assistant Secretary for Transportation Technologies, is responsible for the overall management of the AMFA program.

The plan meets both the intent and spirit of AMFA by encouraging the commercial production of methanol, ethanol, and natural-gas vehicles and the widespread consumer use of these fuels in the transportation sector. Key features include an effort to make maximum use of other Federal, State, and local government projects as well as private-sector initiatives. Industry participation has been actively solicited to gain a better insight into its needs as well as to leverage industry's ongoing efforts to maximize the benefits of the AMFA program to the greatest extent possible.

DOE Programs

The three major programs established by DOE (all began in FY 1990) are the Alternative-Fuel Federal Light-Duty-Vehicle Program, the Truck Commercial Application Program, and the Alternative-Fuels Bus Testing Program. All three of these programs are well under way, and there are plans to expand them to accommodate more and different types of vehicles and to involve more participants.

The Alternative-Fuel Federal Light-Duty-Vehicle Program aims to ensure that the Federal Government annually acquires the maximum practicable number of alternative-fuel passenger automobiles and other light-duty vehicles (LDV's). In 1992, this program expanded significantly, from the 65 vehicles acquired in 1991 to an anticipated total of 3,267 LDV's. Operating data from these first 65 LDV's have been generated, transmitted, and analyzed by the Alternative Fuels Data Center (AFDC) at the National Renewable Energy Laboratory (NREL, formerly the Solar Energy Research Institute) since 1991; the initial findings have been reported in the report *Federal Alternative Fuel Program Light Duty Vehicle Operations—First Annual Report to Congress for Fiscal Year 1991*, dated March 1992. This process will continue, including the current testing and analysis of many of the 1992 model-year fleet.

The objective of the Truck Commercial Application Program is to encourage the use of alcohol and natural-gas fuels by carrying out one or more projects in which trucks or other commercial heavy-duty vehicles (HDV's) operate in a real-world environment. This program will collect data from heavy-duty trucks operating on alternative fuels to establish an emissions, performance, and durability database.

By the end of 1992, approximately 100 alternative-fuel medium- and heavy-duty trucks will be participating in this program. Participants include the American Trucking Association's Foundation/Trucking Research Institute, Federal Express, the New York City Department of Sanitation, the Illinois Department of Natural Resources, the California Energy Commission, and the U.S. Postal Service.

The objective of the Alternative-Fuels Bus Testing Program is to help State and local government agencies test, in urban settings, buses capable of operating on alcohol or natural-gas fuels. In particular, the program aims to generate information on emissions, durability, safety and health, fuel economy, and other issues that industry and other organizations need to supply and operate such buses in commercial environments.

The Department of Transportation's Federal Transit Administration (FTA), formerly the Urban Mass Transportation Administration, has been assigned a lead role for this project by an interagency agreement between DOE and FTA. By the end of 1992, approximately 1,100 alternative-fuel transit buses are projected to be in the program.

Executive Order 12759 Activities

DOE has undertaken a number of activities to implement the requirements of Section 11 of Executive Order 12759, *Federal Energy Management*, which aims to ensure that the Federal Government annually acquires the maximum number of AFV's as rapidly as practicable. The emphasis is on expanding the market for AFV's to encourage original equipment manufacturers (OEM's) to increase the availability of alternative-fuel models, reducing vehicle acquisition costs, and fostering the growth of alternative-fuel refueling facilities and other associated infrastructure elements.

Target goals for the acquisition of AFV's under Executive Order 12759 include 10,000 AFV's for Federal fleets by FY 1995 and AFV purchases by each agency equal to 50 percent of acquisitions by FY 1998. Working closely with the General Services Administration, DOE has assisted other agencies in preparing individual agency 5-year acquisition plans and consolidated them into a single Federal 5-year plan for consideration by industry.

State and Local Government Program

The State and local government program coordinates Federal AFV acquisition with State and local agency AFV acquisition. Combining the Federal procurement plan with State and local plans will maximize the production and development of AFV's and an AFV infrastructure by manufacturers, conversion firms, and alternative-fuel suppliers. State participation in this program is completely voluntary.

The 10 DOE Regional Support Offices (RSO's) will provide technical assistance to State and local agencies for the development of 5-year State and local plans. The RSO's also will contact potential industry partners at the State and local level to increase the amount of commercial involvement in the program, particularly in the development of a fuel infrastructure.

Alternative Fuel School Bus Program

Under the Alternative Fuel School Bus (AFSB) Program, which DOE's Office of National Programs is managing and promoting in cooperation with State energy offices, DOE will cost-share the purchase of OEM alternative-fuel school buses on a case-by-case basis. This program also will provide education and training to State energy offices and local municipalities, collect information and data on in-use operation of school bus fleets using alternative fuels, and coordinate with other programs to reduce school bus energy consumption.

In early 1992, DOE's Offices of Alternative Fuels and National Programs released requests for proposals for AFSB projects to each of the State energy offices. Approximately 10 awards will be granted by DOE, resulting in 40 to 50 alternative-fuel OEM school buses depending on matching funds and level of cost-sharing.

Alternative Fuels Data Center

The AFDC, which began operations in early 1991 at NREL, became fully operational in October 1991. AFDC will provide unbiased, accurate information on alternative fuels and AFV's to

Government agencies, private industry, research institutions, and other interested organizations. The objectives of AFDC are to:

- Design, implement, and operate a computerized database system for storage, retrieval, and analysis of available data on alternative-transportation-fuel demonstration and evaluation efforts

- Provide access to external users in the scientific, industrial, and government communities

Commercialization Efforts

Many types of AFV's have reached the commercialization stage, and significant AFV markets are beginning to develop. Federal, State, local, and private plans for increased use of alternative fuels in the near future have prompted OEM vehicle manufacturers and vehicle conversion companies to increase their capabilities to produce AFV's. The OEM vehicle manufacturers are taking orders: additionally, several HDV manufacturers also are producing alternative-fuel engines and vehicles.

Extensive commercialization efforts are under way in several States, most notably in California, New York, and Texas. California has put more than 2,000 methanol LDV's in service. The California Pilot Test Program requires that at least 150,000 clean-fuel vehicles be sold annually in California from 1996 through 1998 and 300,000 annually thereafter. The New York State Energy Plan calls for 268 alternative-fuel light- and heavy-duty vehicles in State fleets by 1996 and the establishment of numerous refueling facilities across the State. Texas State law requires that new school buses purchased for fleets of more than 50 vehicles or new vehicles purchased for State agency fleets of more than 15 vehicles be fueled with compressed natural gas (CNG) or some other alternative fuel. Transit buses, local fleets, and private fleets are or may also be required to use alternative fuels (see Table 4–4). The law further requires that the number of AFV's for such fleets equal 50 percent by late 1996.

Other States also have called for substantial purchases of AFV's for their State-owned fleets. Several States also offer State fuel-tax exemptions for alternative-fuels for both fuel producers and fuel users. Finally, several States, particularly in the Northeast, have adopted or are planning to adopt the California Low Emission Vehicles emissions standards as allowed under the CAAA.

U.S. Alternative Fuels Council

In September 1992, the U.S. Alternative Fuels Council completed its report on the commercialization of alternative fuels. This report was based on a series of reports prepared by the Congressional Research Service. The Council also adopted a resolution that set a goal for national alternative-fuel use in the year 2005 (since changed to 2010); the resolution is presented in Appendix B of this report. The council held 11 meetings in cities throughout the United States on a variety of topics, including reformulated gasoline, alternative-fuel technology, and the need to integrate the environmental and energy goals of alternative-fuel use.

Effects of Other Legislation and Programs

CAAA provisions to encourage the use of nonpetroleum fuels and fuel additives include the reformulated and oxygenated gasoline requirements, the clean-fuel centrally fueled fleet program, the California Pilot Test Program, the low-polluting fuel requirement for urban buses, and Phase II of the emissions standards for conventional vehicles. Increased use of alternative fuels also could be spurred by the national alternative-fuel-fleet provisions in the pending Senate and House energy bills, California's Low Emission Vehicles and Clean Fuels Program, and various other State and local alternative-fuel programs.

Assuming implementation of these existing programs and passage of the pending energy legislation, approximately 63 percent of all gasoline will be reformulated in 2010 and another 2.5 percent will be oxygenated, though not reformulated. Alternative motor fuels will account for approximately 3 percent of all motor-fuel use (including diesel). The oxygenates will displace slightly more than 200,000 barrels per day (b/d) of oil, and alternative fuels nearly 300,000 b/d. Together, they will displace about 5 percent of all oil used in the transportation sector in 2010.

Research and Development Needs

Recently, alternative motor fuels R&D has received a boost from AMFA, the CAAA, the California Low Emission Vehicles and Clean Fuels Program, the establishment of the U.S. Advanced Battery Consortium, and the 1991–1992 National Energy Strategy. R&D to improve alternative fuels and alternative-fuel vehicles is critical to developing alternative technologies that meet both the needs of society and the consumer.

Gaseous Fuels

Natural-gas-vehicle research, development, and demonstration has concentrated on dual-fuel LDV's and on the adaption of HDV compression-ignition (diesel) engines to operate on CNG. Opportunities to improve CNG vehicle technology exist in fuel storage, fuel metering, optimized engine design, and emissions control. A particularly important area of R&D for CNG vehicles is the development of vehicle systems designed for dedicated operation on either CNG or liquefied natural gas (LNG), including R&D on developing lean emissions-control systems capable of reducing oxides of nitrogen. R&D on catalysts specifically aimed at the particular combustion species produced by natural gas also is essential to realizing the full air-quality benefits of natural-gas vehicles. For LNG, R&D is needed to improve and reduce the costs of cryogenic on-board storage systems to bring this technology closer to commercialization.

LP Gas (Propane)

Propane faces many of the challenges natural gas does, but its differences from gasoline are less extreme. Manufacturers will need to develop optimized fuel metering equipment to reduce emissions, increase fuel economy, and reduce consumer costs. Although on-board storage is less challenging than for CNG, propane tanks are still a major component of propane conversion costs. Improvements in design and cost reductions would benefit the economics of propane vehicles.

Alcohol Fuels

Although methanol and ethanol are corrosive to some conventional engine and refueling components and have caused increased engine wear in some early tests, these problems have been lessened by material substitution and the development of appropriate engine oils. Additionally, methanol and ethanol's poor cold-starting and warmup characteristics have been solved by the addition of a volatile primer (usually gasoline) in amounts of about 15 percent.

Important areas of research are the development of lean exhaust emissions control (lean catalysts) that will capitalize on alcohol fuels' excellent lean-burn properties and thereby reduce emissions and improve fuel economy; the development of engine systems optimized for methanol or ethanol, including optimized dedicated or possibly dual-fuel engines; and the development of practical engine systems that can reduce emissions from compression-ignition engines and solve alcohol fuels' problems of high autoignition temperatures, low viscosity and lubricity, and higher volatility in comparison to conventional diesel fuels.

Electric Vehicles

The chief limitations of electric battery propulsion technology are very low energy density, long recharging time, and battery cost. Improvements in energy density on the order of 10 to 20 percent for lead-acid batteries and 100 percent for advanced batteries are probable.

The key research areas needed for electric-vehicle (EV) batteries are increasing energy and power densities, increasing the number of cycles per battery lifetime to more than 1,000, reducing recharging time to less than 1 hour, decreasing the rate of spontaneous discharge when the vehicle is not in use, reducing battery costs or developing effective financing for battery replacement, lowering the energy-use of accessories such as climate control and other amenities, and integrating effective regenerative braking systems to increase range.

Fuel cells or fuel cell-battery hybrids provide an attractive possibility for EV's. Their chief attractions are their potential for zero emissions at the vehicle point of use (although not necessarily during electricity production) and their theoretically higher energy conversion efficiency, nearly twice that of internal-combustion engines. DOE has been conducting research on the low-temperature proton exchange membrane (PEM) fuel cells for LDV applications and is implementing a demonstration program using medium-temperature phosphoric acid fuel cells for urban buses. R&D is needed to reduce PEM's sensitivity to poisoning of the electrocatalyst by carbon monoxide and to humidify the fuel and oxygen streams to maintain hydration of the membrane. Fundamental research on materials and components to reduce the costs and improve the performance and endurance of PEM fuel cells is in progress.

Biofuels

Research on biofuels production by the Departments of Energy and Agriculture centers on continued efforts toward reducing the cost of producing grain-based ethanol, as well as exploring the use of woody and herbaceous feedstocks and municipal solid wastes to produce ethanol, methanol, gasoline, diesel, or gaseous fuels via thermochemical or biochemical conversion and the use of processed vegetable oils as diesel-fuel substitutes. The focus of the DOE program is on the selection and cultivation of biomass feedstocks and the development of cost-effective, high-yield processes for converting cellulosic feedstocks to sugars, which can then be fermented into ethanol.

Research on methanol production from biomass focuses on thermal conversion. A critical goal is improved gasification to reduce the production of tars, as well as the development of catalysts that can simultaneously reduce synthesis gas tars and produce the required gas shift.

The key research needs for nonpetroleum diesel-fuel substitutes, or biodiesel fuels (obtained from oil-seed crops, such as soybean, sunflower, and rapeseed), are the development of improved feedstocks and production systems and improved processing technologies to develop fuels closer to diesel specifications but with reduced emissions. Further emissions testing is needed to document the environmental properties of biodiesel fuels.

Alternative-Fuels Policy

1.1 Policy Perspective

In the absence of new policy initiatives, U.S. oil consumption is expected to increase by 20 percent over the next 20 years, reaching 20.1 million barrels per day in 2010 (EIA, 1992, Table A-8). With two-thirds of the world's proved reserves and an increasingly large share of world oil production concentrated in the Persian Gulf region, the economic, environmental, and energy security implications of this scenario merit the attention of policymakers.

Several distinct types of policies are useful in addressing concerns related to these projected trends in oil use. For example, energy security can be addressed through the acquisition of strategic petroleum reserves, improved policy coordination with other reserve-holding nations, a reduction in the geographic concentration of world oil production, increased domestic oil production, reduced domestic oil consumption, and greater flexibility in domestic energy markets, each of which can serve to reduce both the likelihood and the impact of future oil price shocks.

A balanced approach will necessarily involve a mix of these policies. However, the important role of reductions in oil use and the fact that the transportation sector accounts for two-thirds of U.S. oil consumption suggest the need to give especially careful attention to measures with the potential to cost-effectively reduce the use of petroleum-based motor fuels.

1.2 Role of Alternative Motor Fuels

Alternative motor fuels can make a major contribution to reducing petroleum use in the transportation sector. Some alternative fuels can be produced domestically; their use represents, to a considerable extent, a substitution of domestic fuel for imported petroleum. Other alternative fuels may be imported. The use of such fuels would contribute to the diversification of U.S. energy sources.

1.3 Long-Term Plan for the Commercialization of Alternative Motor Fuels

Section 400DD of the Alternative Motor Fuels Act of 1988 (AMFA, Public Law 100-494) established the Interagency Commission on Alternative Motor Fuels and charged the commission to develop "a long-term plan for the commercialization of alcohols, natural gas, and other potential alternative motor fuels."

The National Energy Strategy (NES), which addresses the production and use of all forms of energy, includes five initiatives intended to bring alternative motor fuels into the marketplace:

- Elimination of the 1.2-mile-per-gallon cap on corporate average fuel economy (CAFE) credits for flexible-fuel vehicles (FFV's) or diesel dual-fuel vehicles

- Acceleration of the purchase of new alternative-fuel vehicles (AFV's) for Federal fleets

- Modification of the clean-fuel-fleet concept to ensure the use of AFV's

- Increased research and development (R&D) on advanced biofuels technology

- Increased R&D on AFV's

It is through NES, and specifically these five alternative-fuels initiatives, that the commission is fulfilling its requirement to develop a long-term alternative-fuels plan. The Administration is already implementing those measures that do not require new legislation.

To bring this plan to fruition, the Administration also has submitted legislation to Congress. As a result of that submission, omnibus energy legislation has been passed by both the House and the Senate and will go to House-Senate conference in September 1992. The House and Senate bills and their effects are discussed in Sections 1.5 and 1.6 of this report.

1.4 The National Energy Strategy

NES is designed to achieve balance among our increasing need for energy at reasonable prices; our commitment to a safer, healthier environment; and our goal to reduce dependence by ourselves, friends, and allies on potentially unreliable energy sources. NES involves both increases in domestic production and reductions in oil use in all sectors of the economy. To achieve its goals, NES includes major initiatives to bring cost-effective alternative motor fuels into the marketplace.

The development of alternative motor fuels is driven by expectations that technology and market developments will make such fuels economically attractive, national concerns about the level of U.S. oil consumption, and urban air-quality problems associated with the transportation system. Greater reliance on cost-competitive alternative fuels can help to address these concerns while contributing to economic efficiency.

Although Federal and State subsidies have spurred the use of ethanol as a blending agent in almost 10 percent of all U.S. gasoline, the widespread use of alternative fuels such as ethanol, methanol, natural gas, liquefied petroleum gas (LP gas), and electricity is hampered by a variety of infrastructural, technological, and economic factors. Some of these are specific to each alternative fuel, while others are common to all these fuels. As an example of a fuel-specific factor, some alternative fuels are significantly more expensive than gasoline and can also require changes in how vehicles are refueled or recharged. In addition, some AFV's are much more expensive than their gasoline-powered counterparts and may also fall short in performance. Factors common to all fuels include the limited U.S. fuel distribution infrastructure and the difficulty of introducing AFV's to the general public until alternative fuels are widely available. Notwithstanding recent interest in alternative fuels, researchers' experience with advanced AFV's is relatively limited; and they need additional data on AFV performance, fuel economy, and emissions, especially for optimized vehicles in daily real-world service.

In concert with the support of R&D programs to develop engines that can use alternative fuels, Federal support can help to improve the understanding of the fuels, reduce the cost of producing the fuels, and address legitimate market barriers that impede the penetration of cost-competitive fuels into the marketplace. NES is intended to speed the introduction of alternative fuels and AFV's between 1995 and 2010. The Strategy proposes several concurrent actions to encourage vehicle manufacturing, access to vehicle refueling, and new fuel supplies. These policies are described below.

1.4.1 Incentive for Production of Alternative-Fuel Vehicles

NES calls for the elimination of the 1.2-mile-per-gallon cap on CAFE credits for alternative-fuel flexible- or dual-fuel vehicles. AMFA provides CAFE credits for vehicles operated on either alcohol or natural gas. Dedicated AFV's receive an unlimited fuel-economy credit, but they may be limited to niche markets. Production of flexible- or dual-fuel vehicles, however, results in a CAFE credit that is limited to 1.2 miles per gallon initially and then declines to 0.9 miles per gallon. This incentive is unlikely to stimulate the manufacture of more than a few hundred thousand flexible-fuel vehicles per year. As a consequence, fuel-economy credits for AFV's would have little effect on energy use for at least 2 decades. Removing the cap on CAFE credits for flexible- and dual-fuel vehicles should provide a significant incentive for manufacturers to produce vehicles that could operate on alcohol or natural gas, as well as on conventional fuels, thereby establishing the capacity for a large market for future U.S. alternative-fuel production and distribution.

1.4.2 Larger Federal Alternative-Fuel Fleet

The Federal Government plans to increase its purchase of new AFV's to demonstrate Federal leadership in alternative fuels. The Government purchases 44,000 light-duty vehicles (LDV's) per year and operates a civilian fleet of 200,000 cars and light trucks. Large annual Federal purchases, especially if executed in cooperation with State and local initiatives, will increase incentives for auto manufacturers to produce a wider variety of optimized AFV's that use a range of alternative fuels, including natural gas, ethanol, methanol, LP gas, and electricity. Large Federal purchases also would encourage manufacturers to produce vehicles that meet Federal and State fleet specifications.

In response to the need for Federal leadership in alternative fuels, on April 17, 1991, the President issued Executive Order 12759, *Federal Energy Management*, which requires that the Federal Government acquire the maximum number of AFV's as rapidly as practicable. Through August 1992, the Government had purchased 3,267 AFV's. In fiscal year (FY) 1993, the Government plans to convert or purchase an additional 5,000 AFV's. Current plans call for more than 20,000 Federal AFV's to be operating in 1995 and for 50 percent of all Federal vehicles purchased to be AFV's by 1998.

1.4.3 Alternative-Fuel Fleets

The Clean Air Act Amendments of 1990 (CAAA) provide significant new requirements for the use of clean-fuel vehicles. NES proposes a modification of the clean-fuel-fleet concept to ensure use of AFV's (which are not required by the CAAA's clean-fuel-fleet program) and to expand the program nationwide.

The CAAA require that, in 22 urban areas, fleets of 10 or more cars and light- to medium-duty trucks meet stricter emissions standards. NES proposes, as does pending Senate and House legislation (described in Section 1.5), that some of these fleets be required to purchase AFV's. These purchase requirements would also be extended to other urban areas not covered under the CAAA.

This program will emphasize use of public refueling to avoid requiring fleet operators to install refueling facilities that are not cost-effective. Combined with the incentive to encourage manufacture of AFV's for the Federal fleet, these alternative-fuel fleet requirements are expected to stimulate the widespread introduction of AFV's and the availability of alternative fuels at public refueling stations.

1.4.4 Increased R&D on Alternative-Fuel Vehicles

The Federal Government has proposed enhanced R&D on batteries and electric vehicles to move initial commercialization of electric vehicles up to the mid-1990's. Electric vehicles are an environmentally attractive alternative to conventional vehicles, especially in urban areas. Research could accelerate the development of battery concepts that could improve both near-term and long-term commercial competitiveness for electric vehicles. Efficient, durable, and safe batteries that can provide acceptable driving ranges for urban travel are essential for widespread market acceptance of electric-vehicle technology. The U.S. Advanced Battery Consortium, a consortium of vehicle manufacturers, battery developers, and utilities, along with the Department of Energy, was formed in October 1991 to support an aggressive R&D program to make major advances in battery technology. The program will focus on extending electric-vehicle driving range up to 200 miles on a single charge, increasing battery-specific energy and specific power, and improving electric propulsion technology.

The Government is continuing R&D on gas turbine engines. Compared to conventional gasoline engines, ceramic gas turbine engines could be 30 to 40 percent more efficient, operate with high performance on a variety of alternative fuels, have very low emissions, and have reduced maintenance requirements. Worldwide, eight vehicle manufacturers have extensive research programs on gas turbine technology with the U.S. auto industry. The advanced gas turbine also could be used in long-haul trucking.

The Government also is continuing R&D on low-heat-rejection diesel engines for use in heavy-duty trucks. These engines use temperature-resistant ceramic parts to achieve up to 22 percent more efficiency than conventional diesel engines. Continued R&D on ceramic material design, processing, and testing is critical to both gas turbine and low-heat-rejection diesel engine research.

The Department of Energy is performing research on fuel cell vehicles, which are candidates for accelerated development, to produce cost-effective alternatives over the long term. Originally developed as power supplies for electric utilities and space stations, fuel cells are now being applied to transportation. Fuel cell technology could improve fuel economy 70 to 80 percent over conventional engines and could also reduce noise. Fuel cell-powered vehicles could provide an ultraclean technology that could be less expensive than other attainment strategies for areas that do not meet Federal ozone standards. Several fuel cell concepts, such as the proton exchange membrane, are being investigated. Possible applications in urban buses appear very attractive, though they are not commercially viable at this time.

The Federal Government will accelerate efforts started under AMFA and give them additional support. Because AFV's are only now being tested in significant numbers under real-world conditions, data on their performance, fuel economy, and emissions are incomplete. Specific areas where additional data and analysis are needed are environmental emissions from vehicles using alternative fuels, full fuel-cycle costs of alternative fuels compared to fossil fuels, and agricultural impacts stemming from large-scale biomass production. The newly established Alternative Fuels Data Center at the National Renewable Energy Laboratory (formerly the Solar Energy Research Institute) will collect and analyze data on alternative-fuel use from Federal and State fleets. The Alternative Fuels Utilization Program will encourage research on improving the cost, efficiency, and performance of AFV's.

1.4.5 Advanced Biofuels Technology

The Federal Government will accelerate research on biomass conversion technologies, with a goal of identifying cost-competitive alcohol-fuels technology by the year 2000. Domestically produced liquid fuels from biomass, including fuels from nonfood agricultural products, could provide the Nation with significant energy security benefits while strengthening its rural economies. Clean-burning alcohol fuels produced from nonfood biomass constitute a renewable and sustainable alternative for dwindling domestic petroleum reserves. Alcohol fuels can be used as blends in today's vehicles, and they can also be used in pure form in flexible-fuel vehicles or dedicated alcohol vehicles powered by internal combustion engines, new gas turbines, or fuel cells.

The costs of producing alcohol fuels from biomass have dropped significantly, reducing the plantgate price of ethanol from $3.60 per gallon in 1980 to $1.27 per gallon in 1992. This price is equivalent to a wholesale gasoline price of $1.65 per gallon, taking into account ethanol's lower energy content per gallon and its greater efficiency. For comparison purposes, the average wholesale price of gasoline (excluding taxes) was about $0.76 per gallon in 1990. This progress has come through successful R&D on improved alcohol yields, faster production systems, increased alcohol concentrations, and improved enzymes and microbial systems. Accelerated research on pretreatment technologies, membranes used in the conversion and separation process, improvements to the fermentation process, enhancements to the value of coproducts, and enzymatic hydrolysis technologies for ethanol production is expected to further reduce ethanol production costs.

The cost of producing methanol from biomass was about $2.50 per gallon on a gasoline-equivalent basis in 1980, but research on advanced gasifiers has brought the estimated cost of producing methanol from biomass down to about $1.15 per gallon. Methanol-from-biomass costs are expected to decrease because of future improvements in gasification technology, synthesis gas conditioning, and gas product cleanup.

Cooperative research carried out by the Departments of Energy and Agriculture on feedstock and conversion technologies is expected to accelerate development of diverse energy crops for both ethanol and methanol. Additional research on oilseeds and microalgae may yield new feedstocks for diesel fuel and oils from biomass. Research on advanced genetic technology to enhance energy content and to maximize desirable feedstock components of such crops as fast-growing poplar trees and perennial grasses could help improve productivity and reduce costs. In addition, Federal research on the development and processing of coproducts can improve the economics of producing liquid fuels from biomass.

1.5 Pending Comprehensive Energy Legislation

Prompted by the Administration's National Energy Strategy, comprehensive energy legislation has recently been passed by both the Senate and the House. The Senate bill, S. 2166 (National Energy Security Act of 1992), and the House bill, H.R. 776 (Comprehensive National Energy Policy Act), are scheduled to go to a Senate-House conference committee in September 1992. If the Senate-House conference goes smoothly, comprehensive energy legislation could be passed before the end of 1992.

Both S. 2166 and H.R. 776 contain significant alternative-fuel provisions. Table 1-1 shows a side-by-side listing of the key alternative-fuel provisions of each bill.

1.6 Comparison of Projected Effects of NES, S. 2166, and H.R. 776 Alternative-Fuel Fleet Requirements

As a point of reference, the following sections compare the projected effects of the alternative-fuel fleet requirements of NES to those of S. 2166 and H.R. 776. This comparison is done in terms of oil-displacement potential, AFV annual purchases, and the number of AFV's in operation by the year 2010.

1.6.1 Oil-Displacement Potential

As displayed in both Figure 1-1 and Table 1-2, the NES fleet requirements are projected to displace nearly twice as much oil as S. 2166 or

Table 1-1. Comparison of Key Alternative-Fuel Provisions of S. 2166 and H.R. 776

Provision	S. 2166	H.R. 776
Definition of alternative fuels	Defines "alternative fuel" to include methanol, ethanol, and other alcohols; mixtures containing 85% or more by volume of methanol, ethanol, or other alcohol with gasoline or other fuels; natural gas; liquefied petroleum gas, hydrogen; coal-derived liquid fuel; electricity; and any other fuel that is substantially nonpetroleum.	Definition of "alternative fuel" same as S. 2166 except: (1) does not include coal-derived liquid fuel, (2) allows alcohol mixtures to be as low as 80% alcohol by volume, and (3) allows Secretary to add other nonpetroleum fuels.
Replacement and alternative fuel program and displacement goals	Directs DOE to establish a program to promote the development and use of domestically produced replacement and alternative fuels. Preliminary goal is to replace 30% of motor fuel projected to be used in 2010 by alternative fuels.	Similar provision to S. 2166, except preliminary goal is to replace 10% of motor fuel by 2000 and 30% by 2010. A DOE determination in 1998/9 that these goals will not be met could trigger alternative-fuel requirements for non-Federal fleets and increase the requirements for Federal fleets.

Table 1-1. Comparison of Key Alternative-Fuel Provisions of S. 2166 and H.R. 776 (continued)

Provision	S. 2166	H.R. 776
Federal fleet AFV acquisition requirements	- 5,000 AFV's in 1993 - 7,500 AFV's in 1994 - 10,000 AFV's in 1995 Further requires that the following percentages of new Federal vehicle acquisitions must be AFV's: 25% in 1996 33% in 1997 50% in 1998 75% in 1999 90% in 2000 and thereafter	- 5,000 AFV's in 1993 - 7,500 AFV's in 1994 - 10,000 AFV's in 1995 Further requires that the following percentages of new Federal vehicle acquisitions must be AFV's: 25% in FY 1996 33% in FY 1997 50% in FY 1998 and thereafter If the oil-displacement goals mentioned above are not met, these requirements may be increased to: 60% in 2000 70% in 2001 75% in 2002 and thereafter
State fleets AFV acquisition requirements	State fleets of 50 or more vehicles with at least 20 that are centrally fueled or capable of being centrally fueled and are primarily used in an SMSA of > 250,000 must ensure that the following percentages of newly acquired vehicles must be AFV's: 10% in 1995 15% in 1996 25% in 1997 50% in 1998 75% in 1999 90% in 2000 and thereafter	State fleets are not covered. However, should the oil-displacement goals mentioned above not be achieved, State fleets of 10 or more vehicles that are centrally fueled or capable of being centrally fueled and are located in an MSA or CMSA with a 1990 population of > 250,000 must ensure that the following percentages of newly acquired vehicles must be AFV's: 20% by 2002 40% by 2003 60% by 2004 70% by 2005 and thereafter
Private and municipal fleet AFV acquisition requirements	Private and municipal fleets of 50 or more vehicles with at least 20 that are centrally fueled or capable of being centrally fueled and are primarily used in an SMSA of > 250,000 must ensure that the following percentages of newly acquired vehicles must be AFV's: 30% in 1998 50% in 1999 70% in 2000 and thereafter	Private and municipal fleets are not covered. However, should the oil-displacement goals mentioned above not be achieved, private and municipal fleets of 10 or more vehicles that are centrally fueled or capable of being centrally fueled and are located in an MSA or CMSA with a 1990 population of > 250,000 must ensure that the following percentages of newly acquired vehicles must be AFV's: 20% by 2002 40% by 2003 60% by 2004 70% by 2005 and thereafter

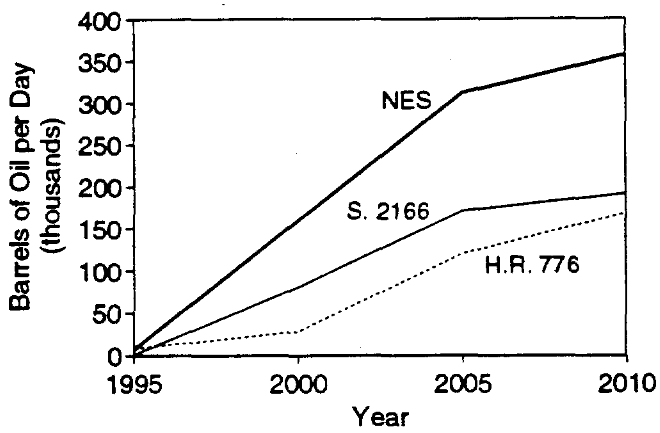
Table 1–1. Comparison of Key Alternative-Fuel Provisions of S. 2166 and H.R. 776 (continued)

Provision	S. 2166	H.R. 776
Fuel provider AFV acquisition requirements	No provision. However, fuel provider fleets would be covered under private and municipal fleet requirements.	100% of covered fuel provider vehicles must be AFV's beginning in 1994. A fuel provider is defined as any person involved in: (1) the production, storage, refinement, processing, transportation, distribution, importation, generation, or retail or wholesale sale of alternative fuel; (2) the transmission, importation, or sale of electricity; or (3) the production and/or importation of an average of 50,000 or more barrels per day of petroleum. (1) All new vehicle purchases of LDV's and HDV's up to 26,000 lbs. (diesel vehicles > 8,500 lbs. are exempt) that are centrally fueled or capable of being centrally fueled should be dedicated AFV's. (2) All new vehicle purchases of LDV's that are not capable of being centrally fueled should be dual fuel and operated on the alternative fuel at least 50% of the time.
Fuel-use requirement	Requires FFV's to operate solely on alternative fuels if they are available.	No provision.
Vehicle credit program	Would provide credits to a State or covered person who acquires more alternative-fueled vehicles than required or acquires them earlier than required. These credits could be sold to other covered fleets who choose not to acquire the required number of AFV's.	Similar to S. 2166, except credits are not allowed for the conversion of, or replacements for, diesel-fueled vehicles.
Electric and electric-hybrid vehicle demonstration and infrastructure development program	Directs DOE to conduct a program to demonstrate electric and electric-hybrid vehicles and associated equipment. Directs DOE to enter into cooperative agreements with non-Federal entities to provide the infrastructure necessary to support the use of electric or electric-hybrid vehicles.	Similar to S. 2166, except infrastructure projects would be joint ventures rather than cooperative agreements.
Alternative-fuel vehicles eligible for Federal procurement	Amends the Energy Policy and Conservation Act to include electric, electric-hybrid, and LP gas vehicles among the types of AFV's that may be acquired by the Federal Government to satisfy AMFA requirements.	Amends the Energy Policy and Conservation Act to allow all AFV's to be acquired by the Federal Government to satisfy AMFA requirements.

Table 1-1. Comparison of Key Alternative-Fuel Provisions of S. 2166 and H.R. 776 (continued)

Provision	S. 2166	H.R. 776
CAFE credits for AFV's	Amends the Motor Vehicle and Information Cost Savings Act to allow vehicles using LP gas to qualify for CAFE credits.	Amends the Motor Vehicle and Information Cost Savings Act to allow vehicles using LP gas, hydrogen, and electricity to qualify for CAFE credits.
Mandatory alternative-fuel supply plan	If the supply of alternative fuels is insufficient to meet public demand and the Secretary of Energy cannot obtain enough voluntary supply commitments, the Secretary may implement a plan requiring motor fuel providers to supply alternative fuels after the plan has been before Congress for 60 days.	No provision.
Tax deductions for clean-fuel vehicles	Provides tax deductions for qualified clean-fuel-vehicle property. Tax deduction limitations by vehicle type are as follows: - Dedicated OEM AFV ($2,000) - Dual-fuel or FFV OEM (the greater of $1,200 or the incremental cost of vehicle up to $2,000) - Dedicated converted AFV (incremental cost up to $2,000) - Dual-fuel converted AFV (incremental cost up to $2,000) - Electric vehicles (tax credit equal to 15% of cost of vehicle) - Heavy-duty truck (10,000 - 26,000 lbs.) ($5,000) - Heavy-duty truck (in excess of 26,000 lbs.) and buses with adult seating capacity of 20 or more ($50,000)	Provides tax deductions for qualified clean-fuel-vehicle property. Tax deduction limitations by vehicle type are as follows: - Dedicated OEM AFV (incremental cost up to $2,000) - Dual-fuel or FFV OEM (incremental cost up to $2,000) - Dedicated converted AFV (incremental cost up to $2,000) - Dual-fuel converted AFV (incremental cost up to $2,000) - Electric vehicles (incremental cost up to $2,000) - Heavy-duty truck (10,000 - 26,000 lbs.) (incremental cost up to $5,000) - Heavy-duty truck (in excess of 26,000 lbs.) and buses with adult seating capacity of 20 or more (incremental cost up to $50,000)
Tax deductions for clean-fuel-vehicle refueling property	Provides tax deductions for qualified clean-fuel-vehicle refueling property. Tax deduction limitation for clean-fuel refueling facility is the incremental cost up to $75,000 (includes electric vehicle refueling).	Provide tax deductions for qualified clean-fuel-vehicle refueling property (excluding electricity). Tax deduction limitation for clean-fuel refueling facility is the incremental cost up to $100,000 (excludes electric vehicle refueling).

Figure 1-1. Oil Displacement Resulting From NES, S. 2166, and H.R. 776 Alternative-Fuel Fleet Requirements



H.R. 776 in 2010.[1] NES, by 2010, is projected to displace 357,916 barrels per day (b/d) of oil versus 192,699 b/d and 169,245 b/d for S. 2166 and H.R. 776, respectively. This largely stems from the fact that NES encompasses a greater amount of "covered" vehicles and because its programs are instituted relatively early within the 1995-to-2010 period compared to S. 2166 and H.R. 776. Under full implementation (that is, by 2010 and assuming the increased fleet requirements of H.R. 776 are triggered in 2000), S. 2166 displaces approximately 14 percent more oil relative to H.R. 776.

1.6.1.1 Costs of Oil Displacement

The cumulative, undiscounted program costs of the NES fleet requirements ($14.1 billion) are projected to be nearly double the costs of the fleet requirements of S. 2166 ($8.2 billion) or

Table 1-2. NES, S. 2166, and H.R. 776 Fleet Requirement Oil-Displacement Projections
(barrels per day)

	Year			
Program	1995	2000	2005	2010
NES	7,396	160,753	312,264	357,916
S. 2166	840	81,109	171,667	192,699
H.R. 776	8,624	29,075	120,922	169,245

H.R. 776 ($8.0 billion) during the 1993 to 2010 period (Table 1-3).[2] However, if these costs are calculated in terms of the undiscounted costs of oil displaced, NES appears to displace oil at a lower cost per barrel ($11.27) relative to S. 2166 ($12.50 per barrel) and H.R. 776 ($17.19; see Table 1-3 and Figure 1-2). The relatively low cost of oil displaced under NES, as well as S. 2166, relative to H.R. 776 stems from NES's early comprehensive coverage of many different fleet types (Federal, State and local, and private), which is more likely to quickly induce economies of scale in AFV production and a more complete public AFV refueling network.[3]

In addition, it is important to note that the incremental vehicle cost phase-ins used in this analysis are based on DOE's 1992 report on vehicle and fuel distribution requirements, and not on prevailing incremental vehicle costs presently experienced by AFV users (DOE, 1992). The cost phase-in assumptions are based on the presumption that incremental vehicle costs will gradually fall as higher levels of AFV production are achieved. This is due to economies of scale,

[1]It is important to note that all results reported in terms of oil displacement, cost of displacement AFV purchases, and AFV's in operation are a result of *only* the fleet requirements of the bills, and not the result of other portions of the bills. It is also important to note that all results for H.R. 776 are predicated on the assumption that increased Federal fleet requirements are implemented in 2000 and non-Federal fleet requirements are implemented in 2002 as a result of these increased requirements being deemed necessary to meet the oil-displacement goals outlined in Table 1-1.

[2]Costs include incremental vehicle and refueling infrastructure costs, as well as resale losses, to covered fleets required to participate in fleet programs. Incremental fuel costs or cost savings are not included. Given NES policies and projected oil prices, alternative fuels are projected to be competitive with conventional fuels. Benefits such as maintenance cost savings or environmental improvements are not incorporated into these estimates.

[3]Costs are cumulative and undiscounted and are based on undiscounted cost streams because the choice of a discount rate is highly subjective.

Table 1-3. Total Alternative-Fuel Fleet Program Costs and Costs of Oil Displaced

Program	Cumulative Undiscounted Costs (billion $)	Cumulative Barrels Displaced (billion)	Cost per Barrel Displaced (undiscounted $)
NES	14.1	1.2	11.27
S. 2166	8.2	0.7	12.50
H.R. 776	8.0	0.5	17.19

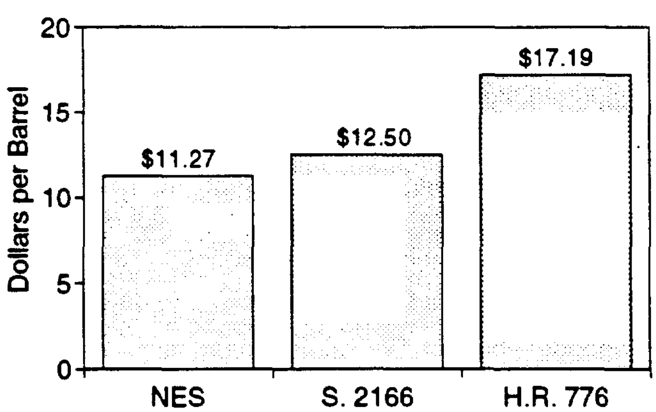
Note: Dividing the first column by the second column will not exactly yield the results in the third column because of rounding.

which induce lower per-unit vehicle costs in AFV production by manufacturers. Recent AFV acquisitions by the Federal Government indicate that the cost phase-in assumptions used in this report may be somewhat high (both in the level and in the rate at which costs fall). As such, the cost estimates contained herein may be conservative and on the high side.

1.6.2 New AFV Purchases

Each bill under consideration would create a significant market for new AFV's. By the year 2010, it is projected that the NES fleet requirements would create a 1.6-million-vehicle-per-year market for new AFV's. H.R. 776 and S. 2166, in 2010, would induce 1.2-million- and 1.0-million-vehicle-per-year markets for new AFV's, respectively. NES would generate the largest market because it casts a relatively large net in terms of what fleets are covered and because it also includes a large number of heavy-duty vehicles (HDV's). H.R. 776 would produce a slightly smaller AFV market than NES because it only includes transit buses in its coverage of HDV's. Despite the fact that it covers a large number of HDV's, S. 2166 would induce the smallest AFV market because it has the largest minimum fleet size requirement and thus would cover a smaller number of LDV's relative to the other bills. See Table 1–4 for annual new AFV purchases under the three bills.[4]

Figure 1-2. Oil-Displacement Costs Under NES, S. 2166, and H.R. 776 Fleet Requirements



Note: Costs are the cumulative, undiscounted program costs during 1993-2010.

1.6.3 AFV's in Operation

In terms of the number of AFV's in operation, the NES fleet requirements are projected to put approximately 5.6 million AFV's on the road by the year 2010. In comparison, S. 2166 (3.3 million) and H.R. 776 (3.7 million) would both put in excess of 3 million AFV's in operation by 2010. (See Table 1–5 for bill-specific AFV projections.)

As shown in Figure 1–3, NES produces a steady buildup to an AFV population of 5.6 million by 2010. On the other hand, S. 2166 starts slowly during the 1995–99 period, but produces large amounts of AFV's from the year 2000 on. Because its increased coverage of other fleets does not kick in until 2002, H.R. 776 induces a relatively small AFV population during the 1995–2000 period. However, once fully implemented, it builds up a large number of AFV's over the 2000–2010 timeframe.

[4]The analysis assumed that all cars were flexible-fuel vehicles that operate on the alternative fuel 50 to 75 percent of the time. All other vehicle types were assumed to be dedicated vehicles that operate on the alternative fuel 100 percent of the time.

Table 1–4. Bill-Specific New Alternative-Fuel-Vehicle Purchases

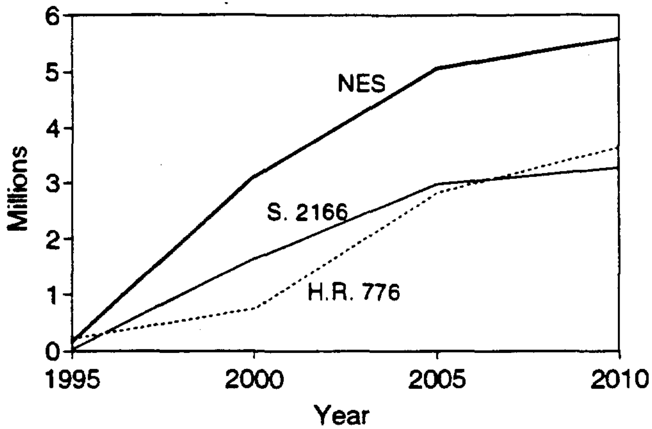
Vehicle Type	Year			
	1995	2000	2005	2010
			NES	
Cars	98,000	917,000	987,000	1,061,000
LDT's	28,000	198,000	212,000	226,000
HDT's	15,000	150,000	169,000	191,000
Transit buses	0	4,000	8,000	8,000
School buses	5,000	57,000	68,000	82,000
Total	**146,000**	**1,326,000**	**1,444,000**	**1,568,000**
			S. 2166	
Cars	7,000	578,000	621,000	668,000
LDT's	6,000	131,000	139,000	148,000
HDT's	0	61,000	69,000	77,000
Transit buses	0	4,000	5,000	5,000
School buses	0	36,000	42,000	51,000
Total	**13,000**	**810,000**	**876,000**	**949,000**
			H.R. 776	
Cars	134,000	150,000	911,000	980,000
LDT's	70,000	80,000	222,000	238,000
HDT's	0	0	0	0
Transit buses	0	0	6,000	7,000
School buses	0	0	0	0
Total	**204,000**	**230,000**	**1,139,000**	**1,225,000**

Note: The analysis assumed that all cars were flexible-fuel vehicles that operate on the alternative fuel 50 to 75 percent of the time. All other vehicle types were assumed to be dedicated vehicles that operate on the alternative fuel 100 percent of the time.

Table 1–5. Bill-Specific Alternative-Fuel Fleet Vehicles in Operation, 1995–2010

Program	Year			
	1995	2000	2005	2010
NES	161,000	3,114,000	5,059,000	5,589,000
S. 2166	25,000	1,645,000	2,984,000	3,279,000
H.R. 776	216,000	747,000	2,824,000	3,658,000

Figure 1–3. Projected AFV's in Operation Resulting From NES, S. 2166, and H.R. 776 Fleet Requirements



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CHAPTER 2

Progress Report on the Implementation of Programs Required by the Alternative Motor Fuels Act of 1988

The Alternative Motor Fuels Act of 1988 (AMFA; Public Law 100-494) was signed into law on October 14, 1988. As stated in AMFA, its purpose is to:

- Encourage the development and widespread consumer use of methanol, ethanol, and natural gas as transportation fuels
- Encourage the production of methanol-, ethanol-, and natural-gas-powered motor vehicles

Congress recognizes that displacing imported oil with clean-burning, nonpetroleum alternative fuels will help achieve energy security and improve air quality. The Federal Government passed AMFA to help alternative transportation fuels reach the threshold level of commercial application and consumer acceptability at which they can successfully compete with petroleum-based transportation fuels.

AMFA directs the U.S. Department of Energy (DOE) to undertake a number of actions and to work with other Federal agencies, most notably the General Services Administration (GSA), the Department of Transportation (DOT), and the Environmental Protection Agency (EPA), to implement its provisions. AMFA also provides for an active role for industry as well as for State and local governments. One of the key factors inherent to the success of the AMFA program has been the frequent and close coordination effort with other participating agencies, notably GSA, DOT, and EPA, as well as with various industry participants and State and local governments.

This chapter summarizes actions DOE has taken since 1988 to implement those sections of AMFA for which it is responsible and also actions taken by other agencies. In fiscal year (FY) 1990, Congress appropriated $4.5 million to initiate implementation of AMFA; $6.8 million and $10 million were appropriated in FY 1991 and FY 1992, respectively.

This chapter also summarizes activities undertaken to implement Executive Order 12759, *Federal Energy Management*, Section 11, "Procurement of Alternative Fueled Vehicles," which was issued by President Bush on April 11, 1991. Activities directed toward assisting State and local governments in acquiring and operating alternative-fuel vehicles (AFV's) also are included. Although these two relatively new DOE initiatives are not a direct part of the AMFA program, they are direct extensions of the AMFA initiative and experience.

2.1 AMFA Requirements

AMFA requires DOE to take a number of actions, with the assistance of other Federal agencies, State and local governments, and industry. The three major programs established by DOE (all began in FY 1990) are as follows (relevant AMFA sections are in parentheses:

- The Alternative-Fuel Federal Light-Duty-Vehicle Program (section 400AA)
- The Truck Commercial Application Program (section 400BB)
- The Alternative-Fuels Bus Testing Program (section 400CC)

AMFA also established the Interagency Commission on Alternative Motor Fuels and the U.S. Alternative Fuels Council, which reports to the Commission. Both the Interagency Commission on Alternative Motor Fuels and the U.S. Alternative Fuels Council will be terminated coincident with the submission of this Final Report.

In addition, AMFA directs DOE and other designated agencies to prepare several studies and reports to Congress; addresses warranty provisions for light-duty vehicles (LDV's) procured by the Federal Government; offers vehicle manufacturers corporate average fuel economy (CAFE) incentives for producing alcohol and natural-gas-powered vehicles; and amends the automobile labeling section of the Motor Vehicle Information and Cost Savings Act.

2.2 AMFA Program Status

This section summarizes the status of the major activities required by AMFA. All three demonstration programs (the Federal light-duty-vehicle, truck commercial application, and bus testing programs) are well under way, and there are plans to expand them to accommodate more and different types of vehicles and to involve more participants. The Alternative Fuels Data Center, which began operations in early 1991 at the National Renewable Energy Laboratory (NREL; formerly the Solar Energy Research Institute, or SERI) became fully operational in October 1991. Finally, all required studies and reports to Congress have been completed in final or draft form.

2.2.1 Alternative-Fuel Federal Light-Duty-Vehicle Program—Section 400AA

The objective of the Alternative-Fuel Federal Light-Duty-Vehicle Program is to ensure that the Federal Government annually acquires the maximum practicable number of alternative-fuel passenger automobiles and other LDV's. An Interagency Agreement between DOE and GSA was negotiated and signed in FY 1990 to procure alternative LDV's for the Federal fleet.

In 1991, 65 General Motors (GM) and Ford methanol AFV's and 16 control vehicles were placed in the Federal fleet in four areas, including Los Angeles (6 GM Luminas and 5 Ford Tauruses), San Diego (6 Luminas and 5 Tauruses), Washington, DC (8 Luminas and 15 Tauruses), and Detroit (5 Luminas and 15 Tauruses). In an attempt to quantify comparisons of the commercial and operational viability of in-use fleet operation, 8 of the 65 M85 vehicles (2 at each location) were operated as "control vehicles" (M85 vehicles are vehicles that operate on a mixture of 85 percent methanol and 15 percent gasoline). These 8 vehicles, referred to as gasoline AFV's, were refueled almost exclusively on gasoline to provide comparative data relative to the remaining 57 vehicles using primarily M85. In addition, 4 original equipment manufacturer (OEM) control gasoline-fuel vehicles (2 Luminas and 2 Tauruses) were placed at each of the 4 locations (16 total) to develop comparative operating data between conventional gasoline vehicles and AFV's.

In 1992, the Federal alternative-fuel light-duty fleet will expand significantly, from the 65 vehicles acquired in 1991 to an anticipated total of 3,287 LDV's. Operating data will be collected from slightly more than 20 percent, or 665, of these vehicles. The 600 additional vehicles added to the data collection program in 1992 include 75 Chrysler compressed natural gas (CNG) 8-passenger vans, 25 GM Lumina ethanol AFV sedans, 250 Chrysler Spirit methanol AFV sedans, and 250 Chevrolet C-20 CNG three-quarter-ton pickup trucks. Figure 2-1 shows the locations of Federal light-duty AFV's participating in the data-collection program.

The primary criteria for placement of vehicles will continue to include air-quality attainment status and the availability of an alternative-fuel infrastructure to support the vehicles. Some of the Federal agencies currently participating in

Figure 2-1. Locations of Federal Light-Duty AFV's Participating in the Data-Collection Program

the Alternative-Fuel Federal Light-Duty-Vehicle Program are noted in Table 2-1. Data from these fleets have been generated, transmitted, and analyzed by the AFDC since 1991; the initial findings have been reported in the report *Federal Alternative Fuel Program Light Duty Vehicle Operations—First Annual Report to Congress for Fiscal Year 1991*, dated March 1992.

As noted in the above report, for the period of operation from January 1991 through September 1991, AMFA vehicles operating in the four cities accumulated nearly 280,000 miles, an average of 3,450 miles per vehicle. More than 70 percent of these miles were traveled using M85 fuel (a mixture of 85 percent methanol and 15 percent gasoline). The total amount of M85 fuel consumed by the AMFA vehicles is estimated at more than 15,000 gallons.

Figure 2-2 shows a monthly summary of miles accumulated by vehicle type for all four cities combined. The limited accumulation of miles during January and February represents the initial implementation of vehicles in the field; the majority began service in March and April 1991.

Because a gallon of M85 has only a little more than half the energy content of a gallon of gasoline, energy-efficiency comparisons were made using the measures of energy economy or gasoline-energy-equivalent miles per gallon (mpg). Energy economy is the fuel energy, measured in British thermal units (Btu's), per mile traveled. A lower energy economy number implies higher efficiency. Gasoline-energy-equivalent mpg is the M85 AFV fuel economy adjusted for the difference in fuel energy content between gasoline and M85.

Table 2-2 summarizes the on-road average fuel and energy economies of the AMFA LDV fleet. The Washington, DC, M85 AFV's have the lowest average fuel economy of the four sites, which may be attributable to the greater-than-average amount of city driving in Washington. The monthly average gasoline-energy-equivalent mpg of the Los Angeles M85 AFV's is lower than that of conventional gasoline vehicles. The Los Angeles energy economy and gasoline-energy-equivalent mpg figures give conflicting indications of the relative efficiency of M85 AFV's compared to conventional vehicles. This conflicting indication is based on a relatively small amount of operating data; more consistent trends may emerge as the data collection and analysis program progresses.

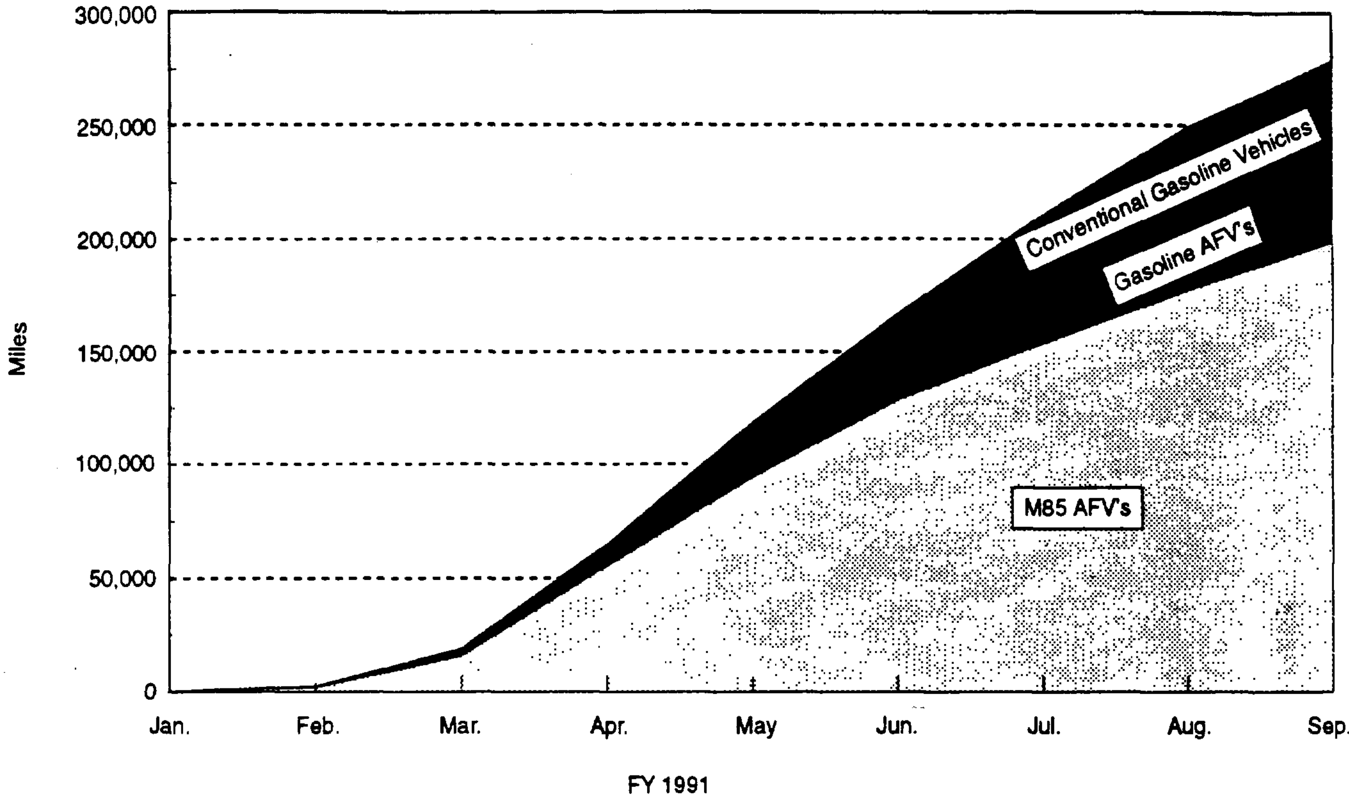
Laboratory exhaust and evaporative emissions levels and fuel economies of selected AMFA vehicles were measured during their first year of operation. These tests were conducted at the National Vehicle and Fuels Emission Laboratory in Ann Arbor, Michigan. Initial laboratory fuel-efficiency results indicate that AMFA M85 AFV's have about half the fuel economy of conventional gasoline vehicles, which is corroborated by actual in-use fuel economy.

The average city- and highway-cycle energy economy values for the M85 AFV's using M85 fuel were 7,624 and 5,043 Btu's per mile,

Table 2-1. Selected Federal Agencies Participating in the Alternative-Fuel Federal Light-Duty-Vehicle Program

Department of Energy	Department of Transportation	Consumer Products Safety Commission
Department of Agriculture	Office of Personnel Management	Department of Veterans Affairs
Department of Labor	General Services Administration	Department of State
Department of the Interior	Treasury Department	Small Business Administration
Environmental Protection Agency	Department of Justice	Department of Housing and Urban Development
Department of Health and Human Services	Defense Contract Administration	U.S. Army
U.S. Navy	U.S. Marine Corps	U.S. District Court
Defense Logistics Agency	U.S. Air Force	
	U.S. Postal Service	

Figure 2-2. AMFA Light-Duty-Vehicle Miles Accumulated, by Month



respectively. The average city- and highway-cycle energy economy values for the M85 AFV's using gasoline were 6,836 and 4,493 Btu's per mile, respectively. The average city- and highway-cycle energy economy values for the conventional gasoline vehicles were 6,123 and 4,212 Btu's per mile, respectively. The average laboratory energy economy values for the M85 AFV's indicate lower equivalent fuel economy than the conventional gasoline vehicles; however, the energy economy values in the fleet sample for the M85 AFV's indicate higher equivalent fuel economy than the conventional gasoline vehicles (see Table 2-2).

Based on the limited emissions and fuel economy testing to date, it is not possible to determine why there is a difference between on-road and laboratory energy economy. Initial AMFA vehicle exhaust and evaporative emissions results indicated that all the AMFA vehicles tested met Federal LDV standards for total hydrocarbons, organic material hydrocarbon equivalent, carbon monoxide (CO), oxides of nitrogen (NO_x), and evaporative emissions.

Safety issues concerning the first year of AMFA AFV operation were addressed, and information was collected from weekly driver survey forms and vehicle maintenance records issued by the authorized dealership service centers. In January 1991, AMFA M85 AFV's were introduced into the Federal fleet. Personnel of the four participating fleets received an orientation that included information on M85 AFV precautions, refueling procedures, and proper operation. The orientations provided essential information on precautions for using M85 compared to those for gasoline; covered fire, health, and safety precautions, including skin contact, inhalation, and ingestion effects; and outlined the specific steps to follow when refueling with M85. In addition, Site Operators Guides were distributed to participating and interested fleet personnel in the four areas: Washington, DC; Detroit;

Table 2-2. On-Road Fuel/Energy Economy Summary of the AMFA LDV Fleet

AMFA Federal Fleet Sites/Vehicles	Monthly Average Fuel Economy: Miles/Gallon	Monthly Average Fuel Economy: Miles/Gallon—Gasoline Energy Equivalent	Cumulative Average Energy Economy: Btu's/Mile
Washington, DC			
M85 AFV's	10.9	19.3	5,959
Gasoline AFV's	19.1	—	6,243
Detroit			
M85 AFV's	14.1	24.8	4,536
Conventional gasoline vehicles	22.5	—	5,404
Los Angeles			
M85 AFV's	13.5	23.7	4,672
Conventional gasoline vehicles	24.6	—	4,771
San Diego			
M85 AFV's	14.7	25.9	4,265
Conventional gasoline vehicles	21.6	—	5,249

Los Angeles; and San Diego. Each guide was tailored to show the locations of the nearby M85 refueling stations for that city. Vehicle owner guide supplements also were made available by the vehicle manufacturers; these supplements informed drivers about such issues as vehicle operation, service and maintenance, dealer assistance, unique components, and precautions in operating the M85 AFV's.

During the first year of operation (January through September 1991), no safety-related accidents or collisions were reported involving operation of AMFA LDV's participating in this program; and there were no documented safety-related incidents concerning refueling, maintenance, or servicing of the M85 AFV's.

Various promotional activities were conducted to educate the public about AFV's and their operation. Magnetic decals affixed to vehicle exteriors indicated these vehicles were flexible-fuel vehicles capable of operating on methanol as well as gasoline. Both vehicle manufacturers have identification on the outside of the 65 AMFA AFV's distinguishing them as variable or flexible-fuel vehicles and have supplemented the original vehicle owner's manual with information on precautions to be observed when using M85 and servicing the vehicle and information on proper vehicle operation.

In 1991, DOE prepared and distributed various publications on the objectives of AMFA program, current and planned AMFA demonstration projects, and technology facts on alternative fuels such as compressed natural gas (CNG), liquefied natural gas (LNG), methanol, ethanol, and liquefied petroleum gas (LP gas). Similarly, the National Renewable Energy Laboratory has published information concerning the initiation, function, and operation of the Alternative Fuels Data Center. The 29 public refueling facilities, which dispense both M85 fuel and gasoline, clearly distinguish M85 fuel dispensers from conventional gasoline fuel dispensers. The M85 fuel dispensers display information pertaining to the safety precautions of refueling with M85 and a warning that M85 fuel should be used only in vehicles designed to operate on it.

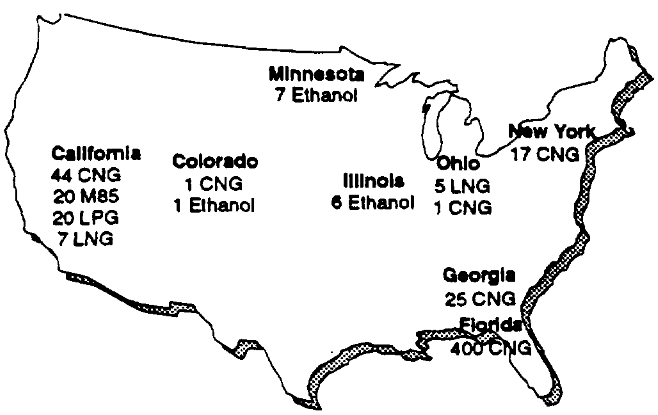
2.2.2 Truck Commercial Application Program—Section 400BB

The objective of the Truck Commercial Application Program is to encourage the use of alcohol and natural-gas fuels by establishing and conducting one or more truck or other heavy-duty vehicle (HDV) commercial application projects that operate in real-world environments. The program will collect data from heavy-duty trucks operating on alternative fuels to establish an emissions, performance, and durability database. The database will be used to provide proper comparisons among alternative fuels and conventional petroleum-based fuels.

By the end of 1992, approximately 100 alternative-fuel medium- and heavy-duty trucks will be participating in the Truck Commercial Application Program. Figure 2–3 shows the number of trucks that will operate in various States and the fuel types used.

The major participants in this program include the American Trucking Association's Foundation/Trucking Research Institute, which is under contract to manage a program that currently includes 14 trucks (4 LNG, 9 CNG, and 1 ethanol) operated by 6 companies in 3 States and 2 Canadian provinces. In a project cofunded with the South Coast Air Quality Management District (SCAQMD), Federal Express is operating 21 CNG, 20 methanol, and 20 LP gas medium-duty delivery vans in California. DOE is partially funding the required fuels and facilities, fleet operations, the study design, and data management. Other participants include the New York City Department of Sanitation (7 CNG refuse packers), the Illinois Department of Natural Resources (6 ethanol heavy-duty trucks), the California Energy Commission (3 CNG heavy-duty trucks), and the U.S. Postal Service (10 CNG heavy-duty trucks).

Figure 2–3. Locations of Alternative-Fuel Medium- and Heavy-Duty Trucks



2.2.3 Alternative Fuels Bus Testing Program—Section 400CC

The objective of the Alternative Fuels Bus Testing Program is to help State and local government agencies test, in urban settings, buses capable of operating on both alcohol and natural-gas fuels. In particular, the program aims to generate information on emissions, durability, safety and health, fuel economy, and other issues that industry and other organizations need to supply and operate such buses in commercial environments.

Because the Department of Transportation's Federal Transit Administration (FTA), formerly the Urban Mass Transportation Administration (UMTA), is the agency most closely involved in urban transit buses, it has been assigned a lead role for this project by an Interagency Agreement between DOE and FTA. Approximately 430 alternative-fuel transit buses are projected to be in the program by the end of 1992. This includes 240 CNG, 170 methanol, 14 ethanol, and 7 LNG transit buses. Several transit authorities, including those in Phoenix, Denver, Los Angeles, and New York City, have been selected to gather more detailed operating, maintenance, and emission data. Data generated from methanol, ethanol, CNG, and LNG fuel transit buses are being transmitted to the Alternative Fuels Data Center for processing and analysis.

2.2.4 Alternative Fuels Data Center

DOE has identified the National Renewable Energy Laboratory (formerly SERI) as the field manager to support the alternative-fuel evaluation-demonstration efforts. The Alternative Fuels Data Center (AFDC), located at NREL, began full operations in October 1991. AFDC's primary purpose is to collect and analyze available data on alternative fuels. AFDC provides unbiased, accurate information on alternative fuels and alternative-fuel vehicles to government agencies, private industry, research institutions, and other interested organizations. The objectives of AFDC are to:

- Design, implement, and operate a computerized database system for storage, retrieval, and analysis of available data on alternative-transportation-fuel demonstration and evaluation efforts
- Provide user access to external users in the scientific, industrial, and government communities

AFDC is collecting and analyzing, among other things, mileage accumulation, driveability, fuel consumption, fuel analyses, oil analyses, and exhaust emissions. Data on maintenance, dynamometer performance, health and safety issues, and other parameters are collected and analyzed as they become available. Data from four sites using alternative-fuel urban buses chosen for in-depth data collection also are being collected by AFDC. The number of sites is anticipated to expand to seven in 1992.

AFDC uses an Oracle® Relational Database Management System along with a statistical software package that can provide statistical, graphic, and textual information. The database has been designed as a multiuser network with remote accessibility controlled by log-in identification.

2.2.5 Interagency Commission on Alternative Fuels

In April 1989, the Secretary of Energy appointed the Deputy Secretary of Energy to be the Secretary's designee to, and Chairman of, the Interagency Commission on Alternative Fuels. Members of the Interagency Commission included representatives of the Departments of Energy, Transportation, Labor, Defense, Agriculture, as well as EPA, GSA, and the U.S. Postal Service. The Commission's functions included the following:

- Coordinating Federal agency efforts to develop and implement a national alternative-motor-fuel policy
- Ensuring the development of a long-term plan for the commercialization of alcohols, natural gas, and other potential alternative motor fuels
- Ensuring communication among representatives of all Federal agencies involved in alternative motor fuels programs or agencies interested in such programs
- Providing for the exchange of information among persons working with, or interested in working with, the commercialization of alternative motor fuels

As noted in section 400DD(h) of AMFA, the Commission will terminate coincident with the submission of this Final Report to the Senate Committees on Commerce, Science, and Transportation and Governmental Affairs and the House Committee on Energy and Commerce.

2.2.6 U.S. Alternative Fuels Council

The Chairman of the Interagency Commission also established a U.S. Alternative Fuels Council, which reports to the Interagency Commission. The Council is composed of 4 members of Congress and 16 persons from outside the Federal Government. The activities of the Council and a discussion of the Council's recommendations to the Interagency Commission are reported in Chapter 3 of this report.

2.2.7 Studies and Reports

The studies and reports program element has been established to undertake several studies mandated by AMFA and to prepare reports to

Congress on the findings of these studies. Studies to date include the following:

- Alternative-fuel LDV performance, fuel economy, safety, emissions, and operating and maintenance costs
- Disposal of alternative-fuel LDV's
- Electric vehicles
- Impacts on residential energy prices
- Natural-gas-to-methanol processing plants
- The environment

Although DOE has had a significant role in each of these studies, the lead responsibility for each varies, as shown in Table 2-3.

Five of these studies have been completed, and reports have been submitted to Congress. The electric vehicle report, *Federal Regulations Needing Amendment to Stimulate the Production of Electric/Solar Vehicles*, was completed in January 1990, as required by Section 7 of AMFA. The residential energy prices report, *Impacts on Home Heating Costs of Incentives for Alternative Fuels Vehicles*, was completed in November 1989, as required by Section 9 of AMFA. The natural-gas-to-methanol-plants report, *Assessment of Costs of Producing Methanol from Unutilized Domestic Natural Gas*, was released for public comment in July 1990, transmitted to Congress on September 30, 1990, and published as a technical report in July 1991. The light-duty-vehicle disposal report was completed in July 1991, and a draft of the environmental study, *Environmental and Economic Study of Alternative Motor Fuel Use Report to Congress*, has been completed. The *Federal Alternative Fuel Program Light Duty Vehicle Operations—First Annual Report to Congress for Fiscal Year 1991*, dated March 1992, also has been completed and submitted.

2.2.8 Program Plan

The initial Alternative Motor Fuels Act of 1988 Program Plan was developed and issued by DOE in January 1989. The program plan outlined the overall management organization, strategy, and approach to implement each element of the AMFA program and provided detailed activity descriptions, work breakdown structures, and an overall schedule to accomplish all work activities. The plan was subsequently revised in May 1989 and was revised and reissued in August 1990 to reflect accomplishments to date, provide a more current timetable for each activity, and incorporate the roles of new organizations involved in the implementation of the AMFA program. The plan has been developed from the perspective of the needs of the interested parties and reflects the experience gained in AMFA and other alternative-fuel transportation programs to date. The plan has always been intended to be flexible and is therefore subject to change as events warrant.

The overall management of the AMFA program has been established in the DOE Office of Alternative Fuels, under the Deputy Assistant Secretary for Transportation Technologies. Management responsibilities have been assigned

Table 2-3. Lead and Supporting Agencies for Studies and Reports

Study	Lead Agency	Supporting Agency	Status
Light-Duty-Vehicle Operations	DOE	EPA/DOT	Complete
Light-Duty-Vehicle Disposal	GSA/DOE	—	Complete
Electric Vehicles	DOT	DOE/EPA	Complete
Residential Energy Prices	DOE	DOT	Complete
Natural-Gas-to-Methanol Plants	DOE	—	Complete
Environmental Study	EPA	DOE/DOT	Draft

to Program Managers within the DOE Fuels Utilization and Data Analysis Division.

The program plan establishes the Alternative Fuels Data Center as the focal point for acquiring, analyzing, and disseminating all data generated during the course of the Alternative-Fuel Federal Light-Duty-Vehicle, Truck Commercial Application, and Alternative Fuels Bus Testing Programs. In addition, the plan intends that AFDC be a repository for complementary sources of analogous data that may be generated by other Federal agencies, as well as cooperating State and local alternative-fuel programs.

The program plan also calls for the development of a Transportable Engine Emissions Testing Laboratory at West Virginia University. This facility has been designed and constructed as a transportable dynamometer to measure the major heavy-duty engine exhaust compounds as the vehicle is operated through a preselected test cycle. The laboratory facility can be transported to a test site located at, or nearby, the home base of the vehicles to be tested. The laboratory consists of two major units: a power absorber unit mounted on a flatbed trailer and an emissions testing unit located in a separate, enclosed instrument trailer that is parked near the power absorber. Through June 1992, the facility conducted emissions tests in Pittsburgh, Houston, Phoenix, and Wood County, West Virginia; the July-December 1992 schedule includes New York City; Dayton, Ohio; Peoria, Illinois; Tacoma, Washington; and Los Angeles and Denver.

The strategy adopted for the AMFA program plan is designed to meet both the intent and spirit of AMFA by encouraging the commercial production of methanol, ethanol, and natural gas vehicles and to promote the widespread consumer use of these fuels in the transportation sector. Key features of the strategy include an effort to maximize the use of other Federal, State, and local government projects as well as private sector initiatives. This is accomplished not by duplicating previous or ongoing efforts but by complementing, where appropriate, those efforts where data and other informational needs exist but are not being met. In addition, industry participation has been actively solicited to gain a better insight into its needs as well as to leverage industry's ongoing efforts to maximize the program's benefits to the greatest extent possible. Hopefully, this will result in a self-sustaining industry that will continue to expand once the AMFA program has ended.

Separate approaches, associated work breakdown structures (WBS's), and schedules were developed for each of the demonstration programs. The principal elements of the Alternative-Fuel Federal Light-Duty Vehicle Program WBS include planning and assessments, light-duty-vehicle procurement, vehicle operations assessment, and vehicle disposal assessment. The WBS elements of the Truck Commercial Application Program include a technical and application assessment and commercial application implementation. WBS elements for the Alternative Fuels Bus Testing Program include initial planning and assessment and testing implementation.

2.3 Executive Order 12759 Program Status

Section 11 of Executive Order 12759, *Federal Energy Management*, states that the "Secretary of Energy, with the cooperation of other appropriate agencies . . . shall ensure that the maximum number of vehicles acquired annually are alternative fuel vehicles as required by the Alternative Motor Fuels Act of 1988." DOE has undertaken a number of activities to implement the requirements of Section 11, with an emphasis on the following areas:

- Expanding the market for AFV's to encourage OEM's to expand the availability of alternative-fuel models
- Reducing vehicle acquisition costs
- Fostering the growth of alternative-fuel refueling facilities and other associated infrastructure elements

This DOE fleet program is intended to supplement DOE's ongoing AMFA program by expanding alternative-fuel efforts from a data collection, demonstration, and analysis activity to one directed toward the widespread acquisition and day-to-day operation of large numbers of AFV's. AMFA will continue demonstration programs to facilitate a steady advancement of commercially available alternative-fuel technologies; the commonalities between the two programs provide for some efficiency of resources in carrying them out. Target goals for the acquisition of AFV's under the Executive Order are as follows:

- FY 1993: 5,000 AFV's in Federal fleet
- FY 1994: 7,500 AFV's in Federal fleet
- FY 1995: 10,000 AFV's in Federal fleet
- FY 1996: AFV's acquired by each agency equal 25 percent of acquisitions
- FY 1997: AFV's acquired by each agency equal 33 percent of acquisitions
- FY 1998: AFV's acquired by each agency equal 50 percent of acquisitions

DOE has developed a strategy to (1) resolve the "chicken-and-egg" issue by working with all Federal agencies to develop a 5-year plan that delineates the combined Federal plans for purchasing AFV's; (2) involve industry by demonstrating a sizable 5-year market for AFV's; and (3) resolve other issues through the issuance of a guidance document. This guidance document, which has been completed and disseminated to all interested Federal agencies, establishes policy goals, defines fuel types, sets funding policy, and outlines the role for OEM's and converted vehicles. It also outlines a fuel infrastructure strategy and identifies education and training needs.

DOE, working closely with GSA, has assisted the other agencies in preparing individual agency 5-year acquisition plans and consolidated them into a single Federal 5-year plan for consideration by industry. Figure 2-4 summarizes the Federal agency requests for AFV's by vehicle and fuel types; Figure 2-5 illustrates the relative number of requests for ethanol versus methanol vehicles. In addition to indicating a widespread Federal agency interest in acquiring AFV's, the results of this planning effort also indicated the need for AFV types that are not readily available from OEM's (these are listed in Table 2-4).

The planning effort also indicated a readiness to undertake conversions of existing vehicles, which will constitute approximately 19 percent of the AFV requests in FY 1993 and decline to 6 percent in FY 1995, FY 1996, and FY 1997. Near-term Executive Order activities include

Figure 2-4. Federal Agency Requests for AFV's

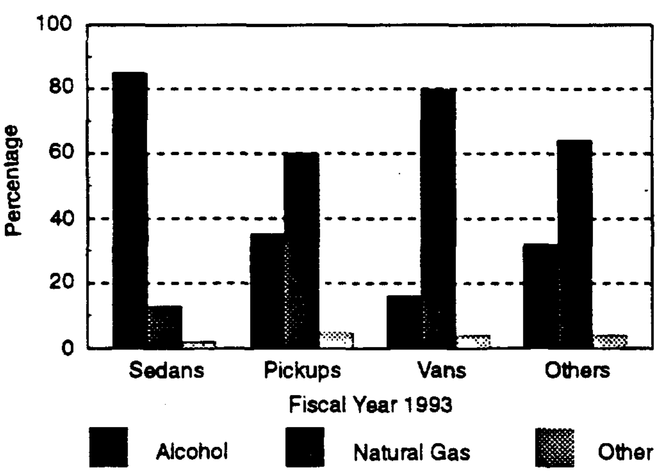


Figure 2-5. Federal AFV Requests: Methanol Versus Ethanol

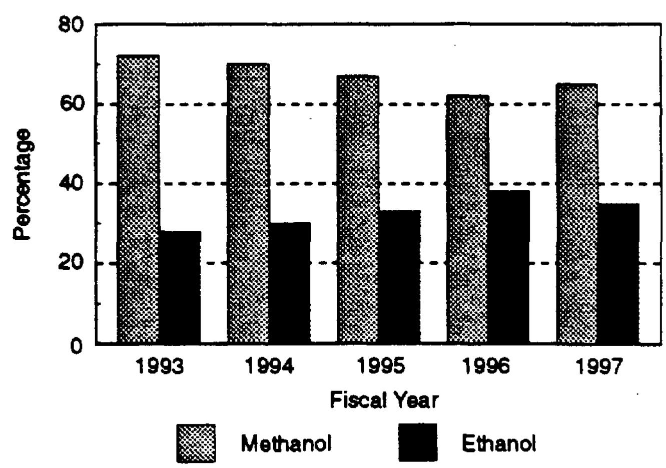


Table 2-4. AFV Types Needed To Meet Federal Agency Requests That Are Not Readily Available From OEM's

Flexible-Fuel Alcohol	Gaseous Fuel
Mini Van	Mini Van
8-Passenger Van	Compact Sedan
Compact Sedan	Midsize Sedan
Fullsize Sedan	4x4 Pickup
Compact Pickup	Light-Duty Truck
Fullsize Pickup	Utility Truck
4x4 Pickup	
Light-Duty Truck	
Medium-Duty Truck	
Utility Truck	

presenting the results of the 5-year combined Federal AFV acquisition plan to industry, determining vehicle placement, initiating infrastructure development, and updating the agency 5-year plans and AFV requests.

2.4 State and Local Government Program Status

The State and Local Government Program coordinates the planned acquisition of AFV's for Federal agency fleets with those of State and local agencies. The program is designed to combine the Federal procurement plan with State and local plans to maximize the production and development of AFV's and AFV infrastructure by manufacturers, conversion firms, and alternative-fuel suppliers. Demonstrating a substantial and sustained demand for AFV's may expand OEM production, thereby lowering incremental AFV costs and increasing the commercial development of an alternative-fuel infrastructure. The program is intended to use DOE's existing national network to produce information of high potential value to the States. State participation in this program is completely voluntary.

DOE's Office of Technical and Financial Assistance (OTFA) and the 10 OTFA Regional Support Offices (RSO's) will interact closely with the State and local agencies. The RSO's will provide technical assistance to State and local agencies for the development of 5-year State and local plans. The RSO's also will contact potential industry partners at the State and local level to increase the amount of commercial involvement in the program, particularly in the development of fuel infrastructure. DOE's Office of Alternative Fuels will provide technical assistance to OTFA and the RSO's.

There are several benefits to the participating State and local agencies. First, they will have early access to technical information from Federal AFV demonstrations and information on Federal procurement specifications and standards. Second, the process can help identify potential problem areas before State and local procurements are initiated. Finally, coordination of Federal, State, and local procurement plans is expected to lower the costs of AFV's for State and local agencies and increase the availability of an infrastructure.

2.5 Alternative-Fuel School Bus Program

With the assistance of DOE's Office of Alternative Fuels, the DOE Office of National Programs, in cooperation with State energy offices, is promoting and managing an aggressive, comprehensive Alternative-Fuel School Bus (AFSB) Program through State energy offices, local municipalities, and public-private nonprofit schools and hospitals. The goal of this program is to introduce the use of alternative fuels in school bus fleets in State government and local municipalities. School buses are very amenable to alternative-fuel use because they typically operate from a centralized location in urban fleets and in major populated cities, where air pollution is of concern and central refueling is feasible.

DOE will cost-share the purchase of OEM alternative-fuel school buses based on a case-by-case evaluation. The DOE RSO's will coordinate AFSB program activities in conjunction and cooperation with local State energy offices and municipalities. Each State energy office and local municipality participating in the program will establish and conduct an alternative-fuel school bus project. Major participants cooperating with the State energy offices and local municipalities include bus and chassis manufacturers, local utilities, fuel suppliers, Federal and State transportation agencies, industry associations, school districts, and other interested parties. An important part of the program will be in-use data collection, with primary emphasis on school bus safety, life-cycle costs, and exhaust emission levels. This program will meet the following objectives:

- Provide support for the purchase and demonstration of OEM alternative-fuel school buses
- Provide education and training to State energy offices and local municipalities
- Support industry on the proper and safe use of alternative fuels
- Collect information and data on in-use operation of school bus fleets using alternative fuels
- Coordinate with other programs to reduce school bus energy consumption

In early 1992, the Offices of Alternative Fuels and National Programs released requests for proposals for AFSB projects to each of the State energy offices. Ten awards will be granted by DOE, resulting in 40 to 50 alternative-fuel OEM school buses, depending on the amount of matching funds/cost-sharing. Approximately 10 DOE RSO's will act as local program coordinators with the State energy offices and municipalities, providing assistance and direction to interested participants. DOE will cost-share purchases of OEM alternative-fuel school buses, assist and conduct training programs on the safe use and operation of alternative fuels, and provide technical assistance. The State energy offices and local municipalities will establish refueling facilities and will be encouraged to cost-share with local utilities or fuel suppliers in promoting the development of refueling facilities for alternative-fuel school buses. The school districts and municipalities will be responsible for the collection and reporting of data, as specified or approved by DOE, on alternative-fuel and "control" school buses over a 5-year period. Currently, the State of West Virginia and the City of Parkersburg are conducting an alternative-fuel school bus project in the Wood County school system. Four dedicated CNG school buses are in operation; data on in-use operation and exhaust emission levels are being collected and communicated to the Alternative Fuels Data Center.

2.6 Commercialization of Alternative Fuels

As the previous sections of this chapter indicate, many types of AFV's have reached the commercialization stage. In addition to the roles of DOE AMFA programs and other AFV programs in this effort, there are a number of other government and nongovernment initiatives that are fostering this growing commercialization trend.

Federal, State, local, and private plans for increased use of alternative fuels in the near future have prompted OEM vehicle manufacturers and vehicle conversion companies to increase their capabilities to produce AFV's. Though the vehicle conversion companies will play a very important role in the early implementation years of AFV's, OEM's will have the greatest impact on long-term, large-scale AFV use because of their enormous production capabilities.

Significant markets for AFV's are beginning to develop, and the OEM vehicle manufacturers are taking orders. General Motors (GM) has indicated that they can produce about 4,000 methanol variable-fuel vehicles (VFV's) annually; however, orders for fleet markets around the United States and Canada and private vehicles in California have currently totaled only about 1,000 for 1992. GM also will produce about 50 ethanol VFV's for fleets in Illinois and Wisconsin and for use in the Federal fleet. Orders for GM-produced CNG pickups have totaled about 2,000 for model year 1992. GM currently offers factory propane retrofits for two of its 1992 medium-duty trucks and also has produced a number of electric G-Vans based on its Vandura, a full-size Chevrolet van. Additionally, GM expects to begin commercial production of its prototype Impact electric sports car by early 1995.

The Chrysler Corporation has announced that it will produce 2,100 methanol flexible-fuel vehicles for markets in Washington, DC, and California in 1993, and they also will produce ethanol FFV's in the near future. Chrysler has already provided 10 methanol FFV vans to the California Energy Commission for demonstration purposes. Chrysler also has stated that they could develop a production capacity of 100,000 in 1994 and 1995. Chrysler presently produces dedicated CNG B-model vans and wagons. Chrysler also has initiated small-scale production of the TeVan electric vehicle, an electric version of its minivan that uses nickel-iron batteries, to help fleets gain experience with electric vehicles.

Ford has been very active in demonstrating AFV's to reach the commercialization stage. In the early 1980's, Ford produced approximately 680 methanol Escorts, most of which were put into service in California. Ford pioneered the development of methanol FFV's, initially applied to Escorts and then to 1986 and 1989 Crown Victorias. Ford, together with GM, produced the first light-duty AFV's for the AMFA Alternative-Fuel Federal LDV Program, and it currently produces methanol FFV Taurus sedans. Natural-gas vehicles produced by Ford include the CNG Ranger pickup trucks in 1984 and 1992 and later-model-year Club Wagons and Econoline Vans. Ford also has produced LPG AFV's, including 1982 through 1984 production LPG Granada and LTD sedans and a current-production F150 4.9L pickup truck prep package. Additional AFV's produced by Ford include full-size methanol FFV vans and CNG Crown Victoria sedans; CNG pickup trucks are planned. Ford also has produced a small number of Ecostar electric vehicles, which are electric versions of its Escort minivan produced and sold in Europe. Ford has offered LPG versions of their medium-duty trucks for many years.

Several heavy-duty-vehicle manufacturers are producing alternative-fuel engines and vehicles. The Cummins Engine Company is producing a natural gas transit bus engine for model year 1993. The Detroit Diesel Corporation (DDC) has produced both methanol and ethanol versions of their 6V–92TA engine for use in bus, truck, and stationary applications. Development of the Cummins natural gas and DDC methanol and ethanol engines was supported in part by DOE. Production of the DDC methanol 6V–92TA engine began in the spring of 1992 to fill an order for more than 300 methanol buses to be operated in California by the Southern California Rapid Transit District. DDC also has produced methanol versions of its 6L–71 engines for use in heavy-duty trucks and plans to offer a limited number of dedicated natural-gas transit bus engines in the fall of 1992 and full EPA- and California-emissions-certified production engines in the summer of 1993. The Mack Truck Company plans to offer a natural-gas engine for heavy-duty-truck use beginning in 1995.

Extensive commercialization efforts are under way in a number of States, most notably in California, New York, and Texas. The California program for demonstrating and commercializing alternative fuels may be the most advanced of any in the country, primarily because of the State's severe air-quality problems. Over the last 14 years, the State of California has helped put more than 2,000 methanol LDV's in service in California. The California Energy Commission also is subsidizing the incremental costs of 100 ¾-ton CNG pickup trucks. In addition to LDV's, several demonstrations of alternative fuels in transit buses and heavy-duty trucks have been held in California as well. In response to the present and future fueling needs of the various methanol demonstration programs around the State, the California Energy Commission established the California fuel methanol reserve. Currently, there are more than 30 retail outlets providing M85 fuel in California, and more are planned. The California Pilot Test Program, a provision of the Clean Air Act Amendments of 1990 (CAAA), requires that at least 150,000 clean-fuel vehicles be sold annually in California from 1996 through 1998 and 300,000 annually thereafter. Several alternative fuels have potential as clean fuels because of their emissions-reduction benefits.

In the State of New York, alternative-fuel use in the transportation sector continues to gain support. The New York State Energy Plan calls for implementation of a total of 268 alternative-fuel light- and heavy-duty vehicles in State fleets by 1996 and the establishment of numerous refueling facilities across the State. The New York State Energy Research and Development Authority is currently overseeing the operation of several methanol and CNG light- and heavy-duty vehicle demonstrations across the State. Several natural-gas utilities in New York are promoting the use of natural-gas vehicles by operating large CNG vehicle fleets and providing CNG vehicle conversion services and CNG refueling station installations. Some of the CNG refueling stations offer public access to encourage local fleet conversions to CNG. New York also has adopted the California Low Emission Vehicle emissions standards (see Chapter 4, Section 4.3) as allowed by the CAAA, which will likely increase the use of AFV's.

Texas has instituted an alternative-fuels program because of its large indigenous supplies of natural gas and significant air-quality problems. Texas state law now requires that new school buses purchased for fleets of more than 50 vehicles or new vehicles purchased for State agency fleets of more than 15 vehicles must be fueled with CNG or some other alternative fuel. The law further requires that the number of alternative-fuel vehicles for such fleets must equal 30 percent of total fleet vehicles by 1994, and 50 percent by late 1996. Transit buses, local fleets, and private fleets are or may be required to use alternative fuels.

A number of other State and local programs to promote the use of AFV's have been established around the country. For instance, several other States besides California, New York, and Texas have called for substantial purchases of AFV's for their State-owned fleets. Several States also offer State fuel-tax exemptions for alternative fuels for both fuel producers and fuel users, thereby making it more economically attractive to produce, dispense, and use alternative fuels. Income tax credits for AFV and refueling station costs have been instituted in some States. Similarly, some States have reduced the State license tax for AFV's or provided a State rebate for the purchase of an AFV. Finally, several States, particularly in the Northeast, have adopted or are planning to adopt the California Low Emission Vehicle emissions standards as allowed by the CAAA.

The U.S. Alternative Fuels Council

3.1 Introduction

The U.S. Alternative Fuels Council was established by the Alternative Motor Fuels Act of 1988 (AMFA, Public Law 100–494). The council is composed of four members of Congress, appointed by congressional leadership, and 16 persons from outside the Federal Government, each appointed by the chairman of the Interagency Commission on Alternative Motor Fuels (see Appendix E for a listing of council members).

3.2 Council Operations and Reports

The council held 11 meetings in cities throughout the United States on a variety of topics related to alternative-fuel use and commercialization. The council discussed issues such as the need to integrate environmental and energy goals of alternative-fuel use, alternative-fuel technology, national energy security, reformulated gasoline, and the cost-effectiveness of using alternative fuels to improve air quality.

Presentations made by invited experts gave the council insight into differing opinions surrounding alternative fuels. Some topics included foreign gas for methanol, domestic biofeedstocks, liquefied petroleum gas (LP gas) feedstocks, the status of the Clean Air Act, pipeline gas in the United States and Canada, and Department of Energy (DOE) research on alternative motor fuels.

At its December 1990 meeting, the council adopted a resolution that set a goal for national alternative-fuel use in the year 2005 (since changed to 2010). The resolution is presented in Appendix B of this report. In response to this resolution, DOE developed a detailed scenario outlining a specific, hypothetical pattern of future alternative-fuel use to provide a context for examining the potential impacts of the use of alternative transportation fuels. The DOE scenario is consistent with the goal contained in the council's resolution and involves the displacement of 25 percent of U.S. motor-fuel use with alternative transportation fuels by the year 2010. The detailed scenario is described in the *Second Interim Report of the Interagency Commission on Alternative Motor Fuels.*

On November 21, 1991, the council cochairmen sent a letter to the then-Chairman of the Commission, Deputy Secretary W. Henson Moore, providing a brief report of the progress of the council to date, with an enclosure describing the council's mission statement and policy guidelines agreed upon. That letter, with enclosure, is presented in Appendix C.

3.3 Report on the Commercialization of Alternative Fuels

At a meeting on September 19–20, 1991, the council tasked the Congressional Research Service (CRS) to prepare a series of reports on commercialization of alternative fuels. In addition to a summary report, individual reports were to be prepared on each of five fuels: ethanol, methanol, LP gas, compressed natural gas, and electric vehicles. For each fuel, CRS was to evaluate a goal of achieving a 5-percent share of the motor vehicle market by the year 2000. Given a hypothetical budget of $1 billion per year for each fuel, CRS was to discuss how this money could effectively be used to achieve commercialization for the fuel.[1] The council would then prepare its own report based on the CRS material and by drawing on the expertise of the council members. The council's report on commercialization of alternative fuels was completed in September 1992.

[1]Commercialization is defined by the council as the point at which the fuel is competitive in the marketplace without continuing subsidy.

Interactions Among AMFA Goals, New National Energy Legislation, the Clean Air Act Amendments of 1990, and State-Level Clean- and Alternative-Fuel Programs

The primary goal of the Alternative Motor Fuels Act of 1988 (AMFA) is to encourage the development and use of alternative transportation fuels to address national energy security and air-quality concerns. The *Second Interim Report of the Interagency Commission on Alternative Motor Fuels* reviewed the interactions among these concerns and provisions of the Clean Air Act Amendments of 1990 (CAAA) and the California Low Emission Vehicles and Clean Fuels Program. Since the publication of that report, energy legislation requiring the purchase of alternative-fuel vehicles (AFV's) in fleets has been adopted by both the Senate and the House of Representatives (see Chapter 1). Additionally, an increasing number of States have adopted specific AFV requirements.

This chapter provides an overview of these activities. It also provides estimates of the level of alternative-fuel use and subsequent oil displacement that can be anticipated as a result of this use.

4.1 1990 Clean Air Act Amendments Requirements

CAAA provisions to encourage the use of nonpetroleum fuels and fuel additives include the reformulated and oxygenated gasoline requirements (section 219 of the Amendments), the clean-fuel centrally fueled fleet program (section 229), the California Pilot Test Program (section 229), the low-polluting fuel requirement for urban buses (section 227), and Phase II of the emissions standards for conventional vehicles (section 203). Each of these provisions is briefly described below.

4.1.1 Reformulated and Oxygenated Gasoline

The oxygen-content requirements of the reformulated gasoline (RFG) and oxygenated gasoline provisions of the CAAA will lead to substantial use of oxygenates in gasoline. Such use of oxygenates will displace petroleum, thereby advancing the goals of AMFA. Methyl tertiary-butyl ether (MTBE), produced from methanol and isobutylene, and ethanol will be among the oxygenates used.

The CAAA require that all gasoline sold year-round in the nine worst ozone nonattainment areas with a 1980 population of more than 250,000 must be reformulated beginning in 1995. Several content- or performance-based standards must be met, including a minimum oxygen content of 2.0 percent by weight. The nine areas are Los Angeles, Houston, New York, Baltimore, Chicago, San Diego, Philadelphia, Milwaukee, and Hartford. Approximately 22 percent of the U.S. population lives in these areas.

All other ozone nonattainment areas (approximately 90) may opt into the program effective 1995 or later. However, if there is insufficient domestic capacity to produce this RFG, the Environmental Protection Agency (EPA) may delay the use of this fuel up to 3 years in these opt-in areas. Another one-third of the U.S. population lives in these areas. All members of the Northeast Ozone Transport Commission (OTC) that have nonattainment areas in their States have formally requested opt-in to the RFG program. The OTC includes 11 States extending from Maine to Maryland, the District of Columbia, and the metropolitan section of Virginia bordering the District.

Beginning in November 1992, 39 carbon monoxide (CO) nonattainment areas also will be required to use oxygenated fuels during that portion of the year (winter) when their areas are prone to high ambient concentrations of CO. These fuels must be used for a minimum of 4 months, but the time period can be longer. The fuel must contain no less than 2.7 percent oxygen by weight. The oxygen level may be raised to 3.1 percent in CO areas classified as "Serious" in 2001.

4.1.2 Clean-Fuel Centrally Fueled Fleet Program

The CAAA clean-fuel centrally fueled fleet program requires that in certain ozone and CO nonattainment areas, vehicles in fleets of 10 or more that are centrally refueled or capable of being centrally refueled must be clean-fuel vehicles (CFV's). Some vehicles are exempt, for example, rental fleet vehicles and law enforcement and other emergency vehicles. This program applies to ozone nonattainment areas with ozone design values of 0.16 parts per million (ppm) or higher and CO nonattainment areas with CO design values of 16 ppm or higher and a population of 250,000 or more. Twenty-two nonattainment areas are included in the program. The program begins in 1998; by model year 2000, 70 percent of all new vehicles in the fleets covered by the program must be CFV's. The program can be delayed to 2001 if vehicles meeting these standards are not being sold in California in 1998.

The clean-fuel centrally fueled fleet program standards for passenger cars (PC's) and light-duty trucks (LDT's) are presented in Table 4–1. Transitional low-emission vehicles (TLEV's) are not part of the clean-fuel fleet program, but are part of the California Pilot Test Program discussed below. Federal standards also are set for heavier LDT's and heavy-duty vehicles (HDV's) up to 26,000 pounds. Fleet vehicles must meet the Phase II standards. As indicated in Table 4–1, the Federal CFV Phase II standards are equivalent to California's Low Emission Vehicles (LEV) exhaust standards. (See Section 4.3 for a discussion of the California program.) Vehicles able to meet the standards using RFG are considered CFV's; AFV's also may be used. For vehicles using a fuel other than gasoline, the level of the nonmethane organic gas (NMOG) emissions will be adjusted based on the ozone reactivity of their emissions relative to vehicles using gasoline.

The CAAA require EPA to establish a credit program that provides credits to fleets exceeding CFV purchase requirements. EPA has drafted a final rule that will provide credits to fleets for purchasing more CFV's than required in the fleet program, for purchasing more cleaner vehicles

Table 4–1. Clean-Fuel Centrally Fueled Fleet Program Vehicle Exhaust Emission Standards for PC's and LDT's at 50,000 Miles
(grams per mile)

CAAA	California	NMOG[a]	CO	NO_x	Formaldehyde
Phase I[b]	TLEV	0.125[c]	3.4	0.4	0.015
Phase II[b]	LEV	0.075[c]	3.4	0.2	0.015
	ULEV	0.040[c]	1.7	0.2	0.008
	ZEV	—	—	—	—

Notes: LDT's less than 3,750-pounds LVW and up to 6,000-pounds GVW
NMOG = nonmethane organic gas; CO = carbon monoxide; NO_x = nitrogen oxide
TLEV = transitional low-emission vehicle; LEV = low-emission vehicle; ULEV = ultra low-emission vehicle; ZEV = zero-emission vehicle
[a] Adjusted for clean fuels
[b] Phase I emission standards applicable to California Pilot Program in 1996. Phase II emission standards applicable to the CAAA fleets program in 1998 and to the California Pilot Program in 2001.
[c] FFV's operating on alternative fuel must meet these standards. When operating on gasoline, they may meet the next less stringent standard.

than required, or for purchasing them earlier than required. Fleets would generate additional credits by purchasing light-duty vehicles (LDV's) and LDT's that meet the ultra-low-emission-vehicle (ULEV) and zero-emission-vehicle (ZEV) standards shown in Table 4–1. A credit program for HDV's also is proposed. Further, the CAAA require EPA to establish a program granting exemptions to fleet CFV's from certain transportation control measures (TCM's). EPA is proposing to limit the exemptions to temporally based TCM's unless the CFV's also qualify as inherently low-emission vehicles (ILEV's). ILEV's must meet additional evaporative emissions standards and, in the heavier classes, more stringent nitrogen oxide (NO_x) standards than required for LEV's.

4.1.3 California Pilot Test Program

The CAAA California Pilot Test Program is distinct from the California Low Emission Vehicles and Clean Fuels Program. The Pilot Test Program requires the production and sale of CFV's in California beginning with the 1996 model year. In the first 3 years of the program, 150,000 new clean-fuel LDV's and LDT's must be sold annually; beginning in 1999, annual sales must reach 300,000. The CFV standards are to be phased in; by 2001, these vehicles must meet California Low-Emission Vehicles and Clean Fuels Program standards. As in the CAAA clean-fuel centrally fueled fleet program, vehicles able to meet the LEV standards with RFG are considered to be CFV's. AFV's may also be used, and other States may opt into the program. However, these States are not allowed to mandate any CFV or clean-fuel sales.

4.1.4 Low-Polluting Fuel Requirement for Urban Buses

Beginning with model year 1994, all new urban buses are required to meet a 0.05-gram-per-brake-horsepower-hour (g/bhph) particulate matter (PM) standard. This standard may be raised to 0.07 g/bhph if the lower standard is not technically feasible. EPA is required to conduct a testing program to determine whether buses can comply with this more stringent standard. If buses cannot meet this standard over their full useful life, then EPA must implement a program requiring the use of low-polluting fuels in urban buses in Metropolitan Statistical Areas (MSA's) or Consolidated MSA's (CMSA's) with populations of 750,000 or more. Under this contingent program, the buses will be required to operate exclusively on methanol, compressed natural gas (CNG), ethanol, propane, or other low-polluting fuels. EPA also may extend this program to smaller urban areas for health benefits.

4.1.5 Phase II Standards

Phase I of the conventional vehicle standards will be implemented beginning with model year 1994 (see Table 4–2). EPA and the Office of Technology Assessment are required to conduct a study to determine if Phase II standards should be required beginning with model year 2004. These standards would cut the Phase I 50,000-mile nonmethane hydrocarbon (NMHC), CO, and NO_x standards in half and extend the useful life for which they must apply. The study will examine the availability of technology to meet the standards and the need for and cost-effectiveness of obtaining further emissions reductions. Other standards also may be considered.

4.2 National Alternative-Fuel Fleet Legislation

Chapter 1 of this report summarizes the fleet provisions of the Senate and House energy bills. Assuming that some version of these bills will be enacted, certain fleets in major metropolitan areas will be required to purchase AFV's, as opposed to CFV's. Vehicles able to operate only on RFG will not qualify for these programs. See Chapter 1 for additional details.

4.3 California's Low Emission Vehicles and Clean Fuels Program

In September 1990, California adopted the Low Emission Vehicles and Clean Fuels Program. The emissions standards for LDV's and LDT's under 3,750 pounds LVW are presented in Table 4–1; fleet average NMOG standards are shown in Table 4–3.

Table 4-2. Conventional Passenger-Car and LDT Standards: Federal and 1993 California
(grams per mile)

CAAA	NMHC	CO	NO_x	PM	Miles
Current[a]	0.41[b]	3.4	1.0	0.20	50,000
1994+ (Phase I)	0.25	3.4	0.4[c]	0.08	50,000
	0.31	4.2	0.6[c]	0.10	100,000
2004+ (Phase II)	0.125	1.7	0.2		100,000
California	**NMHC**	**CO**	**NO_x**	**PM**	**Miles**
Current	0.39	7.0	0.4	0.08	50,000
1993+	0.25	3.4	0.4	0.08	50,000

Note: LDT's less than 3,750-pounds LVW
[a] PC only
[b] THC
[c] Higher for diesel

Under this program, vehicle manufacturers would be allowed to sell any mix of conventional vehicles or transitional low-emission vehicles, LEV's, ULEV's, and ZEV's to meet these standards, with one exception. To foster the development of the cleanest vehicle technologies, California is requiring sales of some ZEV's beginning in 1998. Two percent of each manufacturer's sales must be ZEV's in that year; the ZEV sales share would rise to 10 percent by 2003. California also has established LEV and ULEV emissions standards for medium-duty vehicles under 14,000 pounds gross vehicle weight (GVW). The total number of CFV's sold under this program will be significantly greater than would be sold under the California Pilot Test Program.

California also has adopted regulations to ensure that any clean fuels needed for LEV operation would be available at convenient locations. The fuel-availability requirement would be triggered when more than 20,000 alternative-fuel LEV's are sold statewide. Fuel-availability requirements could start in southern California in 1994 and would go statewide by 1997.

Under Section 177 of the Clean Air Act, other States may adopt California's vehicle emissions standards. Using this approach, other States would be able to mandate production of vehicles meeting these standards. All members of the Northeast OTC have signed a Memorandum of Understanding committing them to propose adoption of the California Low Emission Vehicles emissions standards. Massachusetts and New York have adopted regulations committing these States to the California LEV standards beginning with model year 1995 vehicles. No State in the OTC has proposed adopting the clean-fuels component of the complete California program.

[Tabl]e 4-3. California Fleet Average Standards for Passenger Cars and ZEV Sales Requirements

Model Year	ZEV[a] (%)	Fleet Average Standard: NMOG (grams per mile)
1994	—	0.250
1995	—	0.231
1996	—	0.225
1997	—	0.202
1998	2	0.157
1999	2	0.113
2000	2	0.073
2001	5	0.070
2002	5	0.068
2003	10	0.062

Note: Includes LDT's less than 3,750-pounds LVW
[a] The percentage requirements for ZEV's are mandatory.

4.4 Other State-Level AFV Requirements

There are many State and local alternative-fuel programs already in effect that mandate the use of certain types of vehicles. Table 4–4 lists the State and local programs enacted into law that require the use of alternative (nongasoline) fuels (for more detailed descriptions of most of these programs, see the reference at the end of this chapter). Not listed in the table are the many alternative-fuel pilot/demonstration programs in operation across the country or regulations currently being drafted. None of these programs specifies emissions standards for AFV's, but many do require that such vehicles emit less pollutants than conventional motor vehicles.

4.5 Alternative-Fuel Use and Oil-Displacement Potential

To what extent the above activities will increase the use of alternative fuels and oxygenates in the transportation sector will depend on a variety of factors, including how many areas opt into the RFG program, how many States adopt the California LEV emissions standards, and what technologies and fuels will be chosen to meet the CAAA CFV standards and the California LEV standards. This report presents a baseline estimate of the long-term (year 2010) use of alternative fuels likely to be brought about by these programs. The focus is on 2010 because of the need to have a baseline against which to compare the multifuel, 25-percent-oil-displacement scenario developed by the Department of Energy (DOE) for the U.S. Alternative Fuels Council (this scenario is presented in the Second Interim Report of the Interagency Commission on Alternative Motor Fuels).

Table 4–5 presents the baseline estimate. It shows that, assuming implementation of existing and probable policies, approximately 63 percent of all gasoline will be reformulated in 2010 and that another 2.5 percent will be oxygenated, though not reformulated. Alternative motor fuels will account for approximately 3 percent of all motor-fuel use (including diesel). The oxygenates will displace slightly more than 200,000 barrels per day (b/d) of oil, and alternative fuels nearly 300,000 b/d. Together, they will displace about 5 percent of all oil use in the transportation sector.

The basis for this estimate is discussed below. Even though it is generally based on expected implementation of current policies, many assumptions are required to arrive at the numerical estimates. Alternative assumptions could lead to substantially different estimates.

4.5.1 Effect of the CAAA Clean Fuel Programs

4.5.1.1 Reformulated Gasoline

The baseline estimate assumes that all ozone nonattainment areas will opt into the RFG program by the year 2000. It also assumes that all gasoline sold in the OTC, including attainment areas, will be RFG by that time. The potential use of RFG throughout the OTC area is currently being considered to address the Northeast's severe ozone problem. Therefore, it is assumed that 100 percent RFG use will be required.

Given the logistics of gasoline distribution, there will be some spillover in the distribution and sales of RFG to attainment areas. This analysis assumes a 10-percent spillover rate for all RFG areas other than California. Spillover from the California RFG program is less likely because of the severity of the California RFG specifications and the geography of California gasoline distribution.

Data from the Auto/Oil study and other sources indicate that use of RFG will result in a 3- to 5-percent vehicle fuel economy loss because of the lower energy content of oxygenates and certain aspects of reformulation (for example, lower aromatics). This report assumes 4 percent for Federal and California Phase II RFG.

4.5.1.2 Oxygenated Gasoline

Oxygenated gasoline will be used in CO nonattainment areas that do not use RFG. A 10-percent spillover in the distribution of oxygen-

Table 4–4. State and Local Alternative-Fuel Programs

Jurisdiction	Fuels[a]	Covered Vehicles
Arizona	NG, LP gas, alcohol, H_2, electricity, solar	State-owned vehicles
California	NG, methanol, electricity	Local government fleets (voluntary incentive program)
Colorado		
Statewide	NG, LP gas, alcohol, electricity	State-owned vehicles
Denver	NG, LP gas, alcohol, electricity	Public and private fleets of 30 or more vehicles
District of Columbia	NG, LP gas, alcohol, electricity	Public and private fleets of 10 or more vehicles
Florida	Not specified	State-owned vehicles in non-attainment areas
Missouri	NG, LP gas, alcohol, H_2, electricity	State fleets of 15 or more vehicles
Iowa	NG, methanol, electricity, solar energy	State-owned passenger vehicles and light-duty pickup trucks
New Mexico	Not specified	State-owned vehicles
New York City	NG, alcohol, electricity	City-owned light-duty vehicles, public and private transit buses
Texas	NG, LP gas, methanol, electricity	School bus fleets of 50 or more buses, State fleets of 15 or more passenger vehicles
		Transit fleets, local fleets of more than 15 vehicles, private fleets of more than 25 vehicles
Washington	To be decided	State-owned vehicles

Note: Includes programs that have been enacted into law and that require the use of fuels other than gasoline and diesel fuel.

[a] NG: natural gas
LP gas: liquefied petroleum gas (propane)
H_2: hydrogen
Alcohol: ethanol or methanol, including blends of alcohol and up to 15 percent gasoline
Methanol: Includes neat methanol and blends up to 15 percent gasoline
Ethanol: Includes neat ethanol and blends up to 15 percent gasoline

Table 4-5. Baseline Estimate of RFG, Oxygenated Gasoline, and Alternative-Fuel Use in 2010 and Oil-Displacement Potential

Fuel Type	Fuel Use (billion gallons)	Oil Displacement (b/d)
RFG and oxygenated gasoline	77.3	210,000
RFG	(74.3)	
Oxygenated gasoline	(3.0)	
Conventional gasoline	41.7	
Diesel	29.4	
Alternative fuel	4.5[a]	295,000
Total	153.0	505,000

[a] Gasoline-equivalent

ated gasoline is assumed, as is a 3-percent fuel economy penalty.

4.5.1.3 Clean-Fuel Centrally Fueled Fleet Program

The baseline estimate assumes that the CFV standards specified for the clean-fuel centrally fueled fleet program need not lead to the use of AFV's. It is assumed that the CFV standards will be met by improving gasoline vehicle technology and vehicle operation on RFG. Still, AFV's may be purchased by fleets to take advantage of the credit program and transportation control measure exemptions under the ILEV component of this program. A specific estimate of the number of such vehicles was not made because these vehicles generally would be included among the AFV's required to be in use as a result of the national AFV fleet legislation currently under consideration. AFV penetration as a result of the latter program is discussed below.

4.5.1.4 California Pilot Test Program

As with the CAAA clean-fuel centrally fueled fleet program, the CFV standards specified for the California Pilot Test Program need not result in use of AFV's. Further, the required production of CFV's under this program will be met and surpassed by the California Low Emission Vehicles and Clean Fuels Program. No other States are expected to opt into the California Pilot Test Program.

4.5.1.5 Phase II Standards

There is no reason to believe that these standards, if implemented, must be met with AFV's.

4.5.1.6 Low-Polluting Fuel Requirement for Urban Buses

Alternative-fuel use in urban buses is not projected to be a consequence of the CAAA particulate emissions standard for buses. Urban buses generally are expected to be able to meet the 0.05-gram-per-brake-horsepower-hour particulate matter standard with diesel fuel.

4.5.2 Effect of National AFV Fleet Legislation

It is assumed that a national AFV fleet program will be enacted. Differences between the fleet provisions of House bill 776 and Senate bill 2166 have not yet been resolved. For analytical purposes only, it is assumed that the Senate program is adopted. Though Federal AFV purchases already are under way as a result of Executive Order 12759, it is assumed that the Federal vehicle purchase requirements of the Senate bill would take precedence. Displacement estimates resulting from this program are discussed in Chapter 1. These displacement estimates reflect only the fleet requirements of the Senate bill and not other portions.

4.5.3 Effect of AMFA CAFE Credits on AFV's

Under the current Corporate Average Fuel Economy (CAFE) standards, AMFA CAFE credits are not expected to provide sufficient stimulus to produce AFV's beyond those produced to meet other requirements.

4.5.4 Effect of the UMTA Alternative-Fuel Bus Program

The Federal Transit Administration's (formerly the Urban Mass Transportation Administration) Clean Air Program is a demonstration program that includes clean diesel technology; thus, it is not solely an alternative-fuel program. Though it may eventually lead to a substantial number of alternative-fuel buses, the alternative-fuel fleet requirements of national energy legislation currently being developed will produce more alternative-fuel buses. These buses are accounted for in the estimates developed above for that legislation.

4.5.5 Effect of the California Low Emission Vehicles and Clean Fuels Program

It is assumed that LEV and ULEV standards will be met by conventional vehicles using reformulated gasoline. ZEV's will be electric vehicles with no petroleum consumption (that is, no hybrid vehicles).

Currently, Massachusetts and New York are the only States besides California to adopt the emissions standards of the California Low Emission Vehicles Program. Some States and areas (Virginia, the District of Columbia) within the OTC have considered but voted not to adopt this program for the time being. In other States, adoption of the program is pending. For the baseline, only the effects of adoption of the LEV program by California, Massachusetts, and New York are estimated.

4.5.6 Effect of State-Level Alternative-Fuel Legislation

Only what is now "on the books" is assumed. There is some overlap between the Federal and State fleet legislation, and this overlap is accounted for in these estimates.

Reference

Energy and Environmental Analysis. *Impact of Alternative Fuel Regulations in the Clean Air Act, Task 1: Clean Fuel/Fleet Requirements*. Arlington, VA, January 1992.

CHAPTER 5

Research Needs for Alternative Fuels and Alternative-Fuel Vehicles

Although alternative, nonpetroleum motor fuels have been known and occasionally used since the introduction of motor vehicles more than a century ago, they have not benefited from the intensive research and development (R&D) efforts that have produced the highly evolved, petroleum-fueled, modern motor vehicle. Scientific investigation of alternative motor fuels was rekindled in the late 1960's by concern in academia and government over the growing problem of urban air quality. This interest waned as interim solutions were found through technical modifications to conventional vehicles that reduced new vehicle emissions levels by an order of magnitude.

The energy supply and price shocks of the 1970's added a second impetus for alternative fuels, stemming from a desire to reduce dependence on imported petroleum. Research initiated by the Environmental Protection Agency (EPA) and continued by the Energy Research and Development Administration (and subsequently the Department of Energy) focused on establishing the foundation of technical information for development of the options to replace petroleum fuels (Exxon Research, 1974; Institute of Gas Technology, 1974). Once again, however, the major policy implemented to reduce dependence on foreign oil called for dramatic improvements to light-duty vehicle (LDV) fuel economy, rather than alternative fuels.

However, improvements to conventional petroleum-fueled vehicles have been unable to eliminate air-quality and oil-dependency problems. Despite impressive reductions in emissions from conventionally fueled motor vehicles, achieved mainly by technical advances in fuel injection, computerized engine control, and the three-way catalytic converter, many areas of the Nation still failed to attain National Ambient Air Quality Standards. In the mid-1980's, new car and light-truck fuel economy improvements stalled as fuel prices dropped and fuel economy standards remained at a constant level. Petroleum consumption and petroleum imports increased toward historic highs. Federally sponsored alternative-fuels research continued at a moderate pace, but was joined by rapidly expanding State- and industry-sponsored research aimed specifically at solving the air-quality problems of urban areas (U.S. DOE, 1985; Mueller Associates, 1988). During the 1980's, automobile manufacturers and industry research groups, responding to increased interest in cleaner fuels inspired by air-quality concerns, demonstrated major advances in alternative-fuel-vehicle technology.

Recently, alternative motor fuels research has received a boost from several major governmental and private sector initiatives (the Alternative Motor Fuels Act of 1988, or AMFA; the Clean Air Act Amendments of 1990, or CAAA; the California Low Emission Vehicles and Clean Fuels Program, which other States may choose to implement under the 1990 CAAA; the establishment of the U.S. Advanced Battery Consortium; and the 1991–1992 National Energy Strategy). With implementation schedules beginning in the mid-1990's to the early 2000's, these and other programs are generating significant research activity and substantial technical advances.

This chapter reviews the status of several important alternative-fuel technologies and highlights existing research needs. Although the focus primarily is on vehicle technology, technological issues bearing on production, storage, and distribution are included as warranted. The review covers the status of gaseous fuels (including natural gas and liquefied petroleum gases or propane), alcohol fuels (including methanol and ethanol), and electricity (including battery-electric vehicles, hybrids, and fuel cells). Biofuels production issues cut across fuel types and are treated separately. The chapter concludes with an overview of current Federal, State, and local demonstration programs.

5.1 Status of Alternative-Motor-Fuels Technology and R&D Needs

Despite environmental and energy shortcomings, petroleum-fueled internal combustion engines have given alternative fuels stiff competition at every turn. The substantial R&D efforts that have been undertaken to improve petroleum-based technology so far have been able to meet every new emissions or energy-efficiency standard. Because the technology of conventional petroleum fuels and vehicles is so highly evolved and continues to improve, R&D to improve alternative fuels and alternative-fuel vehicles (AFV's) is critical to developing alternative technologies that meet both the needs of society and the consumer. Every alternative fuel has advantages and disadvantages in comparison with existing vehicles. Some disadvantages, such as higher costs, may be solved by achieving economies via the mass production of alternative vehicles and fuels. The large-scale demonstration programs now under way or about to begin should help AFV's achieve some of the economies of mass production.

Some weaknesses of alternative fuels will require technological solutions, while others, such as lower energy densities, will remain shortcomings that must be counterbalanced by other unique benefits. One disadvantage all alternative fuels share is the relative amount of scientific and engineering research effort that has been devoted to their perfection. As a result, numerous areas remain open to fruitful R&D. This section reviews the status of alternative-fuel technology with respect to key areas of research need.

It is desirable that safety and health considerations be carefully examined in the research and developmental phases of studies of alternative motor fuels and the related vehicles. Safety and health implications range from the hazards encountered by workers involved in developing the fuels and vehicles, through those encountered by workers involved in the delivery systems, to those encountered by the final users of the fuels and vehicles. Ideally, research on potential safety and health problems should be integrated into the most basic research elements of the alternative-motor-fuel program so that user and worker safety and health issues, including employee and user risk, exposure levels, and recommended control technology, can be studied and resolved during the research, development, and demonstration (RD&D) phases of the program in the same way that emissions and environmental impact are studied.

The Occupational Safety and Health Administration (OSHA) already has a number of regulations that might apply either directly or indirectly to the developing and handling of alternative motor fuels and the associated vehicles. Further regulations might need to be developed as specific alternative-motor-fuel systems and machines enter the experimental test phase.

5.1.1 Gaseous Fuels

The principal gaseous fuels under consideration as motor fuels are natural gas; liquefied petroleum gas (LP gas), in particular, propane; and hydrogen. Although hydrogen holds potentially enormous promise as an environmentally benign fuel, the state of development of hydrogen fuel technology is so far behind the other gaseous fuels that it is not a likely candidate for widespread implementation in the next two decades. As a result, though it is a fruitful area of R&D and a potentially crucial long-run technology, it will not be treated here.

Because petroleum fuels are liquids under normal ambient conditions, there are greater differences between the technology required for gaseous motor fuels and conventional technology than there are for other liquid alternative fuels. The greatest areas of difference are refueling, on-board storage, and fuel delivery to the combustion chamber, especially metering. R&D aims to accentuate gaseous fuels' unique advantages in these areas and minimize their disadvantages.

5.1.1.1 Natural Gas

Natural gas (consisting mainly of methane, or CH_4) is nearly ubiquitous in the United States, thanks to an extensive pipeline transportation network that continues to be extended. With a boiling point of -162 °C, natural gas must be compressed to 140 to 220 atmospheres (atm) or stored cryogenically to achieve sufficient energy density for practical on-board storage as a motor-vehicle fuel. Even with compression to 220 atm, compressed natural gas (CNG) has an energy density only one-fifth that of gasoline on a volumetric basis (on the basis of mass, the energy density of methane is greater than that of gasoline). Liquefied natural gas (LNG), on the other hand, has an energy content in excess of 70 percent that of gasoline on a volumetric basis (Owen and Coley, 1990).

Distinct advantages of natural gas include its high octane number (approximately 120), its wider flammability limits, and better mixing with air in the combustion chamber. These properties should allow increased compression and leaner air/fuel ratios, and thus greater energy efficiency. It may also be possible to recover some of the energy used in liquefying natural gas by allowing the expanding gas to cool the air/fuel charge, thereby reducing the energy penalty of compression.

Vehicle refueling with CNG or LNG is entirely different from refueling with gasoline or diesel fuel. Refueling is especially important to CNG vehicles because the low energy density of CNG limits vehicle range to 80 to 200 miles, depending on the number of storage cylinders and the storage pressure. "Fast-fill" technology uses a cascade of tanks filled with gas at 250 atm to refuel light-duty vehicles to 220 atm within 3 to 5 minutes, just slightly longer than required for conventional fuels (Heath, 1991). In the "slow-fill" technique, a vehicle is connected directly to a small compressor, which fills it directly from a gas distribution line over a period of several hours. Thus, not only may adequately fast service be delivered at commercial outlets, but home refueling is possible at a slower rate, using a home compressor.

Natural-gas-vehicle RD&D has concentrated on dual-fuel light-duty vehicles and the adaptation of heavy-duty vehicle compression ignition (diesel) engines to CNG. Natural gas is an excellent fuel for spark-ignition engines but cannot be used in unmodified compression-ignition engines because of its very low cetane number. By modifying diesel engines to operate at higher ignition temperatures and adding "glow plugs" to aid ignition, natural gas has been made to work satisfactorily in compression-ignition engines.

The conversion of gasoline engines to dual-fuel CNG/gasoline operation is a thoroughly proven technology. Dual-fuel CNG vehicles have been proven to operate well and have fewer overall maintenance problems than comparable gasoline vehicles. But they do have several drawbacks because they do not take full advantage of the properties of natural gas. These include reduced performance, owing to the fact that natural gas displaces air in the cylinder, thereby reducing the effective engine displacement; limited driving range due to CNG's lower energy density; and loss of storage space, owing to the need for separate fuel systems and the bulkiness of the cylindrical tanks currently used in conversion technology.

Opportunities for manufacturers to improve CNG vehicle technology exist in fuel storage, fuel metering, optimized engine design, and emissions control. Development of advanced, electronically controlled fuel metering systems is progressing from the research to the developmental stage. Natural-gas fuel injection for medium- and heavy-duty engines already has been introduced as a commercial product, and research on improving and perfecting light-duty-vehicle injector systems continues (Carter, 1991). Use of adsorbents to reduce the pressure required for storage of larger quantities of methane has shown some promise, but systems superior to 220-atm compressed gas cylinders have yet to be developed. Low-pressure storage has the advantage of being conducive to inexpensive home refueling of natural gas vehicles. Because of the cost and bulk of storage cylinders, improved storage technology would improve both range and cost. Additionally, original equipment manufacturer (OEM) vehicles with fuel storage integrated into the vehicular design should be able to reduce the loss of storage space and increase storage capacity and range. Research to improve and reduce the costs of cryogenic on-board storage systems for LNG are needed to bring this technology closer to commercialization.

A particularly important area of R&D for CNG vehicles is the development of vehicle systems designed from the ground up for dedicated operation on either CNG or LNG. Such vehicles would have higher compression ratios to take advantage of methane's 120 octane rating. They probably would be designed to run lean for better fuel economy and reduced carbon monoxide (CO) emissions. A important area of research for such vehicles is the development of lean emissions control systems capable of reducing oxides of nitrogen (NO_x) in the presence of excess oxygen in a lean exhaust stream. R&D on catalysts specifically aimed at the particular combustion species produced by natural gas is essential to realizing the full air-quality benefits of natural-gas vehicles and is being actively pursued (Summers, 1991). Though they are much further away from commercialization, LNG vehicle systems could benefit from improved on-board cryogenic storage and original engine design work to take advantage of the low temperature of the liquid fuel.

5.1.1.2 Liquefied Petroleum Gas (Propane)

Liquefied petroleum gases are mixtures of propane and butanes in which propane usually predominates. When used as a motor fuel, LP gas is no less than 97.5 percent propane (Owen and Coley, 1990). A hydrocarbon like natural gas, propane is mainly produced as a byproduct of natural-gas processing, although some propane is produced in the processing and refining of crude oil. Very little compression (7 to 20 atm) is required to liquefy propane. For use as a transportation fuel, propane is stored in liquid form, and offers a volumetric energy density 75 to 80 percent of that of gasoline. Because of the lower storage pressures and its handling in liquid form, propane refueling and on-board storage are less difficult than for natural gas. With a C:H ratio lower than gasoline, propane has a somewhat higher octane number and burns cleaner than gasoline. It also has excellent cold-starting characteristics and is very low in sulfur. Like natural gas, propane has a very low cetane number but has been successfully tested in compression-ignition engines converted in a fashion similar to those for use on natural gas.

Chemically intermediate between natural gas and gasoline, propane faces many of the challenges natural gas does, but its differences from gasoline are less extreme. The technology for converting gasoline vehicles to dual-fuel operation on propane, though well established, compromises some of the superior properties of propane fuel. Once again, the need for dual-fuel systems adds complexity and cost and sacrifices storage space. Further R&D on propane vehicles is needed to develop optimized fuel metering equipment to maximize possible emissions reductions, optimize fuel economy, and reduce consumer costs. Technology can typically cross-flow between natural gas and propane engine designs, so techniques that have been recently used to improve results on natural gas are candidates for transfer to propane applications. Although on-board storage is less challenging than for CNG, propane tanks are still a major component of propane conversion costs. Improvements in tank design and cost reductions would benefit the economics of propane vehicles.

5.1.2 Alcohol Fuels

Alcohol fuels, which are liquids at ambient temperatures and atmospheric pressure, also have energy densities one-half (methanol) to two-thirds (ethanol) that of gasoline. Their higher octane ratings and higher heats of vaporization allow engines designed for alcohol fuels to produce more power than engines of equal size optimized for gasoline. Alcohol fuels also have superior emissions properties. Because they are less photochemically reactive than gasoline components, their evaporative emissions contribute less to smog formation; and because they contain oxygen, they tend to reduce formation of CO in exhaust emissions. The higher latent heat of vaporization of the alcohols (greater for methanol than ethanol) results in lower combustion temperatures, thereby inherently reducing generation of NO_x.

Though methanol and ethanol are corrosive to some of the metal and plastic components of conventional vehicles and refueling systems, these problems have been readily solved in flexible-fuel vehicles (FFV's) by substituting alternative materials. Increased engine wear was also observed in early tests, but material substitution and the development of appropriate engine oils have ameliorated this problem.

The relatively low vapor pressures and high latent heats of vaporization of neat alcohol fuels lead to poor volatility and, thus, cold-starting and warm-up problems. However, these problems have been solved by the addition of a volatile primer in amounts of about 15 percent. Gasoline is most widely used (M85 [85 percent methanol, 15 percent gasoline] and E85 [85 percent ethanol, 15 percent gasoline]), but other substances, such as dimethyl ether, isopentane, and other hydrocarbons, also perform well (Owen and Coley, 1990). The addition of gasoline also gives alcohol fuels a foul taste, reducing the risk of intentional or unintentional ingestion (methanol is highly toxic), and gives them a visible flame, which may be a safety advantage.

Alcohol-gasoline blends of less than 10 percent alcohol have been widely used around the world in unmodified conventional vehicles. In the United States, 7.5 billion gallons of gasohol were sold in 1991, containing approximately 750 million gallons of ethanol. International development of alcohol-fuel vehicles received a major stimulus from the ambitious Brazilian alcohol fuels program. Experience in designing and mass producing neat and near-neat alcohol vehicles, together with technological advances in sensors and computer-controlled fuel injection systems, led to the development of the FFV, which permits the use of either methyl or ethyl alcohol fuels or gasoline in any mixture (J.E. Sinor, 1992). A major advantage of FFV's over dual-fuel vehicles (DFV's) is that in FFV's the fuels share the same fuel system, eliminating the extra cost, complexity, weight, and space requirements of dual systems.

FFV technology for spark-ignition engines is already highly developed and is nearly ready for full-scale marketing. However, a disadvantage of the FFV concept is that the emissions advantages of methanol and ethanol are seriously compromised by the addition of even 15 percent gasoline. It is likely that reformulated gasolines will be able to achieve the same level of emissions performance as M85 or E85. The emissions characteristics of lower alcohol content mixtures (which are likely to be present in FFV fuel tanks from time to time) could be worse. Though FFV technology allows fuel metering to be precisely controlled for any gasoline-alcohol mixture, the engine design is limited to characteristics suitable to gasoline, thereby sacrificing some of the advantages of alcohols. Thus, properties such as higher octane and the lean-burn capability of alcohol fuels cannot be fully exploited at this time.

One important area of research is the development of lean exhaust emissions control (lean catalysts) to capitalize on alcohol fuels' excellent lean-burn properties and thereby reduce emissions and improve fuel economy (J.E. Sinor, 1991). Another important area is the development of engine systems optimized for methanol or ethanol. Dedicated engines optimized for methanol or ethanol are needed to fully take advantage of the low emissions and high fuel-economy potential of alcohol fuels.

Use of alcohols in compression-ignition engines is particularly difficult because of their high autoignition temperatures, low viscosity and lubricity, and higher volatility in comparison with diesel fuels. Several designs using ignition assists, diesel fumigation, or ignition improvers have been field tested (King, Kirshenblatt, and Bol, 1990). The Detroit Diesel Corporation has certified a methanol-fueled two-stroke compression-ignition engine for production. This engine is designed for use in urban transit buses. Remaining problems, including fuel-injector-tip blockage, glow plug durability, and valve seat wear, have been reported to be resolved (Heath, 1991; Miller, 1992). Additional research is needed to develop practical systems that can take advantage of the potential of alcohol fuels to reduce emissions from a wider range of compression-ignition engines.

5.1.3 Electricity

In 1900, 22 percent of the cars on U.S. roads burned gasoline, 40 percent were steam-powered, and 38 percent were battery-powered electric vehicles (EV's). Despite the eventual dominance of the internal combustion engine, EV's have received continuous use in specialized applications. In the United Kingdom, about 35,000 low-speed electric delivery vans are presently in operation (Interagency Commission on Alternative Motor Fuels, 1990). Other applications include public transit buses and minibuses, thousands of special-purpose lightweight vehicles, and numerous passenger vehicle demonstration projects. In 1990, there were approximately 450 EV's in testing and evaluation programs in the United States. Since the mid-1970's, a substantial Federal research effort has led to significant improvements in motor and drivetrain design, technology for conventional lead-acid batteries, and improvements to the cost, weight, and durability of advanced battery concepts. In 1990, the California Air Resources Board promulgated standards requiring the production and sale of zero emission vehicles (ZEV's), beginning with 2 percent of a manufacturer's fleet in 1998 and increasing to 10 percent by 2003. Other States with serious air-quality problems have adopted the California standards or expressed an intention to do so. Battery-powered EV's are the only technology expected to qualify as ZEV's (Davis and Morris, 1992).

Electric hybrid vehicles (EHV's), though not likely to meet ZEV standards, do have considerable potential to reduce emissions in congested areas and to displace petroleum fuels. EHV's add another power source, usually a small internal combustion engine (possibly powered by cleaner fuels), to extend range, allow a reduction in the size of the battery system, and provide additional peak power. Fuel cell-battery hybrids also have ZEV potential, but marketable vehicular fuel cell systems are not likely by 1998 or even 2003.

The chief limitations of electric battery propulsion technology are very low energy density, long recharging time, and initial battery cost. Energy density on a volumetric basis ranges from about 1 percent of that of gasoline for lead-acid batteries to up to 2 percent for advanced sodium-sulfur batteries. On a weight basis, the range of energy densities compared to gasoline is from less than one-half of a percent to almost 1 percent. Improvements in energy density on the order of 10 to 20 percent for lead-acid batteries and 100 percent for advanced batteries are probable, but gains of an order of magnitude are not to be expected (Kiehne, 1989).

Recharging times for batteries are on the order of hours rather than minutes. Recent advances in ultracapacitor-type batteries, however, have demonstrated the ability to recharge in considerably less than an hour (U.S. DOE, 1992).

Initial battery cost and lifetime are jointly of great concern for the economics of EV's. Though it is generally agreed that the lifetime costs of EV's can be lower than internal-combustion vehicles, the requirement to purchase a battery system costing on the order of $3,000 to $5,000 every few years poses a unique problem for consumer acceptance (Interagency Commission on Alternative Motor Fuels, 1990).

After 20 years of federally sponsored research and significant advances in advanced battery technology, marketable EV technology is still dependent on the lead-acid battery. In part this is due to advances in the lead-acid battery resulting from research on advanced lead-acid concepts. In January 1991, Chrysler, Ford, and General Motors formed the U.S. Advanced Battery Consortium (USABC) to develop an advanced battery that could satisfy the performance and cost requirements necessary for the EV market acceptance required by the California ZEV standards (U.S. DOE, 1992). This group, subsequently joined by the U.S. Department of Energy and the Electric Power Research Institute, was formed out of a recognition that advanced batteries would be essential to meeting the 10-percent market-share requirements of the California standards. The USABC's advanced battery goals are summarized in Table 5–1. The midterm goals are within the capabilities of advanced batteries, such as the sodium-sulfur or lithium-iron sulfate batteries.

The realistic key research areas needed for EV batteries are as follows:

- Increasing energy (Wh/kg and l) and power (W/kg and l) densities
- Increasing the number of cycles per battery lifetime to more than 1,000
- Reducing "quick charge" time to less than 1 hour (at least 80 percent of full capacity)
- Decreasing the rate of spontaneous discharge when the vehicle is not in use
- Reducing battery costs or developing effective financing for battery replacement

Table 5-1. USABC Advanced Battery Technology Primary Criteria

Primary Criteria	Midterm Goals	Long-Term Goals
Power Density W/L	250	600
Specific Power W/kg (80% DOD/30 sec)	150* (*200 desired)	400
Energy Density Wh/L (C/3 Discharge Rate)	135	300
Specific Energy Wh/kg (C/3 Discharge Rate)	80* (*100 desired)	200
Life (Years)	5	10
Cycle Life (Cycles) (80% DOD)	600	1,000
Power & Capacity Degradation (% of rate spec)	20%	20%
Ultimate Price ($/kWh) (10,000 units @ 40 kWh)	<$150	<$100
Operating Environment	-30 to 65 °C	-40 to 85 °C
Recharge Time	<6 hours	3 to 6 hours
Continuous Discharge in 1 hour (No Failure)	75% (of rated energy capacity)	75% (of rated energy capacity)

- Lowering the energy use of accessories such as climate control and other amenities (Dieckermann, 1992)

- Integrating effective regenerative braking systems to increase range

Because limited range and long recharging time are the chief obstacles to marketability of battery-powered EV's, fuel cells (electrochemical devices that combine oxygen and hydrogen and convert the chemical energy into electricity) or fuel cell-battery hybrids provide an attractive possibility. This is especially true because fuel cells produce only water (or water and carbon dioxide) as a waste product. Batteries also obtain electrical energy from a chemical reaction, but the reaction is reversed by the application of electrical energy to the battery during recharging. In fuel cells, the chemical energy is supplied externally in the form of fuel (H_2) that is continuously supplied and consumed, as in a conventional internal combustion engine. The chief attractions of fuel cells are their potential for zero emissions and their theoretically higher energy conversion efficiency, nearly twice that of internal combustion engines (U.S. DOE, 1992).

The hydrogen used for fuel cell operation may be supplied in elemental gas or liquid form, or by reforming alcohol or hydrocarbon fuels (including methane). In the latter case, carbon dioxide will be a waste product of the reforming process and thus of the fuel cell system (Fischer, 1989).

The Department of Energy (DOE) has been conducting research on the low-temperature (less than 100 °C) proton exchange membrane (PEM) fuel cells for light-duty-vehicle applications and is implementing a demonstration program using medium-temperature (about 200 °C) phosphoric acid fuel cells (PAFC's) for urban buses (U.S. DOE, 1990a). The PAFC system is a more mature technology than PEM and has a demonstrated capability to operate on reformed methanol (U.S. DOE, 1992). The PEM technology, which uses a fluorocarbon ion-exchange membrane as an electrolyte, also could utilize hydrogen from reformed hydrocarbon or alcohol fuels. R&D is needed to reduce PEM's sensitivity to poisoning of the electrocatalyst by carbon monoxide. This and the need to humidify the fuel and oxygen streams to maintain hydration of the membrane are major research concerns for the PEM fuel cell (U.S. DOE, 1992). To date, DOE's research is in the stages of demonstrating feasibility and conducting prototype systems designs. Fundamental research on materials and components to reduce the costs and improve the performance and endurance of PEM fuel cells is in progress.

A problem facing the application of fuel cell systems to motor vehicles is that they respond slowly to peak power demands. One possible solution is to augment the fuel cell system with a relatively small, high-power-density battery system (DeLuchi, Larson, and Williams, 1991). A fuel cell-battery hybrid should also qualify as a ZEV. DOE's fuel cell bus prototype design includes a battery system to provide peak power, which is recharged by the fuel cell during idle periods. Another important area of research is the development of appropriate mobile reformer technology or, alternatively, safe and economical hydrogen storage. To date, reformers have been developed for stationary applications. Scaling down size and costs to make them suitable for light-duty vehicles while maintaining performance is a critical challenge.

5.1.4 Biofuels

Biofuels usually are considered to be all solid, liquid, and gaseous fuels derived from plant materials and wastes from biological systems, including municipal solid waste. Biofuels for transportation usually include ethanol, methanol, and ethyl and methyl tertiary butyl ethers (ETBE and MTBE) derived from them; synthetic gasoline and distillate; methane; and distillatelike vegetable oils. The chief advantages of biofuels are that they produce no net addition of greenhouse gases (depending on the energy sources used in their production), they are renewable resources, and they can be produced using domestic resources, thereby displacing imported petroleum. Today, the only significant use of biofuels in transportation is the use of grain-based ethanol in gasohol.

Research on biofuels production by the Departments of Energy and Agriculture centers on continued efforts to reduce the cost of producing grain-based ethanol; the use of woody (cellulosic) and herbaceous feedstocks and municipal solid wastes to produce ethanol, methanol, gasoline, diesel, or gaseous fuels via thermochemical or biochemical conversion; and the use of processed vegetable oils as diesel fuel substitutes. Mature, economical technology exists for generating and distributing electricity and for recovering and/or processing the hydrocarbon fuels, natural gas, and propane. The one area of fuel production (other than biomass) involves improved catalysts aimed at once-through production of methanol. Other technologies are also being pursued, such as the well-publicized, DOE-sponsored liquid-phase methanol process, which can be effectively combined with electric generation in an integrated-gasification-combined-cycle/once-through methanol (IGCC/OTM) system (IAC, 1990). This approach can be applied to all feedstocks, whether fossil or biomass, and other technologies are available to reduce costs of fuel methanol (IAC, 1990; U.S. DOE, 1990a).

The grain-based ethanol research program includes an expanded research effort to use conventional and biotechnological techniques to enhance fuel yields; increase the cost effectiveness of starch conversion by increasing yields, reducing hydrolysis and fermentation times, and improving the efficiency of fuel and coproduct separation and recovery; and develop a broad range of marketable, high-value coproducts with a high-volume demand. The cellulosic ethanol research focuses on the selection and cultivation of biomass feedstocks and the development of cost-effective, high-yield conversion processes (U.S. DOE, 1991). Energy crops include short-rotation woody crops, such as black locust, silver maple, sweetgum, sycamore, and poplar trees, as well as herbaceous energy crops, such as forage crops, grasses, and legumes. DOE believes target yields of 10 or more tons per acre at a cost of $2 per million British thermal units of biomass are within reach.

In addition to fuel ethanol produced from corn, research efforts also are focused on converting cellulosic feedstocks to sugars, which can then be fermented into ethanol. Research is examining new strains of xylose-fermenting yeast and ways to convert cellulose to ethanol via enzymatic treatment (U.S. DOE, 1991). The composition of biomass feedstocks is typically 75 percent cellulosic and 25 percent lignin, with trace amounts of ash and organic compounds (U.S. DOE, 1990a). The lignin, which currently cannot be broken down to form sugars, can be burned as a fuel or converted to other chemicals.

Research on methanol production from biomass focuses on thermal conversion: gasification of the biomass to form synthesis gas, followed by a gas shift reaction to adjust the ratio of hydrogen to carbon monoxide to that of methanol, followed by catalytic conversion of the syngas to methanol. A critical research goal is improved gasification to reduce the production of tars, as well as the development of catalysts that can simultaneously reduce synthesis gas tars and produce the required gas shift.

Nonpetroleum diesel fuel substitutes can be obtained from oil-seed crops such as soybean, sunflower, and rapeseed. These fuels, referred to as biodiesel, are produced via chemical or thermal processes that alter fuel properties. Unprocessed oils have relatively high boiling points (low volatility) and a viscosity an order of magnitude higher than diesel fuel.

Testing of unprocessed fuels in diesel engines has revealed several problems. Engine deposits cause ring sticking, injector blockage, and increased viscosity of the lubricating oil. These problems were particularly prevalent in open chamber (direct injection) diesel engines, the type most prevalent in heavy-duty vehicles. Several techniques have been explored to eliminate these problems, the most promising of which appears to be the chemical conversion (transesterification) of vegetable oils to less complex fatty esters. Methyl and ethyl esters made from soybean and industrial rapeseed oils have been found to have properties much closer to conventional diesel fuel, although high viscosity is still a problem (Ziejewski, Kaufman, and Pratt, 1983; Clark et al., 1983).

Limited emissions testing has indicated that biodiesels produce little or no sulfur, significantly reduce particulate and carbon monoxide emissions, slightly reduce hydrocarbon emissions, and produce similar levels of oxides of nitrogen compared to conventional diesel fuel. The key research areas are the development of improved feedstocks and productions systems and improved processing technologies to develop fuels closer to diesel specifications but with reduced emissions.

5.2 Demonstrations, by State, of Vehicles Operating on Alternative Fuels

Spurred by the Clean Air Act Amendments of 1990, the Alternative Motor Fuels Act of 1988, and the California Clean Fuel Vehicles Program standards, alternative-fuel-vehicle research, development, and demonstration has accelerated rapidly over the past 2 years. Table 5-2 summarizes, by State, demonstration projects involving natural gas, LP gas, alcohol fuels, and electric vehicles.

Nearly every State in the United States has an active alternative-fuels demonstration project, and most have several. Natural-gas-vehicle demonstrations are most prevalent, followed by electric, alcohol fuels, and LP gas. Only one State, Florida, has an active hydrogen vehicle demonstration project, located at the University of Miami.

Table 5–2. Demonstrations, by State, of Vehicles Operating on Alternative Fuels

State	Natural Gas	LPG	Alcohols	Electric Vehicles	Unidentified	Other
Alabama	LD(S,L,Un)		E(S)			
Alaska	[a]; (Ut)	[a]				
Arizona	LD(S,L,Un,Ut) TB(L)	(S,C)	E,M/LD(S) M/TB(L)	(Ut); TB(L)		
California	LD(S,L,Ut) MD,HD(S) SB(S); TB(L)	LD(L,Ut) MD(C) MB,TB(L)	M/LD(F,S,L,C) M/HD(S,L,C) M/MD(S); E/LD(S) M/SB(S); M/TB(L)	(S)	H_2(Un)	
Colorado	(C,Ut); E(Un) SB,TB(L)	[a] LD(C)	E/HD(C); E,M(Un) M/TB(L)	[a]; EX(Un)		
Connecticut	LD(Ut)		(S)			
Delaware	(Ut)					
District of Columbia	LD(Ut)		LD(Ut)			
Florida	LD,MD,TB(L)	(S,L)	M/TB(L)	(Un)	(S,L,C)	
Georgia	MD(C); (L,C,Ut)	LD,MD(Ut)				
Hawaii		All types		(Ut)		
Idaho	(Ut)					
Illinois	LD(Ut); TB(L)		E,M/LD(F,S); E/HD(S); E/TB(L)	FC(S)		
Indiana	LD(L,Un,Ut) MD(Ut); SB(L)			EX(Un)		
Iowa	LD(L,Ut) MD(Ut)	HD(L); (C)	E/LD,HD(S) E/TB(L)			
Kentucky	(S,L)					
Louisiana	LD(F); SB(L) (S,L)					
Maryland	TB(L); (C,Ut)	(S)	M/LD(L)	EX(Un)		
Massachusetts	(Ut)	MB(L)			LD(L)	
Michigan				EX(Un)		
Minnesota	LD(Ut); TB(L,C)	LD,MD,HD(L)	E(C); E/TB(L)	EX(Un)		
Mississippi	LD(Ut)	MB(L)				
Missouri		LD(C)				VO(Un)
Montana	LD(Ut)	[a]				VO(S)
Nebraska	HD(Un)		E/TB(L) E/HD(Un)			
Nevada	LD(Ut); C	LD(C)				

Table 5-2. Demonstrations, by State, of Vehicles Operating on Alternative Fuels (continued)

State	Natural Gas	LPG	Alcohols	Electric Vehicles	Unidentified	Other
New Hampshire		MB(Un)		EX(Un)		
New Jersey	LD(Ut); TB(L)		E,M(Ut)	LD(Ut)		
New Mexico	L; SB(L)	(S)	M/TB(L)			
New York	LD,MD,TB(L)		M(L); M/TB(L)	LD(L)		
North Carolina	(S,C);S B	(L)		(C)		
North Dakota	(Ut)					
Ohio	LD,MD,HD(Ut) SB,MB,TB(L)					
Oklahoma	LD(S,L,Un) SB(L)					
Oregon	LD(S,L); TB,MB(L)					
Pennsylvania	LD(S,L,Ut,Un) MB(L); SB(C) TB(L,Ut)			EX(Un); FC		
Puerto Rico				(Un)		
Rhode Island	(S)				(L,C,Un,Ut)	
South Carolina	(Ut)	LD(L)		(Un)		
South Dakota			E(C,Un)			
Tennessee	(Ut)		M/LD(F)	EX(Un)		VO(Ut)
Texas	(S,L,C,Ut) SB,TB(L)	b	M/LD(F)	(Ut)		
Utah	LD(S,Ut)					
Vermont	(L,Ut)	(C)				
Virginia	(S)					
Washington	LD(L,C,Ut) MB,SB,TB(L)		M/TB(L)			
West Virginia	SB(S)					
Wisconsin	(S,L,Ut); SB(C)	(S,L,Ut) SB(C)	E,M(S)			
Wyoming	TB(L)					

Notes: States/territories with no identified demonstrations: AR, GU, KS, ME

LD=Light Duty; MD=Medium Duty; HD=Heavy Duty; SB=School Bus; MB=Mini/Shuttle Bus; TB=Transit Bus[c]; EX=Experimental Vehicle; FC=Fuel Cell.

Users identified within parentheses ( ): F=Federal; S=State or state sponsored; L=Local; C=Commercial; Un=University or Technical School; Ut=Utility.

[a] Multifuel unidentified activity; [b] Unidentified fuel; [c] Most largely funded by U.S. DOT (UMTA).

Sources: Alternative Motor Fuels National Inventory, Washington, DC. CE/OTFA, U.S. Department of Energy, 1991. *The Clean Fuel Report*, vol. 2, nos. 4 and 5; vol. 3, no. 5.

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Reformulated Gasoline

Introduction

The reformulation of gasoline (that is, the changing of its physical and chemical characteristics) currently is being pursued by both the Environmental Protection Agency (EPA) and the California Air Resources Board (CARB) as a method of reducing vehicle emissions of carbon monoxide (CO), toxics, and volatile organic compounds (VOC's). In response to specific provisions contained in Title II of the Clean Air Act Amendments of 1990 (CAAA), EPA is implementing a reformulated gasoline (RFG) program that will go into effect in nine cities in 1995. Requirements will tighten in the year 2000, and States with ozone problems (in an additional 89 areas) can opt into this program. California, which has the worst air-quality problems in the country, is developing a similar but separate set of reformulation requirements, with an accelerated timetable and greater stringency.

The Federal Government (the Department of Energy and EPA) and California also are leading the development and implementation of alternative-fuel programs based on methanol, ethanol, natural gas, liquefied petroleum gas (LP gas), and electric-powered motor vehicles. These "clean-fuel" alternatives are expected both to improve air quality and to reduce petroleum use. However, because these alternative fuels can only be used in specially designed or modified vehicles, the transition to their use will occur only as the vehicle population is gradually replaced. Therefore, RFG is an alternative to both current gasoline and these alternative fuels. It will provide a means to reduce both emissions from conventional automobiles and oil use (through the addition of nonpetroleum-based components).

The combined effect of the EPA RFG program, the California reformulation program, and the pressure created on States by the other provisions of the CAAA to reduce emissions is expected to result in most gasoline being reformulated by the year 2000. Based on 1989 consumption, it is anticipated that RFG will account for 23 percent of U.S. gasoline demand to meet the needs of the nine specified RFG cities. If other eligible regions choose to opt in, that volume would increase to about 63 percent of U.S. gasoline consumption. In this context, RFG is the appropriate comparative benchmark in terms of cost-efficiency and performance for alternative fuels.

RFG Provisions of the Clean Air Act Amendments of 1990

The CAAA define "reformulated" gasoline by using two methods: specific gasoline characteristics and performance standards. Starting in 1995, the benzene content of gasoline may not exceed 1 percent by volume. Oxygen content must equal or exceed 2 percent by weight, and detergents must be present in amounts large enough to prevent the accumulation of deposits in engines or vehicle fuel-supply systems. The CAAA also ban lead or heavy metals. In addition to these characteristic requirements, performance standards also must be met.

The emissions performance standards are set in relation to emissions from "baseline" vehicles using "baseline" gasoline. The CAAA define a baseline vehicle as one that is representative of model year 1990. Summer baseline gasoline is specified by the CAAA; winter baseline gasoline is to be determined by EPA.

Three performance standards apply. Nitrogen oxide (NO_x) emissions from baseline vehicles using RFG may not exceed NO_x emissions from the same vehicles using baseline gasoline. Under Phase I of the CAAA standards (1995–1999), aggregate VOC emissions from baseline vehicles during the high-ozone season should be 15 percent lower than emissions from the same vehicles using baseline gasoline.

For Phase II, starting in the year 2000, the 15-percent reduction will be increased to at least 25 percent, unless 25 percent is technologically infeasible, in which case EPA can lower the requirement to 20 percent. However, the requirement can be increased to above 25 percent if EPA determines it is feasible and cost-effective.

The performance standards for toxics are approached in a similar manner, comparing the total emissions of four specific chemicals from baseline vehicles using baseline gasoline to baseline vehicles using RFG. Toxics reductions are effective year-round, with toxics emissions from baseline vehicles using RFG required to be 15 percent lower than the toxics emissions from the same vehicles using baseline gasoline. Beginning in the year 2000, 15 percent will be increased to at least 25 percent if technologically feasible. Again, EPA has the discretion to lower this to a 20-percent reduction if necessary.

California's RFG Activities

On September 28, 1990, CARB approved regulations for California Phase I RFG. Beginning on January 1, 1992, no gasoline with a Reid vapor pressure (RVP) above 7.8 pounds per square inch (psi) may be sold or supplied to designated air basins during specified high-ozone time periods, and all California gasoline must meet a sulfur limit of 300 parts per million. In addition, all gasoline sold in California must be lead-free and must contain detergents to control deposits in the engine and fuel lines.

On November 22, 1991, CARB adopted requirements for Phase II California RFG. Beginning January 1, 1996, RFG in California will have to meet requirements similar to the Federal requirements for the year 2000; that is, it will have to meet specific stringent limits on RVP, sulfur and olefin content, and the T-50 and T-90 distillation points (temperatures at which 50 percent and 90 percent of gasoline components boil, respectively).

Current Commercial "Reformulated" Gasolines

In the past 2 years, many refiners have begun marketing their own versions of "reformulated" gasoline. For the most part, "reformulated" gasolines have been gasolines with reduced volatility and some added oxygen in the form of methyl tertiary-butyl ether (MTBE) or ethanol. Atlantic Richfield Company (ARCO), a west coast gasoline marketer, has received much attention for several of the emissions-reducing gasolines it has created, and they are representative of what parameters are important in this context.

ARCO has developed three reformulated products: EC-1, EC-Premium, and EC-X. EC-1, which went on sale in September 1989 for use in cars that run on leaded gasoline. In September 1990, EC-Premium entered the market as a low-polluting, high-octane premium gasoline. EC-X is the latest gasoline proposed by ARCO; it has very low RVP, sulfur, and olefin contents and a high oxygen content. ARCO believes that EC-X will meet EPA's Phase II emission performance standards and parameter requirements for RFG in the year 2000. According to ARCO, EC-X, as compared to conventional gasoline, is reputed to produce 28 percent fewer hydrocarbon tailpipe emissions, 36 percent fewer evaporative emissions, and 26 percent fewer NO_x emissions. In addition, ARCO claims a 25-percent reduction in CO emissions and a 47-percent reduction in emissions of toxic compounds.

A number of refiners and gasoline marketers also have adopted programs to market lower emission "reformulated" gasoline in various parts of the country. These include Exxon, Amoco, and Sun, among others; they market on the east coast, in the Midwest, and in California.

Status of Federal Rulemaking

As of this writing (September 1992), EPA had completed the process of developing the proposed rules governing RFG, including what characteristics will meet CAAA requirements, how gasoline formulations will be approved, and how the rules will be enforced. EPA worked through a "regulatory negotiation" with the interested parties. In August 1991, an agreement was signed by members of the regulatory negotiation. In April 1992, EPA published a Supplemental Notice of Proposed Rulemaking (SNPRM) reflecting that agreement. The EPA supplemental proposal contains a "simple-model" compliance specification in 1995 and 1996, with more flexibility and complexity (allowing tradeoffs between parameters) after 1996. For 1995–1996 reformulated gasoline, EPA is concentrating on a few parameters for emission control: RVP, benzene, and oxygen. Under the "simple model" contained in the EPA proposed rule, the initial 15-percent reduction of VOC's will be met almost entirely by RVP reduction. Volatility requirements already in place will limit RVP to 8.7 psi in "Class C" areas and to 7.8 psi in "Class B" areas. Using the current version of EPA's emissions model, Mobile–4, EPA has decided that lowering RVP to 8.1 psi and 7.2 psi will result, respectively, in a VOC reduction of 15 percent in Class C and Class B areas. The 15-percent toxics reduction also will be determined with an emissions model; compliance will be dominated by benzene control and RVP control, which indirectly cuts toxics (because the toxics are a subset of the vehicle's VOC emissions, and benzene is the dominant toxic).

Other gasoline parameters (olefin content, aromatic content, sulfur content, distillation) also influence the performance of NO_x, VOC, and toxics. With the implementation of the "complex model" for 1997, refiners will be allowed to trade off among all these parameters when trying to achieve the CAAA's performance standards. The SNPRM also contains two options for early use of the "complex model," if refiners elect to do so, in 1995.

EPA is now developing the "complex model," with a proposed rule expected before the end of 1992. This proposed rule also will contain proposals for Phase II performance standards. A final rule is expected in early 1993.

Likely Reformulation Characteristics in the Year 2000 and Beyond

Current emissions testing indicates that the key parameters to control are RVP, sulfur, olefins, T–50, aromatics, heavy aromatics, T–90, benzene, and oxygen. For Phase II RFG, EPA likely will require a 25-percent-or-greater reduction of VOC emissions, because it now appears technically possible to meet such a standard. The required reduction in toxics is less certain because changes in gasoline characteristics to reduce toxics may not be cost-effective if evaluated on a standalone basis. Toxics reductions will depend on volatility, aromatic content, benzene content, and oxygenate type. However, the CAAA require a minimum 20-percent toxics reduction. The VOC reduction likely will be met through further volatility reductions and reductions in olefins and sulfur.

California is proceeding to prescribe gasoline quality limits that look as though they may meet or exceed the Federal RFG program requirements for the year 2000. CARB's requirement for 1996 severely restricts sulfur and olefin content, and it also places limits on T–50 and T–90.

Comparison of Current and Future Gasolines

Table A–1 shows the physical and chemical characteristics of current gasoline and the likely characteristics of gasolines in the year 2000, based on the status of ongoing research and rulemaking programs of EPA and CARB. The principal nonpetroleum components that will be used in RFG are oxygenates. Federal RFG is required to contain at least 2.0 percent oxygen by weight. Oxygenates that could be used include ethers such as MTBE, ethyl tertiary-butyl ether (ETBE), and tertiary-amyl-methyl-ether (TAME), or alcohols such as methanol and ethanol. Refiners principally will use MTBE and ethanol because they are the only oxygenates currently produced in significant amounts. Oxygenates will be needed not only for the RFG program, which is in effect year-round, but also at higher levels for the carbon monoxide-control

Table A-1. Characteristics of Gasoline and Various Reformulations

Characteristic	1990[a] Industry Average Gasoline	1990[b] CAAA Summer Baseline Gasoline	1990[b] CAAA Winter Baseline Gasoline	1992[c] California Phase I Reformulated Gasoline	1995[d] Federal Reformulated Gasoline	1996[e] California Phase II Reformulated Gasoline	2000[f] Federal Reformulated Gasoline
RVP, psi[g]	8.6	8.7	12.9	7.8 max	8.1 or 7.2 max	7.0 max	?
Oxygen %	0	0	0.52	N/S	2.0[h] avg	2.0[i] avg	2.0
Benzene %	1.6	1.53	1.64	N/S	1.0 max	1.2 max (1.0 flat)	1.0
Aromatics %	34.4	32.0	26.3	N/S	25.0 max[j]	30.0 max (25.0 flat)	?
Sulfur, ppm	349	339	340	N/S	No increase	80.0 max (40.0 flat)	?
Olefins %	9.7	9.2	11.9	N/S	No increase	10.0 max (6.0 flat)	?
T-90, °F	323	330	332	N/S	No increase	330.0 max (300.0 flat)	?
T-50, °F	213	218	199	N/S	N/S	220.0 max (210.0 flat)	?

Note: N/S = not specified.

[a] *New Fuels Report*, July 15, 1991.
[b] EPA Draft Rules Federal Register Notice 56 FR 31239.
[c] Title 13, California Code of Regulations, Section 2251.5.
[d] EPA Supplemental Notice of Proposed Rulemaking, Federal Register (40 CFR Part 80) 13416–13495, April 16, 1992 (some averaging of most parameters allowed with some tightening of requirements).
[e] November 22, 1991, CARB resolution 91-54 to amend Title 13, California Code of Regulations, Sections 2262.1–2262.7 as adopted by the Board November 22, 1991, and changes published June 5, 1992.
[f] EPA Draft Rules Federal Register Notice 56 FR 31187–88.
[g] These RVP limits apply during summer ozone season only.
[h] 1.5% minimum and 2.1% maximum except for MTBE, which has a 2.7% maximum.
[i] 1.8% minimum and 2.2% maximum.
[j] Aromatic limit in the Act is not binding if toxic limit is met.

program, primarily in the winter in about 39 cities. MTBE and ETBE may be favored for summer oxygenates because of their lower volatility. All other changes in gasoline characteristics are expected to occur through changes in refining methods— equipment, operations, and gasoline blending practices.

Anticipated Refinery Changes To Produce RFG

Producing these RFG's will require changes to existing refineries. Because individual refineries vary significantly, not all refineries will need to make all changes listed below, and some changes may occur that are not listed here. The most likely changes are as follows:

- To meet RVP requirements, refiners will have to stop blending butanes into summer gasoline entirely, and some will need to adjust distillation operations to remove butanes and pentanes from other blendstocks. Butane currently is used as an inexpensive octane-enhancing component, but because it has a very high RVP, around 60 psi, it will need to be eliminated. The unused butane can be burned, used as a chemical feedstock for production of MTBE, or chemically converted to a low-RVP component.

- Reformer severity will be reduced to reduce the aromatic and benzene content of its output. The reformer has served as an octane source since lead was removed from gasoline; but the addition of oxygenates such as MTBE will boost octane ratings and allow less severe reformer operations. Certain benzene precursors also may be removed from the reformer feed.

- Alkylation operations will increase. Alkylate is a low-toxic, low-reactivity, high-octane blendstock with a very low RVP.

- Refiners will need to install hydrotreaters to remove the sulfur from feedstocks and, thereby, from gasoline. Hydrogen plants and sulfur recovery units also will be needed to support hydrotreating operations.

- Many refineries also will install or expand their own MTBE products to meet oxygenate needs. Furthermore, to cut olefins and create oxygenates, refiners may reoptimize catalytic cracking operations to produce large amounts of small olefins, then react those with methanol or ethanol to produce low-RVP ethers.

Cost Impact of Gasoline Reformulation

It is difficult to assess the long-term cost effect of these dramatic changes to gasoline. Final parameters, options to average, trade credits, and the number of markets to be served are not set. In addition, each refinery will face different challenges; the leading oxygenates are produced and sold in radically different world markets. These uncertainties preclude the development of a definitive cost analysis; but based on the analysis completed to date by industry and government, an incremental cost of 5 to 8 cents per gallon over the cost of conventional gasoline for 1995 is possible. This includes the fuel economy loss due to the lower energy content of the reformulated fuel. Additional costs for Phase II reformulated gasoline cannot be estimated now.

Resolution of the U.S. Alternative Fuels Council

Resolution Of
The U.S. Alternative Fuels Council
December 12, 1990

Resolved, that the President, the Congress, and the private sector proceed forthwith to establish a national energy security policy for the commercialization of alternative fuels;

Be it further resolved, that the federal government should promptly take steps to assist the marketplace and remove impediments to the widespread commercialization of alternative motor vehicle fuels. Legislation and administrative action should carefully evaluate costs and benefits of alternative fuels, measures such as fuel economy incentives, tax incentives, research and demonstration, accelerated fleet purchases, cooperation with states and localities, and other steps. The program should make progress from year to year with a goal that, by the year 2005*, alternative fuels will be used for at least 25 percent of all motor vehicle miles traveled. These alternative fuels should be derived from resources other than petroleum, and the steps taken to promote alternative fuels should be consistent with our environmental laws. The term "alternative fuels" in this resolution includes electricity, natural gas, methanol, ethanol, LPG, hydrogen, and non-petroleum components of reformulated gasoline and diesel.

* This figure was amended to the year 2010 by the Council on February 14, 1991, in Denver, Colorado.

Letter to W. Henson Moore, U.S. Alternative Fuels Council Mission Statement

AEI American Enterprise Institute for Public Policy Research

CALIFORNIA ENERGY COMMISSION

November 21, 1991

The Honorable W. Henson Moore
Deputy Secretary of Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

Dear Mr. Moore:

As noted in its Second Interim Report of the Interagency Commission on Alternative Motor Fuels, the Administration has included strong measures to promote the use of alternative fuels in its National Energy Strategy. The Alternative Fuels Council applauds this leadership and would like to express its appreciation of your significant personal role both in developing the strategy and in working with the Council. This letter provides you with a brief report of the U.S. Alternative Fuels Council's progress.

In October 1988, the Senate and House of Representatives enacted the Alternative Motor Fuels Act of 1988. This act created the United States Alternative Fuels Council and the Interagency Commission on Alternative Motor Fuels. The Council has been meeting for the past twenty months and is pleased to submit this report of its latest activities.

At the December 1990 U.S. Alternative Fuels Council meeting in Washington, D.C., the Council recommended that by the year 2010 alternative fuels should be used for at least 25 percent of all motor vehicle miles traveled provided such fuels are cost effective. The Council met most recently in September 1991 in Kansas City, Missouri, to continue its discussions.

Over the past twelve months and especially at its last meeting, the Council reviewed and discussed a wide array of technical, economic, social, environmental and political issues associated with the manufacture, distribution and use of alternative motor fuels. These issues are extremely complex. While this complexity poses a substantial challenge to the Council, we are pleased to report that we reached unanimous consensus at our last meeting on several policy matters, including a Council mission statement. You will find the Council's mission statement and the policy guideline statement in the attachment. Future Council

Mr. Henson Moore
November 21, 1991
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meetings will revisit these issues and take up others as we work toward submission of the Interagency Commission's Final Report in September 1992.

Respectfully,

Dr. Robert W. Hahn
Co-chair, United States
Alternative Fuels Council

Honorable Charles Imbrecht
Co-chair, United States
Alternative Fuels Council

Enclosure

cc: Members of the U.S. Alternative Fuels Council

MISSION STATEMENT

The United States Alternative Fuels Council shall recommend a plan for developing cost-effective alternative transportation fuels that promotes environmental quality and energy security.

POLICY GUIDELINES AGREED UPON

It is the position of the United States Alternative Fuels Council that the United States should:

1. Maintain government-established standards for the environment.

2. Encourage diversification of energy supply dependence with regard to location and type while encouraging increased domestic production of all practical, efficient and economic sources of energy, traditional and non-traditional.

3. Maintain U.S. competitiveness in a global economy.

4. Encourage coordination of a national strategy and program development which accounts for local, state and regional requirements.

5. Encourage a robust and durable policy, valid across the broadest range of economic, environmental and fuel supply balance scenarios.

6. Avoid any drastic petroleum taxes or import fees.

7. Encourage a "Level Playing Field" that allows alternative fuels and vehicles to compete fairly based on their cost and performance characteristics.

8. Increase supply-side-push incentives to produce alternative fuel vehicles and alternative fuels.

9. Periodically reexamine existing fuel and vehicle supply/production requirements relative to meeting national goals.

10. Not insist on "tight" early links between alternative fuel vehicles and alternative fuel sales.

11. The Congressional Research Service should carry out the following two tasks:

    Task 1: Provide a ranking of different policy levers to encourage alternative fuels on the basis of cost, energy security and environmental quality. The analysis should evaluate all relevant information sources, especially newly emerging data on alternative fuels, vehicles, and blends. The ranking should reflect key scientific and economic uncertainties in deriving estimates of cost-effectiveness measures for environmental quality and energy security.

    Task 2: Evaluate the external costs of petroleum in the American economy that are not reflected in the retail price.

Appendix D

Members of the Interagency Commission on Alternative Motor Fuels

Mr. J. Michael Davis (Chairman)
Assistant Secretary
for Conservation and Renewable Energy
Department of Energy

Mr. David J. Berteau
Principal Deputy Assistant Secretary
of Defense Production and Logistics
Department of Defense

Mr. Joseph Canny
Deputy Assistant Secretary
for Policy and International Affairs
Department of Transportation

Mr. Roger D. Daniero
Commissioner of the Federal Supply Service
General Services Administration

Dr. Bruce Gardner
Assistant Secretary for Economics
U.S. Department of Agriculture

Mr. Arthur I. Porwick
Assistant Postmaster General
U.S. Postal Service

Mr. William Rosenberg
Assistant Administrator for Air and Radiation
Environmental Protection Agency

Mr. Gerard F. Scannell
Assistant Secretary
for Occupational Safety and Health
Department of Labor

APPENDIX E

Members of the U.S. Alternative Fuels Council

Dr. Robert W. Hahn (Co-chairman)
Visiting Scholar
American Enterprise Institute

The Honorable Charles R. Imbrecht (Co-chairman)
Chairman
California Energy Commission

Senator Charles E. Grassley
Iowa

Senator John D. Rockefeller, IV
West Virginia

Congressman Bill Alexander
Arkansas

Congressman Jerry Lewis
California

J.K. Aldous
Senior Vice President
American Automobile Association

Mr. George Babikian
President
ARCO Products Company

Mr. Robert Campbell
President and CEO
Sun Company, Inc.

Mr. Ben Henneke, Jr.
President
Energy Fuels Development Corp.

Mr. David A. Hentschel
Chairman
Occidental Oil and Gas Corporation

Mr. Howard Hinton
Vice President
Midwest Grain Products

Mr. Elwin S. Larson
President and CEO
Brooklyn Union Gas Company

Mr. Ray Lewis
President
American Methanol Institute

Mr. David F. Merrion
Senior Vice President
Detroit Diesel Corporation

Mayor Federico Pena
Denver, CO

Ms. Helen Petrauskas
Vice President of Environmental and Safety Engineering
Ford Motor Company

Mr. Henry B. Schacht
Chairman and CEO
Cummins Engine Company

Mr. Theodore Weigle, Jr.
Vice President
Bechtel Corporation

Mr. Robert E. Yuhnke
Senior Counsel
Environmental Defense Fund