

Alternative Fuel Vehicles: Should the Federal Government Bridge the Economic Gap?

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ABSTRACT

The future of Alternative Fuel Vehicles (AFVs) is uncertain because consumer demand for them has not been established. AFVs are environmentally friendly and have the potential to provide short, mid, and long term solutions to the United States' problem of dependence on foreign sources of oil. At this time, however, there is little economic incentive to encourage consumers to purchase AFVs.

The federal government has taken the lead in establishing a market for AFVs by mandating their purchase across federal and state vehicle fleets. In addition, the government has offered incentives to automobile manufacturers to encourage the production of AFVs. The government has also established consumer awareness programs which are educating the public about the benefits of AFVs.

It is basic government research, however, which is the key to maximizing the long term potential of AFVs. Currently, AFVs can provide protection from potential short term oil spikes and alternatives to increasing oil prices. Eventually, they will be able to alleviate a major portion of this country's dependence on foreign sources of oil. If the government continues AFV research and development programs, a market for AFVs will develop, and their maximum potential benefits could be realized.

INTRODUCTION

The United States is facing an almost insurmountable problem: the dependence on foreign sources of oil. Forty-four percent of the oil used in this country in 1995 came from foreign sources. By the year 2015, that number is expected to be 61 percent [1] (see Figure 1). It is imperative that other energy options be explored.

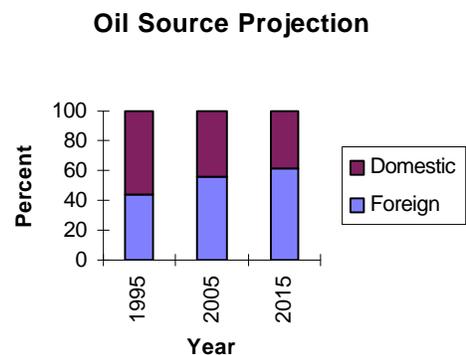


Figure 1. Sources of oil consumed in the US.

In the United States, one of the major uses for oil is as automotive fuel. In fact, 44 percent of the oil used in this country in 1995 went to fuel automobiles [1] (see Figure 2).

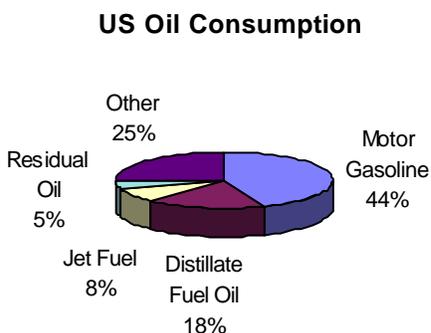


Figure 2. Uses of oil consumed in the US in 1995.

There are a variety of “alternative” fuels which may be used to power vehicles. “Alternative fuels are defined to be methanol, ethanol, and other alcohols; mixtures containing 85 percent or more by volume of methanol, ethanol, or other alcohols and gasoline or other fuels; natural gas, liquefied petroleum gas; hydrogen; coal-derived liquid fuels; electricity; and any other fuel that is substantially non-petroleum, including fuels other than alcohol that are derived from biological materials” [27].

Reformulated gasoline (RFG) and reformulated diesel fuels are sometimes included in the category of alternative fuels. These fuels have better emissions characteristics than regular gasoline and diesel fuels due to the addition of oxygenates which enhance combustion. They will not, however, be included in the discussions in this paper because they are oil derivatives.

Electricity is also defined as an alternative fuel. Automobiles which run on electricity are called Electric Vehicles (EVs). Electricity is considered an alternative fuel because EVs have zero emissions, but the cost of EVs prohibits them from being widespread. The

expense incurred in manufacturing of an EV is high because the normal internal combustion engine (ICE) must be replaced with an electric motor and a set of batteries for electricity storage. Another problem with EVs is limited range. Because of these factors, EVs will not be considered in the discussion in this paper.

“Alternative fuel vehicles (AFVs) are defined as automobiles which operate on either an alternative fuel alone, or on a combination of an alternative fuel and gasoline” [27]. Vehicles which will run only on an alternative fuel are called dedicated AFVs. Vehicles which can run on gasoline or an alternative fuel are called “dual fuel” or “flexible fuel” vehicles. Dual Fuel Vehicles (DFVs) have two separate fuel tanks, one for each kind of fuel, while Flexible Fuel Vehicles (FFVs) have only one tank which is used for both fuels. All of these vehicles utilize ICEs with only minor modifications from their stock gasoline counterparts.

The benefit of AFVs has been touted by environmentalists as being their potential to reduce automotive emissions. Alternative fuels are inherently less polluting than petroleum based fuels because their chemical make-up is less complex. This allows alternative fuels to burn more completely in the engine and, thus, create less emissions. However, while air quality improvement is a large potential benefit of the use of AFVs, it is not the only one.

There are many potential benefits which could be realized from the development of AFVs. In his Executive Order entitled *Federal Alternative Fueled Vehicle Leadership*, President William J. Clinton said, “. . . the use of alternative fueled motor vehicles will, in many applications, reduce the Nation’s dependence on oil, and may create jobs by providing an economic stimulus for domestic industry, and may improve the Nation’s air quality by reducing pollutants in the atmosphere.” [8]

In fact, the potential for AFVs to reduce dependence on foreign oil is staggering. In 1995, the amount of oil used for motor gasoline was equal to the amount of oil imported to this country. At this level of

consumption, even if just the portion of oil used for motor gasoline was replaced by alternative fuels, there would be no need to import foreign oil.

BACKGROUND

HISTORY - Alternative fuels have been present in the automotive fuel market since the invention of the automobile. Gasoline was not introduced as a motor fuel until the late 1800s. Prior to that time, alternative fuels such as electricity stored in lead acid batteries and the gas emitted from burning coal, a form of methane gas, were commonly used in vehicles. Vehicles which ran on some form of ethanol, or other alcohols produced from biological material, were also common near the beginning of the 20th century. In fact, Henry Ford fueled one of his first automobiles on ethanol in the 1880s [20].

Despite their availability, alternative fuels have had a minimal impact throughout history. As refinery technology developed, AFVs were rejected in favor of gasoline vehicles because gasoline became more easily produced than other forms of fuel and, therefore, less expensive for the consumer. In the last several decades, however, AFVs have been introduced back into the automotive market.

Increased pollution in the 1970s and 1980s created a consumer awareness of the need for improved air quality. The 1970 Clean Air Act (CAA) legislated these improvements by initiating National Ambient Air Quality Standards (NAAQS). In order to achieve the NAAQS, vehicle emissions standards were also introduced in the CAA which targeted carbon monoxide, hydrocarbons and oxides of nitrogen [27]. Environmental concerns continue to be the salient motivation for AFV use and research.

The energy crises of 1973 and 1979 renewed interest in alternative fuels for motor vehicle use. AFVs became an option automotive consumers who had been inconvenienced by the dramatic rise in oil price and the shortage of gasoline. As quickly as it

began, the end of the energy crises spelled the end of the new attraction to AFVs.

Research efforts declined in the mid 1980s with the advent of a more stable world situation. They were revived again following the Persian Gulf War (1990-91), when the fear of elimination of foreign oil sources promoted renewed interest and investment in research. The stability of the world oil market in the past five years has once again reduced concern about an oil price spike, and optimistic estimates of world oil reserves have reduced concern about oil scarcity.

ISSUE DEFINITION - The practicality of alternative fuel vehicles (AFVs) has been debated in recent years by the automotive industry, the government and the public. The four main factors which are used by these groups to determine the success of new technologies are performance, availability, environmental friendliness and cost effectiveness. The current state of AFV technology has proven that alternative automotive fuels can meet the first three of these requirements for success. However, AFVs are still not economical.

It is clear that if the fate of AFVs is left to economics, they will have no near-term future in the United States. This brings up the question, then, of whether a small market share for AFVs should be maintained during this period of minimal demand by utilizing government mandates to promote sales.

The answer lies in the recognition that AFVs will be in demand in the future. It is not possible to predict exactly how far in the future that demand will surface, but it is justifiable that it will occur within the next century. If AFVs are allowed to disappear from the current marketplace, the research and infrastructure utilized to make them a reality will also be discontinued. Elimination of both AFVs in the marketplace and the research which is improving AFV technology would leave the United States vulnerable to the

effects of increasing dependence on foreign oil sources.

Energy dependence is a complicated issue. There are three main problems with being dependent on a foreign source of oil. The first is the threat of an interruption of flow in the world oil market resulting in a short term spike in oil price. This type of interruption could be caused by a war, an embargo or other foreign policy, or by an accident such as a fire.

The second problem of energy dependence is the increasing cost of oil. Increased demand for oil and decreased oil resources will combine to drive the price of oil higher in the future.

Finally, the long term problem with foreign oil dependence is scarcity. At some point in the future, world oil reserves will be depleted to the point where it is more expensive to drain the remaining oil than it is to utilize alternative technologies.

AFVs can address all of these issues. The short, mid and long term goals necessary to reduce energy dependence can be attained by instigating a continuing AFV research thrust with a well defined development and implementation plan.

The future of alternative fuels research and AFVs without the driving force of government mandates is clear. If federal AFV mandates continue to be enforced, research and product development will continue. If the federal government eliminates all mandates, the future of AFVs will be determined by the current market. Economic analysis shows that the market will not support AFVs; sales and research will cease. The current stage of alternative fuel research is critical. Now is the time for the government to uphold its far-sighted legislation and continue environmental benefit from AFVs' reduced emissions while pursuing the long term goal of decreased dependence on foreign sources of oil that alternative fuels can provide.

LEGISLATION

In the past three decades, much environmental legislation has been considered

for implementation. There are several main laws that have been enacted which have direct impact on alternative fuels usage in this country. These laws mandate either the development or implementation of alternative fuel usage by awarding special incentives for the use of alternative fuel vehicles. Thus, it is important to study the effects of this legislation on alternate fuels research. Three of these will be focused on in this report:

- Alternative Motor Fuels Act (AMFA), 1988
- Clean Air Act Amendments (CAAA), 1990
- Energy Policy Act (EPACT), 1992

Each of these pieces of legislation will be discussed in detail in the following sections.

ALTERNATIVE MOTOR FUELS ACT (AMFA), 1988 - This legislation added a twist to the familiar Corporate Average Fuel Economy, or CAFE standardsⁱ to which vehicle production companies must adhere. Under the provisions in the AMFA, companies are allowed to calculate the fuel economy of alternative fuel vehicles on a special scale. They can calculate the fuel economy of an M85ⁱⁱ vehicle, for example, based solely on the percentage of gasoline in each gallon of fuel used. This rating system can give auto manufacturers a great advantage because the high fuel economy ratings of AFVs can be included in their average to offset the lower ratings of less efficient vehicles in the corporate fleet.

The AMFA also addresses the use natural gas as an alternative motor fuel. Dedicated natural gas vehicles are also allowed to calculate effective fuel economy based on a 15% gasoline per gallon scale.

All vehicles must meet range requirements established by the National Highway Transportation and Safety Administration (NHTSA) in order to qualify for effective fuel economy ratings. The requirements for ethanol, methanol and natural gas AFVs are:

- Ethanol - 200 miles
- Methanol - 200 miles
- Natural Gas - 100 miles

Dual fuel vehicles may only benefit from half of the fuel economy rating of similarly fueled dedicated vehicles. The maximum allowable increase in a manufacturer's overall CAFE rating, through the inclusion of AFVs, is 1.2 mpg [27].

CLEAN AIR ACT AMENDMENTS (CAAA), 1990 - The 1990 Clean Air Act Amendments addresses the issue of automotive emissions. The Act has 11 Titles and the first two of these pertain to automotive emissions. Title I of the CAAA includes a general overview of the Amendments, their purpose and plans for implementation. It specifically addresses the issue of automotive pollutants and the plan for achieving attainment of National Ambient Air Quality Standards (NAAQS) across the United States.

Title II of the Act, "Provisions for Mobile Sources," sets standards for automotive emissions. It also authorizes the EPA to study auto emissions and apply stricter standards in the future if warranted. [7].

The CAAA charges individual states with developing State Implementation Plans (SIPs) to address the air quality problems in their states. In addition, the CAAA provides for fleets to earn air quality credits by utilizing alternative fuel vehicles. The credits may only be earned if the vehicles have been certified to meet California Ultra Low Emissions Vehicle Standards (ULEV) or California Zero Emissions Vehicle Standards (ZEV) [27].

ENERGY POLICY ACT (EPACT), 1992 - The purpose of the Energy Policy Act was to specifically address increased energy use in the United States. The goals set out in the Act address short-term and long term oil use. The main goals of EPACT are to:

- Reduce Oil Consumption - from 40 percent (of total US Energy

Consumption) in 1990 to 33 percent in 2010.

- Reduce Oil Imports - limited to 50 percent or less of US Oil Consumption
- Increase Energy Efficiency - increased by 10 percent over 1990 levels every five years, therefore reaching an increase of 40 percent by 2010.
- Increase Utilization of Renewable Energy - from 8 percent in 1990 to 14 percent in 2010.

In order to achieve these goals, EPACT mandated the purchase of AFVs by federal, state, private and municipal fleets. In general, these mandates require that a certain percentage of all new fleet vehicles be AFVs (see Table 1). "A fleet is defined as a number of vehicles (at least 20) that are centrally fueled or otherwise controlled by a Federal agency, state or person (corporation, partnership, municipality, etc.)." [27]

Fleets covered under EPACT include:

- Fleets of 20 or more vehicles which are primarily operated in a metropolitan area which has a population of 250,000 or greater
- Fleets that operate 50 or more vehicles in the US
- The US Post Office Fleet

Table 1. *Energy Policy Act Purchase Requirements of Light-Duty Alternative Fuel Vehicles* [12].ⁱⁱⁱ

| Year | Federal | State | Fuel Providers | Private* |
|---------|---------|-------|----------------|----------|
| 1993 | 5000 | -- | -- | -- |
| 1994 | 7500 | -- | -- | -- |
| 1995 | 10000 | -- | -- | -- |
| 1996 | 25% | 10% | 30% | -- |
| 1997 | 33% | 15% | 50% | -- |
| 1998 | 50% | 25% | 70% | -- |
| 1999 | 75% | 50% | 90% | 20% |
| 2000 | 75% | 75% | 90% | 20% |
| 2001 | 75% | 75% | 90% | 20% |
| 2002 | 75% | 75% | 90% | 30% |
| 2003 | 75% | 75% | 90% | 40% |
| 2004 | 75% | 75% | 90% | 50% |
| 2005 | 75% | 75% | 90% | 60% |
| 2006-on | 75% | 75% | 90% | 70% |

* Under the early rulemaking scenario. Required additional rulemaking by December 15, 1996 for private AFV requirements to take effect.

Certain vehicles are exempt from the Act. The following is a brief, but not all-inclusive list of those vehicles [27]:

- vehicles held for daily lease or rental to the public
- demonstration vehicles and vehicles for sale by dealers
- manufacturer's product evaluation and testing vehicles
- law enforcement vehicles
- emergency vehicles
- military vehicles (when requested for reasons of national security)
- non-road vehicles (farm equipment, etc.)

STATE LEGISLATION - The legislative impact on AFVs goes beyond the federal level. The government of the state of California in conjunction with the California Air Resources Board (CARB) has developed emissions standards for vehicles which are above those set out by the Federal government. This type of state legislation may help promote the use of AFVs around the country.

STAKEHOLDERS

In order to determine the future of AFVs and alternative fuels research, it is important to view the topic from the perspective of each of

the stakeholders in the AFV arena. Stakeholders include federal and state governments, the automotive industry and automotive consumers. The benefits received by each of these groups are varied, but they all have the potential to profit from continued development of AFVs and alternative motor fuels.

GOVERNMENT - There are many reasons that legislators and government agencies could choose for supporting the use of AFVs in the federal fleets. The two major problems which the use of AFVs can address are automotive emissions and dependence on foreign sources of oil.

The Federal government has shown that it recognizes the potential benefits of AFVs in both of these categories. The environmental benefits are addressed by the CAAA which, as previously mentioned, provide states with air quality credits for the use of AFVs. AFVs' potential for reducing foreign oil dependence is targeted in the AMFA and EPACT. It is clear that the government is trying to maximize the benefits of AFVs while maintaining a balance between government mandates and consumer demand.

INDUSTRY - The position of the automotive industry is that research and development of alternative fuels for automotive use will continue only because it is required by the government. In part, this is because sales of AFVs have been minimal to date. Automobile manufacturers, like all businesses, are subject to the demands of the market and will not continue to produce low-demand products unless they perceive a change in these demands or are forced to do so by the government. It is important to recognize, however, that if the market favored AFV sales, auto makers would likely increase production and thereby reduce the overall cost of AFVs.

Currently, the imposition of government fuel economy standards, and subsequent provisions for AFVs in those standards, has prompted auto makers to develop lines of AFVs. There are two types of AFVs, those

manufactured by the auto maker called Original Equipment Manufactured (OEM) and those converted by after-market conversion companies. The OEM AFVs manufactured and available for purchase in the United States are described in the following sections.

Ford Motor Company - Ford currently offers two models of dedicated AFVs. The Crown Victoria is available as a dedicated natural gas vehicle. The F-700, which has been in service for the past 20 years, runs on propane. The Taurus is available as a methanol or ethanol FFV. The newest member of Ford's AFV fleet is the Contour, which is a dual fuel natural gas AFV [18].

Ford also announced recently that the company will be producing a line of ethanol FFVs. Beginning in 1999, the 3.0-Liter Ford Ranger line of trucks will be produced with an ethanol flexible fuel engine. The company plans to produce 250,000 of these vehicles over a four year period [29].

General Motors - GM is currently not offering any AFVs. This is probably because they are concentrating their efforts on marketing the EVI, their electric vehicle [21].

Chrysler Corporation - Chrysler has adopted a large scale AFV strategy. The corporation has designed and implemented a flexible fuel engine in all of their LH platform vehicles. This line includes the Chrysler Concorde, Dodge Intrepid, and Eagle Vision. These are methanol AFVs which will run on any blend of gasoline and methanol, up to M85 [6].

Chrysler also announced recently that it will produce 200,000 ethanol flexible fuel minivans. These vehicles will be available in the 1998 model year [29].

Non-OEM AFV Developers (After-Market AFVs) - There are numerous companies across the United States who convert OEM vehicles from gasoline operation to alternative fuel operation. The cost for an after-market conversion ranges from \$500 to \$4000, mainly depending on vehicle make, conversion type, and geographic location.

CONSUMERS - Automobile buyers today have a choice of seven OEM AFVs, all of which have performance characteristics comparable to those of their gasoline counterparts. Still, consumer demand for AFVs is low. The major obstacles to the increased demand for AFVs are low gasoline prices and minimal alternative fuel infrastructure.

POSITIONS ON THE ISSUE

Current policy mandates the use of AFVs in certain applications. These mandates have prompted further research into the use of alternative fuels in automotive applications. However, the mandates have failed to provide the impetus needed to create consumer interest and adequate market viability for the future of AFVs to look anything but dim. The question is whether governmental mandates are necessary and/or sufficient to generate market.

Three positions on the topic have been uncovered. The federal government wants AFVs to be utilized to control pollution and reduce dependence on foreign oil. American auto makers are not overly enthusiastic about producing AFVs because they involve additional research and development costs to build. Consumers do not want to buy AFVs because they do not feel they can meet the range, efficiency, and comfort requirements they have come to expect in their vehicles.

AFV CHALLENGES

INFRASTRUCTURE - One major stumbling block in the deployment of AFVs is the problem of refueling. Gasoline stations are found on almost every corner in most urban areas; alternative fuel stations are not. In fact, there are only 5844 alternative fuel stations in the US (see Table 2). This causes AFVs to be impractical for many drivers.

Table 2. *US Refueling Site Counts by Fuel Type*^{iv} [36].

| Fuel Type | Number of Stations |
|-----------|--------------------|
| M85 | 95 |
| CNG | 1417 |
| E85 | 62 |
| LPG | 4074 |
| LNG | 72 |
| Total | 5720 |

Even those consumers who do have dual fuel AFVs are affected by this situation, being forced to run their vehicles on gasoline when filling stations for their alternative fuel are not along the route to their current destination. However, the new FFVs should alleviate many of the range and station location problems consumers experienced in the past.

COST - In the past, the cost of purchasing an AFV has been prohibitive for most consumers. However, although consumer demand for AFVs has not increased dramatically, OEMs (Chrysler and Ford) have taken the incentives offered by the Federal government for AFVs and will be utilizing the cost reduction effects of mass production to offer FFVs at no additional cost to consumers in the 1998 and 1999 model years.

CONSUMER AWARENESS - Consumers have a basic lack of knowledge regarding the issue of AFVs. This needs to be addressed if the market for AFVs is to be expanded. The Department of Energy (DOE) was charged with improving consumer awareness in the EPACT. In response to this commission, the DOE created the Clean Cities program which has generated interest in AFVs in cities across the country. Currently, there are 44 Clean Cities in the DOE program, with another 8 in the process of becoming designated Clean Cities [12].

CHOICE OF "THE" ALTERNATIVE FUEL - It appears that the stakeholders would like for there to be a determination of "the" alternative fuel. There are so many alternate fuel choices which, in addition to battery technology, could provide alternative fuel systems for vehicles. It is understandable that both auto

manufacturers and consumers are leery of being burdened with a new fuel technology which may or may not be the "fuel of the future" for automobiles. Because of these factors, it is important to consider the practicality and benefits of regional alternative fuels production and implementation.

Regional AFV production would involve manufacturers selling different types of AFVs in different regions of the country. For example, an OEM might offer ethanol AFVs in the Mid West, and Natural Gas AFVs on the East Coast. This type of plan could allow regions to focus capital and infrastructure development costs on one alternative fuel instead of many.

AFV BENEFITS

ENVIRONMENTAL IMPACT - The other major reason for governmental mandates promoting alternative fuels is the improved environmental impact these vehicles will have. In order to evaluate the size of this impact, a comparison of alternate fuels emissions to those of gasoline must be made. The emissions standards for gasoline vehicles in the 1997 model year are shown in Table 3. AFV emissions must be below these to provide environmental benefit. A comprehensive list of AFV emissions is not available at this time.

Table 3. Federal Emission Control Requirements for Automobiles for 1995 and on (grams per mile).

| Hydro-carbons (HC) | Carbon monoxide (CO) | Nitrogen Oxides (NOx) | Particulate Matter (PM) |
|--------------------|----------------------|-----------------------|-------------------------|
| 0.25 | 3.4 | 0.4 | 0.08 |

RENEWABLE FUELS - AFVs utilize alternative fuels, some of which are renewable. Not only could these fuels decrease dependence on foreign sources of oil, but they could also decrease dependence on fossil fuels.

DECREASED ENERGY DEPENDENCE - Of all the benefits of alternative fuels, the most critical is that their use reduces this country's reliance on foreign oil. One only has to look at the figures on oil imports to recognize how our dependence on other countries for our oil supply is increasing each year. In 1995, the United States used 17.7 million barrels of oil per day (b/d). Of that 17.7 million, 9.8 million were produced domestically while the remaining 7.9 million were imported. In that year, 44.6 percent of the oil used in this country was imported. Projections for 1997 indicate that that percentage will increase to 49 percent or that we will import 9 million b/d of oil [1].

The largest single use for this oil is as automotive fuel. Of the 17.7 million b/d used in 1995, 7.9 million, or 44 percent, were used to fuel automobiles. Reduction in the amount of oil used for fueling automobiles can help reduce the amount of oil which must be imported [1].

CONCLUSIONS

The major benefit of AFVs is their short, mid, and long-term potential to address the issue of increased energy dependence. AFVs, particularly FFVs, can be depended on to provide transportation during a short-term price spike caused by war embargo, or other issue which interrupts the foreign oil supply. AFVs, utilizing alternative fuels, can provide relief from increasing oil prices. AFVs will be available for use when the supply of oils runs out. Even though this is not a near-term event, it is a guaranteed future event. It would be shortsighted and irresponsible to set aside AFVs and alternative fuel research now, knowing that future generations will have to address the oil scarcity issue.

Continuation of research is imperative to the continued success of AFVs. Private companies complete research which addresses short-term technology needs for their products, in this case, current AFV models.

Government research is aimed at mid-long term goals such as fuel economy in the Program for a New Generation of Vehicles (PNGV).

RECOMMENDATIONS

The purpose of this paper has been to explore the challenges facing the implementation of alternative fuels in the United state's automotive industry, to outline them, and to present the options for meeting them with regard to active legislation which will produce the necessary results.

AFV and alternative fuel research must be continued. The federal government should continue to uphold far-sighted legislation like EPACT which provides for this research, development and implementation of AFVs.

Government incentive programs which encourage auto makers to produce AFVs should be continued. Their effectiveness has been shown by the large-scale AFV production efforts introduced by Ford and Chrysler.

The future of AFVs can be successful if the Federal government continues to be the leader in alternative fuel technology. To accomplish this, the government must bridge the current economic gap and provide the impetus for continued AFV research and development.

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ACRONYMS AND ABBREVIATIONS

| | |
|-------|-----------------------------------------------------------|
| AFV | Alternative Fuel Vehicle |
| AIAM | Association of International Automobile Manufacturers |
| CAA | Clean Air Act of 1970 |
| CAAA | Clean Air Act Amendments of 1990 |
| DFV | Dual Fuel Vehicle |
| EPACT | Energy Policy Act of 1992 |
| FFV | Flexible Fuel Vehicle |
| ICE | Internal Combustion Engine |
| LEV | Low Emission Vehicle (California) |
| NAAQS | National Ambient Air Quality Standards |
| NHTSA | National Highway Transportation and Safety Administration |
| OEM | Original Equipment Manufactured |
| PNGV | Program for a New Generation of Vehicles |
| SIP | State Implementation Plan |
| ZEV | Zero Emission Vehicle (California) |

ABOUT THE AUTHOR

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Cynthia was selected as one of 15 students from across the United States to participate in the 1997 Washington Internships for Students of Engineering (WISE) Program. During this ten week internship in Washington, DC, she researched and compiled this paper. Cynthia's participation in WISE was supported by the Society of Automotive Engineers.

ⁱ CAFE Standards were first implemented in 1978. They require that automobile manufactures meet a minimum average fuel economy for all vehicles sold.

ⁱⁱ M85 is a mixture of methanol and gasoline, specifically it contains 85 percent methanol and 15 percent gasoline.

ⁱⁱⁱ Table is listed as 5.3 in TEDB edition 16; source listed is National Alternative Fuels Hotline for Transportation Technologies, 1993.

^{iv} This table modified from table in source indicated; source table includes state locations of refueling sites.