REPLACEMENT FUEL AND ALTERNATIVE FUEL VEHICLE

TECHNICAL AND POLICY ANALYSIS

Pursuant to Section 506

of the

Energy Policy Act of 1992

July 1997

Energy Efficiency and Renewable Energy
Office of Transportation Technologies

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EPACT INITIATIVES FOR ALTERNATIVE FUEL VEHICLES, U.S. Department of Energy, Office of Transportation Technologies, March 1995.

ALTERNATIVE FUEL VEHICLES FOR STATE GOVERNMENT & FUEL PROVIDER FLEETS (A Guide to 10CFR Part 490), U.S. Department of Energy, Office of Transportation Technologies.

REPLACEMENT FUEL AND ALTERNATIVE FUEL VEHICLE TECHNICAL AND POLICY ANALYSIS (Pursuant to Section 506 of the Energy Policy Act), DRAFT, U.S. Department of Energy, Office of Transportation Technologies.

MARKET POTENTIAL AND IMPACTS OF ALTERNATIVE FUEL USE IN LIGHT-DUTY VEHICLES: A 2000/2010 ANALYSIS. Technical Report 14 in the Flexible and Alternative Fuel Series, U.S. Department of Energy, Office of Policy and Office of Energy Efficiency and Renewable Energy, January 1996.

ALTERNATIVE FUEL TRANSPORTATION PROGRAM, 10 CFR Part 490, *61 Federal Register 10622*, March 14, 1996.

ALTERNATIVES TO TRADITIONAL TRANSPORTATION FUELS: AN OVERVIEW, U.S. Department of Energy, Energy Information Administration, Report DOE/EIA-0585/O, June 1994.

ALTERNATIVES TO TRADITIONAL TRANSPORTATION FUELS 1993, U.S. Department of Energy, Energy Information Administration, Report DOE/EIA-0585(93), January 1995.

ALTERNATIVES TO TRADITIONAL TRANSPORTATION FUELS 1994, VOLUME 1, U.S. Department of Energy, Energy Information Administration, Report DOE/EIA-0585(94)/1, February 1996.

ALTERNATIVES TO TRADITIONAL TRANSPORTATION FUELS 1994, VOLUME 2: Greenhouse Gas Emissions, U.S. Department of Energy, Energy Information Administration, Report DOE/EIA-0585(94)/2, August 1996.

PREFACE

The Energy Policy Act of 1992, Pub. L. 102-486, (EPACT) includes section 506 entitled "TECHNICAL AND POLICY ANALYSIS." Section 506 provides as follows:

(a) REQUIREMENT--Not later than March 1, 1995, and March 1, 1997, the Secretary shall prepare and transmit to the President and the Congress a technical and policy analysis under this section. The Secretary shall utilize the analytical capability and authorities of the Energy Information Administration and such other offices of the Department of Energy as the Secretary considers appropriate.

(b) PURPOSES--The technical and policy analysis prepared under this section shall be based on the best available data and information obtainable by the Secretary under section 503, or otherwise, and on experience under this title and other provisions of law in the development and use of replacement fuels and alternative fueled vehicles, and shall evaluate--

(1) progress made in achieving the goals described in section 502(b)(2), as modified under section 504;

(2) the actual and potential role of replacement fuels and alternative fueled vehicles in significantly reducing United States reliance on imported oil to the extent of the goals referred to in paragraph (1); and

(3) the actual and potential availability of various domestic replacement fuels and dedicated vehicles and dual fueled vehicles.

(c) PUBLICATION--The Secretary shall publish a proposed version of each analysis under this section in the Federal Register for public comment before transmittal to the President and the Congress. Public comment received in response to such publication shall be preserved for use in rulemakings under section 507.

This report represents the first of the two technical and policy analyses required by EPACT section 506. It addresses each of the elements that the statute called on the Department of Energy (DOE) to evaluate. Each of the three statutory elements, called for by section 506(b)(1)-(3), is discussed in a separate section of the report (Sections III, IV, and V respectively) following the Executive Summary and the Introduction. In addition, DOE has chosen to identify and discuss some additional issues and perspectives not specifically suggested by the statute. These are included principally in Section VI of the report, entitled "Summary of Key Issues and Perspectives," although the Introduction (Section II) and the Conclusions/Recommendations section (Section VII) also include some conceptual discussion.

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LIST OF ACRONYMS

AEO	Annual Energy Outlook
AFTM	Alternative Fuels Trade Model
AFV	alternative fuel vehicle
AMFA	Alternative Motor Fuels Act of 1988
bpd	barrels per day
Btu	British thermal unit
CAA	Clean Air Act
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CRS	Congressional Research Service
DOD	Department of Defense
DOE	Department of Energy
E10	10 percent ethanol (90 percent gasoline)
E85	85 percent ethanol (15 percent gasoline)
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPACT	Energy Policy Act of 1992
EV	electric vehicle
FFV	flexible fuel vehicle
FY	fiscal year
GNP	gross national product
GSA	General Services Administration
GVW	gross vehicle weight
LDV	light-duty vehicle
LEV	low emissions vehicle
LNG	liquefied natural gas
LPG or LP gas	liquefied petroleum gas
MTBE	methyl tertiary butyl ether
M85	85 percent methanol (15 percent gasoline)
M100	100 percent methanol (“neat methanol”)
NAFTA	North American Free Trade Agreement
NGL	natural gas liquids
OEM	original equipment manufacturer
OPEC	Organization of Petroleum Exporting Countries
PNGV	Partnership for a New Generation of Vehicles
ppm	parts per million
psi	pounds per square inch
QVM	qualified vehicle modifier
R&D	research and development
RD&D	research, development and demonstration
ULEV	ultra low emissions vehicle
ZEV	zero emissions vehicle

I. CONCLUSIONS

The Energy Policy Act of 1992 (EPACT) has set in motion substantial efforts, probably surpassing any previous activity seen in the U.S. alternative fuels sphere. These activities, however, are still largely at the incipient stages and DOE cannot yet be certain as to the magnitude of the programs' scope or their effects on fuel replacement.

The EPACT section 502(b)(2) goals of 10 percent fuel displacement by 2000 and 30 percent fuel displacement by 2010 are very ambitious, the 2010 goal being extremely ambitious. The U.S. appears to be on the way to meeting the 10 percent goal, due largely to blending of oxygenates in gasoline, which is classified as replacement fuel use under EPACT. If natural gas liquids were also counted as replacement fuels, the U.S. could possibly reach the 10 percent goal by 2000. The 30 percent goal for year 2010 is more remote at this point.

Despite the many uncertainties, a number of conclusions can tentatively be drawn from the information available and the analyses performed to date:

- Replacement fuel use in transportation at levels corresponding to the section 502(b) goal for 2010 (30 percent) could be sustainable based on underlying economics if the transitional impediments could be overcome.

- Reaching the goal of 30 percent replacement fuel use would entail a very steep ramp of alternative fuel vehicle (AFV) purchases from the present through 2010. The AFV purchases required by the EPACT fleet mandates would barely begin the progression toward these goals. The degree of spillover from the fleet AFV use into household use is very uncertain but will almost certainly be determined by perceived economic advantages/disadvantages of the different fuels; current prices and tax structures do not appear to favor substantial spillover. A smoother progression of AFV sales could reach the 30 percent goal but probably not before 2020.

- While current fuel price relationships do not appear to favor substantial spillover from EPACT fleet programs into the general motoring public, these relationships are subject to possible change in a number of ways. Current tax differentials penalizing some key alternative fuels relative to conventional fuels could be reversed. Relative prices might also change independently, such as in the event of an oil shortage. Programs that introduce alternative fuels and AFVs into the market, establish even seminal infrastructure networks, and familiarize the public with alternative fuel options are likely to enhance the ability of the public to switch fuels in such an eventuality. In the absence of such programs, fuel switching by the public in an oil emergency is likely to be negligible, as it has been in the past.

- The history of (constant dollar) oil prices has been one of abrupt rises followed by gradual declines over two to two and a half decades. If this pattern is followed, another price shock could be expected in around the next seven to fifteen years.

- Substantial timely progress toward the 30 percent replacement fuel goal could help avert another oil shock if oil exporters anticipate potential fuel switching; could help alleviate the magnitude of the shock if one were to occur; could facilitate and accelerate the necessary adjustments to such a shock; and could ameliorate the economic damage that such a shock could cause. Possibly, even creating the preconditions for such fuel switching could help avert or ameliorate such a shock.

U.S. policy toward alternative fuel use and energy security has been primarily reactive. EPACT represented a somewhat unique initiative in seeking to preempt future energy shocks by taking at least tentative advance moves toward substantial changes in transportation energy usage. In light of the abundant market uncertainties, it could be critical to further define and reconfirm the Federal Government commitment to achieving a successful transition to a fuel-flexible transportation sector. It is clear that the elevation of alternative fuel issues to national attention that occurred with the Alternative Motor Fuels Act (AMFA), the Clean Air Act and, especially with EPACT, has catalyzed the myriad of efforts currently underway among State and local governments, the auto and fuels industries, and among many vehicle fleet operators. Continuity of Federal commitment and policy is essential to any future for alternative transportation fuels in this country. In addition, continuing research and development of new transportation technologies is clearly needed, both for alternative fuels utilization (and also to help assure that AFVs provide substantial environmental benefits) and for fuel economy in conventional vehicles as DOE has documented in its report under EPACT section 2021.

The U.S. transportation sector and economy remain vulnerable to major shocks from disruptions in petroleum supplies. While no such disruptions appear likely in the immediate future, warning clouds are visible on the not too distant horizon. Analysis of the history of petroleum markets throughout the century since the rise of travel by automobile indicates a fairly consistent pattern of such price shocks. The direct costs to the U.S. economy from such a shock could be in the tens of billions of dollars, while the indirect costs could be in the hundreds of billions or over a trillion dollars if a recession were to result, which would also be consistent with historical experience.

The costs of undertaking a transition to substantial use of replacement fuels could also be considerable. The direct transition costs could be substantially lower than the potential wealth transfer resulting from an oil shock, and of a lower order of magnitude altogether than the economic costs of an oil shock with the resulting recession. In a sense, such costs could be likened to a form of insurance policy. There is, of course, no basis for complacency that even the most rigorous of programs would achieve results early enough to head off the next oil shock if it were to occur within the historical pattern. Nor, for that matter, is there any certainty that a future oil shock will occur in the absence of alternative fuel use.

Despite the many uncertainties, it preliminarily appears that the programs authorized by Congress in EPACT will fall substantially short of the year 2010 goal of 30 percent. DOE may need to modify that goal under EPACT section 504, possibly by rolling back the target dates. EPACT provides ample flexibility for DOE to so scale back the ambitious statutory goals.

The vulnerability of American society to oil supply disruptions is real and is quite probably growing.[1] DOE is aware of three basic conceptual approaches for dealing with such vulnerability in terms of replacement fuel policy:

- The U.S. could accept the risks associated with potential future oil supply disruptions to an almost wholly petroleum-based transportation sector and contend with the consequences in the eventuality of such disruptions. DOE believes such an approach to be profoundly unwise, believes that EPACT represented a definitive rejection of that path, and believes that the American public and Congress continue to reject it.

- The U.S. could adopt a concerted and accelerated program intended to achieve substantial substitution of replacement fuels for petroleum fuels prior to the likely next occurrence of an oil price disruption. Varying degrees of effort could be marshaled within such a framework. This approach might well, in retrospect, turn out to be the best option for the U.S. to take. However, there is no assurance that such fuel displacement could be achieved before such a disruption in any event; and overly focusing on short-term perceived imperatives could result in costly mistakes that might actually delay or even prevent achievement of a more deliberate outcome.

- The U.S. could adopt a more deliberate but still aggressive strategy designed to leverage its investments in replacement fuels, alternative fuel vehicles and infrastructure to obtain the most energy security for the investment, which would be limited in relation to the overall fuel sector and to the potential economic costs that could be imposed by an oil shock. This might mean postponing, scaling back, and/or otherwise modifying the statutory goals. While the strategy and resulting fuel substitution would be less likely to be fully implemented in time for a potential next energy disruption, such a strategy might, nonetheless, ameliorate the effects of such a disruption and facilitate the adjustment once such a disruption takes place. It might lay the groundwork for a more substantial transition to alternative fuels to take place in the context of changes in relative fuel prices, which seems to happen periodically.

While DOE believes that both of the latter two "insurance policy" approaches are valid interpretations of the intent of EPACT, it also believes that further consensus between the Executive Branch and Congress will be required in order to most effectively pursue either approach. At the same time, DOE understands that many in the Congress, as well as in the affected communities are very concerned over what is perceived as EPACT's excessive reliance on mandates rather than economic incentives.

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[1] See, for example, *The Effect of Imports of Crude Oil and Refined Petroleum Products on the National Security*, An Investigation Conducted Under Section 232 of the Trade Expansion Act of 1962, as amended, U.S. Department of Commerce, Bureau of Export Administration, December 1994. The Commerce Department made a formal finding that petroleum imports do "threaten to impair the national security," and included as its second recommendation that the Federal Government continue programs to "bring alternative fuels and vehicles into the marketplace." pp. E'S-6, E'S-7.

Considering the great magnitude of consequences at stake, it would be prudent for DOE and interested committees of Congress to begin discussions now on possible additional programs and authorities that would contribute to reaching, or more meaningfully approaching, EPACT goals, whether the 30 percent replacement fuel goal is maintained or modified in some way, if EPACT programs fall considerably short of that goal, as now appears likely. The dialog might well involve various alternative concepts and mixes of concepts of energy security and fuel displacement. Possible roles for alternative fuel vehicles and infrastructures in establishing capabilities for fuel switching in contingency situations might be considered as partial substitutes for actual ongoing alternative fuel use. DOE will also be soliciting stakeholder views and undertaking background analysis pertinent to these issues as part of the process of establishing its program under section 502 of EPACT. In any event, given the obvious need for further clarity and continuity in Federal policy, early engagement in such a dialog by the Executive Branch and the Congress appears to be a pressing imperative at this critical juncture.

II. SUMMARY OF FINDINGS

This report represents the first of the two technical and policy analyses required by section 506 of the Energy Policy Act of 1992 (EPACT). It addresses each of the elements that the statute called on the Department of Energy (DOE) to evaluate:

- Progress made in achieving the goals described in EPACT section 502(b)(2), as modified under section 504;
- The actual and potential role of replacement fuels and alternative fueled vehicles in significantly reducing United States reliance on imported oil to the extent of the goals identified in section 502(b)(2); and
- The actual and potential availability of various domestic replacement fuels and dedicated vehicles and dual fueled vehicles.

In addition to addressing the issues posed by the statute for the Technical and Policy Analysis, DOE has chosen to identify and discuss some additional issues and perspectives. These also represent DOE perspectives at this particular moment in time on issues believed to be potentially significant to implementation of EPACT Title V programs and possible future directions for alternative fuel policy. In many cases, the answers are yet incomplete but it is believed that timely public and congressional discourse would be useful in further delineation of issues and approaches.

Energy Security Concerns

The geopolitical context surrounding energy security has changed enormously since the oil shocks of the 1970s, with the end of the Cold War, the Organization of Petroleum Exporting Countries (OPEC) in disarray, and the cementing of U.S. security ties to the most important oil exporting nations. Unfortunately, these developments have engendered a complacency on the part of the American public not unlike that which preceded previous oil shocks. Historically, periods of low prices have been followed by steep price spikes, a pattern that could well be repeated in coming years.

In contrast to the current geo-strategic environment, economic realities and trends seem to be recreating many of the preconditions for a potential oil shock in the U.S. sometime in the future. Economic growth in the Pacific rim is giving rise to a growth in world oil demand that could well lead to a short-supply situation within the next five to ten years. The world's oil resources are as concentrated as ever in the OPEC nations, notably in the Persian Gulf. DOE's Energy Information Administration (EIA) projects that by 2010, OPEC's market share is likely to reach the levels of the 1970s, as its share of world exports grows from 41 percent in 1993 to 53 percent in 2010.

The costs to the U.S. economy from a future oil price shock could be enormous. Based on analyses of previous oil shocks, a number of recent studies have estimated the macroeconomic impacts as reducing U.S. economic activity by an average of over 2 percent per year for three to four years or more, which translates into gross national product (GNP) reductions in the range of six hundred billion dollars over three years, up to possibly $3 trillion over fifteen years if the lost economic growth were not subsequently made up.

Unlike other energy using sectors, which have introduced substitute fuels and fuel switching flexibility since the oil shocks of the 1970s and 1980s, the transportation sector remains overwhelmingly dependent on petroleum-based fuels (approximately 97.5 percent of transportation energy coming from petroleum) and on technologies that provide virtually no flexibility. The transportation sector currently accounts for approximately two-thirds of all U.S. petroleum use and roughly one-fourth of total U.S. energy consumption.

Substitution of petroleum-based transportation fuels (gasoline and diesel) by non-petroleum-based fuels ("replacement fuels," including alternative fuels such as electricity, ethanol, hydrogen, liquefied petroleum gas, methanol, and natural gas) could be a key means of reducing the vulnerability of the U.S. transportation sector to disruptions of petroleum supply. Centrally fueled fleets are probably critical to the transportation sector's transition to alternative fuels and vehicles. Early introduction of alternative fuels in these fleets is more feasible since they generally refuel at a central facility and operate within a fuel tank's driving range of that central facility. Accordingly, fleets feature prominently in Title V of EPACT, which aims to displace substantial amounts of petroleum-based motor fuel with alternative fuels.

Since EPACT was enacted in 1992, transportation petroleum consumption has risen from 10.3 million barrels per day to 10.7 million barrels per day in 1994. EIA projects this consumption to rise to 14.0 million barrels per day by 2010. U.S. dependence on imported petroleum has also grown since EPACT enactment. In 1992, 41 percent of total U.S. petroleum consumption was derived from foreign sources. By 1994, imports had increased to 45 percent. EIA projects U.S. petroleum import dependence to reach approximately 54 percent of consumption by 2000 and 57 percent of petroleum consumption by 2005.

In that dependence of U.S. autos and trucks on imported oil was one of the major driving forces behind congressional passage of EPACT, the imperatives are even stronger now than at the time of passage.

Progress Toward Achieving the Goals Described in Section 502(b)(2)

Section 502(b)(2) of EPACT suggests tentative goals of displacing 10 percent of transportation fuel with replacement fuels by the year 2000 and displacing 30 percent by the year 2010. DOE is making steady progress in carrying out the provisions of EPACT Title V and related programs, which should yield measurable results in alternative fuel and AFV usage in the future. DOE supports and coordinates the Federal Fleet Program for acquisition of alternative fuel vehicles (AFVs), which had put over 20,000 AFVs into the Federal fleet by late 1995. DOE's Clean Cities Program promotes voluntary commitments and coordinated action by the key groups within participating city regions for installation of alternative fuel infrastructure and acquisition of vehicles. As of fall 1996, 50 cities and over 1,000 stakeholder organizations were participating. DOE is also carrying out the rulemaking and analytical activities prescribed by EPACT Title V, including its assessment of the technical and economic feasibility of reaching the 10 percent and 30 percent goals. The Research, Development, and Demonstration (RD&D) program has been instrumental in fostering technology development in its two spheres, Advanced Vehicle Propulsion Technologies and Alternative Fuels Research and Demonstration. The latter is now turning its focus to alternative fuels infrastructure technology. DOE is also involved with the Environmental Protection Agency (EPA) in Clean Air Act programs that promote use of advanced technology vehicles, including alternative fuel vehicles, for use in ozone non-attainment areas. Many of the programs authorized by EPACT have not been in place long enough to allow a credible assessment of program impacts. The statutory requirement for this Technical and Policy Analysis actually precedes the start of implementation for some of the EPACT programs.

Actual and Potential Role of Replacement Fuels and AFVs in Reducing Oil Imports

While DOE modeling suggests that the potential use of replacement fuels in the U.S. is very high, by 1996 the transportation sector has barely scratched the surface of this potential. The actual use of replacement fuels in 1996 in the U.S. is estimated by EIA to be about 4.6 billion gallons gasoline equivalent (or 3.1 percent of total highway transportation fuel). Of this, 4.2 billion equivalent gallons was oxygenates blended into gasoline (2.9 percent of highway fuel) and 323 million equivalent gallons was alternative fuel use by AFVs (0.2 percent of highway fuel). The preliminary partial results of DOE's study of the feasibility of reaching the goals suggested by section 502(b) indicate that the potential use of replacement fuels sustainable by the market could be as high as 30 to 38 percent in 2010 under various scenarios and could ultimately be nearly double that.

In order to reach such levels of alternative fuel use, however, major transitional impediments would have to be overcome, including changes in relative fuel/vehicle prices to consumers. For example, the EPACT suggested goals of displacing 10 percent of transportation fuels in the year 2000 and 30 percent in the year 2010 would require that AFV sales:

- grow to between 35 and 40 percent of total new light-duty vehicle (LDV) sales by 1999 to meet the 2000 goal; and

- stay in the range of 30 to 38 percent to build an AFV population sufficiently large to meet the 2010 goal.

Even to meet a 30 percent goal for year 2020, AFV growth would have to:

- double every year between 1995 and 2000, going from approximately 30,000 to 500,000 sales per year;

- increase by 50 percent per year to 4,000,000 in the period from 2001 through 2005; and
- remain at a constant 32 percent of total LDV sales in the period of 2005 through 2010.

Under this scenario, the AFV population in 2020 (ten years later than the EPACT 30 percent goal) would be large enough so that 30 percent of LDV motor fuel would be replacement fuel (alternative fuels plus oxygenates used in conventional vehicle fuel). This alternative scenario is believed to be more representative of new vehicle technology market introduction generally than the growth paths necessary to meet the (unmodified) EPACT goals but would still be enormously ambitious.

Analysis indicates that currently authorized Federal, State, and local AFV programs could displace approximately 220,000 barrels per day of motor fuel or roughly 3 percent of the LDV transportation fuel use projected by EIA for 2010, while replacement fuels in the form of oxygenates could contribute an additional 4.8 to 6.7 percent of LDV motor fuel during this period. The gap between these volumes and those necessary to reach or approach the EPACT section 502(b)(2)(B) goal of 30 percent fuel displacement by 2010 would have to be met by AFV use by motorists not covered by these programs, largely by the general public.

Examination of international policy experience shows EPACT fleet programs to be a unique approach. Nonetheless, experience of other country programs does provide the following lessons:

- Spillover into voluntary use of alternative fuels and AFVs in non-mandated sectors is likely to be determined by the relative economic costs and benefits during each stage of the transition, including (at least for dedicated AFVs) some differential to compensate for future uncertainty and for the operational disadvantages of dedicated AFVs.

- Merely putting in place novel and limited infrastructure networks is likely to be insufficient in generating high levels of spillover to non-mandated motorists, even in conjunction with cognizance of societal benefits and potential future widespread availability.

Applying these lessons to the U.S. environment suggests that changes in the overall economics, access, and convenience factors (or the perception of such imminent changes) will be necessary preconditions for AFV penetration in the general public. Such changes could occur in various ways, including policy induced changes, cyclical price swings, or market disruptions. It is important to note that current U.S. tax policy is unfavorable to all alternative fuels other than ethanol, natural gas, and electricity.

Experience of other countries also suggests that the political will to support alternative fuel programs is greatest when oil prices are at peak levels. When incentives are most critical to sustaining alternative fuel momentum, at the low end of the oil price cycle, governments have often been least committed.

Actual and Potential Availability of Replacement Fuels and AFVs

Alternative fuel vehicle technologies are available for the principal alternative fuels believed most likely to play major parts in any transition to substantial alternative fuel use. Alcohol, liquefied petroleum gas (LPG), and natural gas vehicle technologies are sufficiently developed for such vehicles to be introduced into the market on large scales. Electric vehicle technology per se is also close to market-ready but battery cost and range probably limit penetration to select market niches for the next five to ten years. Hybrid electric, fuel cell, and hydrogen vehicle technologies are in various stages of development and could play significant roles in the future, probably after 2010.

A number of types of vehicles are currently available for purchase from original equipment manufacturers (OEMs) by the public and fleets but not the whole range of vehicles for each of the alternative fuels.

- Passenger cars are available for use with 85 percent alcohol/15 percent gasoline mixtures or any mixtures down to straight gasoline, at the same price as the same conventional model.

- A pickup truck may soon be available for 85 percent ethanol use.

- Pickup trucks, vans and mini-vans are available from OEMs for dedicated and bi-fuel compressed natural gas (CNG) use. A full sized sedan is available for dedicated CNG operation and others may follow. Costs for dedicated CNG vehicles are generally $3000 - $5000 more than conventional models.

- CNG vehicles (bi-fuel and dedicated) may also be obtained by conversions of conventional vehicles by many small conversion firms.

- Electric vehicles are expected to soon be available, mostly subcompact and small pickup models.

Although alternative fuel refueling sites have been proliferating in recent years, none of the alternative fuels are currently available at retail for vehicle refueling in adequate networks to support widespread use. Adequate refueling sites could be available as a transition proceeds but would involve additional capital costs.

All of the major alternative fuels are available at national and regional levels in volumes sufficient for transportation use at levels significantly greater than the current levels. While this available supply includes both domestic production and imports, domestic supply will be adequate to serve AFV needs for coming years. If alternative fuel use were to approach the levels suggested by the EPACT 30 percent goal, market pressures could change the split between domestic and import supply. Natural gas, ethanol, and electricity have the greatest potential for domestic production to meet large-scale transportation use. LPG and methanol could be available in adequate quantities either domestically or internationally.

Key Issues and Perspectives

While available evidence indicates that substantial spillover from EPACT Title V programs into household AFV acquisitions is unlikely in the absence of some economic incentive to households to make the shift, such incentive might occur in any one of a number of ways. It would not necessarily have to represent a Government incentive program.

An oil price rise could well cause dramatic changes in relative prices between gasoline and a number of alternative fuels, resulting in natural fuel switching if the conditions enabling motorists to switch fuels are in place. Comparative historical movements in relative prices for alternative fuels and their feedstocks show clear divergences in price movements from crude oil and gasoline, particularly for electricity, ethanol, and methanol. There is probably no way of reliably assessing the impact of a future oil price rise on the effectiveness of EPACT programs until such an event occurs. On the other hand, it does appear possible to infer from prior experience that a price spike is unlikely to result in major fuel switching in the transportation sector in the absence of certain preconditions relating to the availability of AFVs and alternative fuel infrastructure, which EPACT Title V begins to address. It should be noted that most of the fuel switching in Brazil and the Netherlands, the two countries where AFV programs have been most effective, occurred after an oil shock that had been preceded by more modest programs promoting the alternative fuel to which the country partly switched after the shock.

EPACT also provides incentives to restrain rising oil demand before it leads to a run-up in oil prices of the nature of those discussed above. EPACT programs could also reduce the likelihood or magnitude of a future oil shock in another way. One potential benefit of developing a fuel switching capability is the potential to alter the behavior of primary fuel suppliers. If viable competing fuels are available, the likelihood of a restriction of oil supplies could be diminished. EPACT has the potential to shorten the time lag between an oil price shock and the oil use reductions following it and to magnify such reductions in the key transportation sector, precisely the sector where they have been least substantial up to now. The better the perceived potential of the U.S. to introduce alternatives in the event of an oil price increase, the less the likelihood and/or magnitude of the price increase likely to be sought by oil exporting countries in the event of a supply disruption.[2]

It is also possible that a well designed EPACT initiated process of fuel switching could avoid or reduce the magnitude of problems involved with the relatively abrupt technological transitions in transportation that historically follow major oil shocks and which have also characterized historical fuel switches. Alternative fuel transportation systems could be more fully ripe for widespread deployment and the American public more amenable to fuel switching as results of EPACT fleet programs (as well as DOE RD&D programs). It may never be possible to know with certainty the actual contributions of the EPACT programs in these "insurance policy" roles.

Despite the many uncertainties, it preliminarily appears that the programs authorized by Congress in EPACT will fall substantially short of the year 2010 goal of 30 percent. DOE may need to modify that goal under EPACT section 504, possibly by rolling back the target dates. EPACT provides ample flexibility for DOE to so scale back the ambitious statutory goals rather than to adopt draconian policies. At the same time, DOE understands that many in the Congress, as well as in the affected communities, are very concerned over what is perceived as EPACT's excessive reliance on mandates rather than economic incentives.

Considering the great magnitude of consequences at stake, it would be prudent for DOE and interested committees of Congress to begin discussions now on possible additional programs and authorities that would contribute to reaching, or more meaningfully approaching, EPACT goals. Such dialog and such consideration of additional programs will be beneficial whether the 30 percent replacement fuel goal is to be maintained or is to be modified in some way due to the EPACT programs falling considerably short of that goal, as now appears likely. The dialog might well involve various alternative concepts and mixes of concepts of energy security and fuel displacement. Possible roles for alternative fuel vehicles and infrastructures in establishing capabilities for fuel switching in contingency situations might be considered as partial substitutes for actual ongoing alternative fuel use. DOE will also be soliciting stakeholder views and undertaking background analysis pertinent to these issues as part of the process of establishing its program under section 502 of EPACT. In any

[2] While the U.S. share of world oil imports and its importance in the world oil market are likely to be less in the next century than in the 1970s and 1980s, U.S. leadership in alternative transportation fuel policy and technology development could well catalyze similar developments in other importing countries.

event, given the obvious need for further clarity and continuity in Federal policy, early engagement in such a dialog by the Executive Branch and the Congress appears to be a pressing imperative at this critical juncture.

III. INTRODUCTION

Energy Security Concerns

Between October 1973 and January 1974 world oil prices doubled following production cutbacks amounting to 4.2 million barrels per day by certain members of the Organization of Petroleum Exporting Countries (OPEC). Again in 1979-80, a 5.4 million barrel per day production loss from Iran and Iraq, about 9 percent of world production, resulted in a doubling of oil prices. In both instances, OPEC members restrained production in succeeding years, electing to keep prices at the new higher levels. From May to December of 1990 (following the Iraqi invasion of Kuwait), total oil output from Kuwait and Iraq fell by 4.8 million barrels per day, about 7.6 percent of world production. From the second to the fourth quarter of 1990, oil prices again nearly doubled, from $17.50 to $33 per barrel.[3] This latest price shock was short-lived in comparison to the others, as Saudi Arabia put its slack capacity to use, expanding production by 3 million barrels per day to make up most of the lost supply.

The geopolitical context surrounding energy security has obviously changed enormously since the oil shocks of the 1970s. The Gulf war brought home to the Persian Gulf oil producers their own extreme insecurity and dependence on the West and on the U.S. in particular. The prompt increase in output by Saudi Arabia, along with the more efficient functioning of U.S. energy markets, free from the regulatory constraints in place during previous oil crises, preempted actual shortages for U.S. consumers and limited the duration of the speculative run-up in prices to a few weeks, even as the Iraqi occupation of Kuwait continued and the war ensued. Since the Gulf war, the longstanding irritant to U.S. relations with the nations of the Arabian peninsula has been partly eliminated through breakthroughs in the Middle East peace process. The end of the Cold War and the breakup of the Soviet Union have reduced some of the risks associated with access to foreign oil supplies by the U.S. and its allies. Greater diversification of import sources, the existence of the Strategic Petroleum Reserve, more efficient global markets, including futures markets, and the removal of harmful price and allocation controls all suggest that the U.S. may be less vulnerable to the economic damages of supply disruptions than was the case 20 years ago. Unfortunately, these developments, along with oil prices that have been generally low for the last ten years and recently approached historically low levels, may have engendered a complacency on the part of the American public not unlike that which preceded previous oil shocks.

Historically, low prices have been followed by steep price spikes, a pattern that could well be repeated in coming years (see Figure 1). It is true that key oil producing nations have evidenced an awareness that oil price shocks resulting in recessions in the industrialized world or in substitution of energy sources are not in their interest. Some exporters have generally exhibited restraining influence on prices for the last decade. Most, if not all major oil exporting countries have seen their economic and social development devastated by the oil price cycles of the 1970s and 1980s and realize that repetition of the cycle is in neither their interest nor that of the consuming nations. This

[3] Constant 1993 dollars.

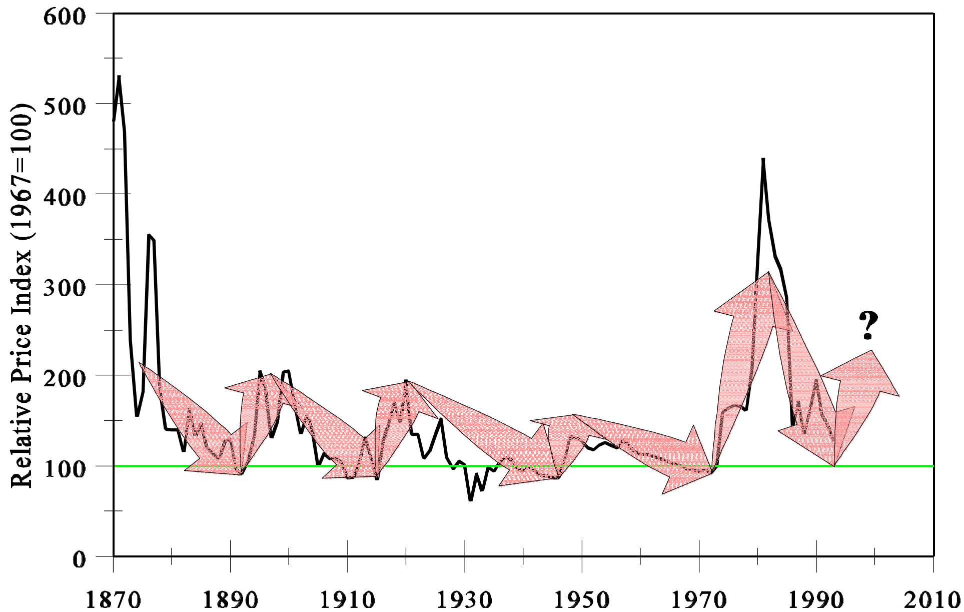

Figure 1. Wellhead Crude Oil Price Movements; Will History Repeat?
Compiled by Argonne National Laboratory

is not to say that the interests of the oil exporters have come to coincide with those of the consuming countries. On the contrary, the pressures for higher prices within many of those countries have probably never been greater. In the event of some supply reducing event, the prices or output levels that they might target could cause substantial economic hardships in the U.S. This is particularly true if the supply disruption affects those key OPEC members with which our strategic relationships are in place.

Existing geopolitical relationships cannot be relied on as the principal sources of energy security for the medium or long term. The political stability of even the most critical and most moderate oil producing nations cannot be taken for granted. Neither future regional wars nor revolutions nor coups d'etat can be ruled out in the volatile Middle East region with its many animosities and still inherently unstable internal political structures. Nor, for that matter, can blockage of vital sea lanes such as the Strait of Hormuz be ruled out.

In contrast to the current geo-strategic environment, economic realities and trends could be recreating many of the preconditions for a potential oil shock sometime in the future. Economic growth in the Pacific rim is giving rise to a significant growth in world oil demand that could outstrip the growth of both world and non-OPEC oil capacity, possibly creating a short-supply situation within the next five to ten years. In the 1970s, East Asia consumed less than half as much oil as did the U.S. Within ten to fifteen years, East Asian nations will probably be consuming more than the U.S. In the event of any oil crisis, cooperation among consuming nations could be made more difficult by the greater diffusion of oil demand. Production from the major new oil sources developed during the seventies and eighties within the Western World (North Sea and Alaska North Slope) is now beginning to decline. So also are other major non-OPEC sources, at least relative to world markets. The former

Soviet Union and Eastern European nations are unlikely to expand exports substantially until at least 2005. The world's oil resources and particularly its low cost oil resources are as concentrated as ever in the OPEC nations, notably in the Persian Gulf. With the rest of the world drawing down its reserves at nearly twice the rate at which OPEC is using its reserves, OPEC's share of world oil supply is bound to rise, which is exactly what is already happening. DOE's Energy Information Agency (EIA) projects that by 2010, OPEC's market share is likely to reach the levels of the 1970s, as its share of world supply grows from 41 percent in 1992 to 53 percent in 2010. Almost all of the increased OPEC production is expected to be in the Persian Gulf countries.

The U.S. still consumes more than one-fourth of the world's oil production. About 45 percent of U.S. oil consumption is currently imported compared to about 35 percent at the time of the 1973-74 oil shock. According to EIA, imports are expected to grow to 54 percent of U.S. consumption by 2000 and 57 percent by 2005 as domestic oil production continues to decline. Although the Strategic Petroleum Reserve's inventory increased in volume from 1988 to 1994, it decreased relative to the growth in U.S. net imports so that it now provides the equivalent of only 77 days import supply compared to 96 days supply in 1988.

The costs to the U.S. economy from a future oil price shock could be enormous. Based on analyses of previous oil shocks, a number of recent studies have estimated the macroeconomic impacts as reducing U.S. economic activity by an average of over 2 percent per year for four years or more. This translates to reductions to U.S. GNP in the hundreds of billions of dollars. If the economy were not to subsequently make up for the lost output but only to resume its natural rate of growth, the costs could amount to some $3 trillion over fifteen years, using a discount rate of 10 percent.

Moreover, U.S. national security is directly related to the security of its energy supplies. Changes in U.S. military doctrine and force structure amplify this relationship. For example, the 582,000 U.S. forces during the Operation Desert Storm consumed more than 450,000 barrels of light petroleum products per day, more than four times the daily use by the entire 2 million person Allied Expeditionary Force in World War II Europe. The ability to redeploy forces around the globe rapidly, requiring highly intensive energy use, is one of the fundamental pillars of the new strategic framework.[4]

<u>Importance of Transportation Sector</u>

Since the oil supply/price shocks of the 1970s, U.S. energy use has changed dramatically as our economy, technology, and consumption patterns have responded in a wide variety of ways, including reductions in consumption, increases in efficiency, and diversification of energy types. The single major exception to this positive market response has been the transportation sector. The beneficial effect of federally mandated fuel economy standards for automobiles has been largely offset by motorists driving more miles every year. And, unlike other sectors where mixes of fuels have

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[4] *Natural Gas Vehicles: Helping Ensure America's Energy* Security, The National Defense Council Foundation, 1995, p. 4, citing Oil *and War*, Robert Goralski, William Morrow & Co., 1987; *Moving Mountains: Lessons in Leadership and Logistics from the Gulf War*, Lt. Gen. William G. Pagonis, Harvard Business School Press, 1991.

emerged — in many cases with user capability to switch on moderately short notice — the transportation sector remains overwhelmingly dependant on petroleum-based fuels (approximately 97.5 percent of transportation energy coming from petroleum) and on technologies that provide virtually no flexibility.

The transportation sector currently accounts for approximately two-thirds of all U.S. petroleum use and roughly one-fourth of total U.S. energy consumption. The gap between the transportation sector's demand for petroleum and U.S. petroleum production continues to widen (see Figure 2). U.S. consumption of petroleum in the transportation sector alone exceeds by 4 million barrels total U.S. domestic petroleum production; that gap is projected to rise to 9 million barrels per day by the year 2010. According to EIA projections, the transportation sector will consume 14.1 million barrels per day of petroleum in 2010. About 7.4 million of these barrels are projected to be used by light-duty vehicles. Energy for the transportation sector truly represents one of the major sources of short- and medium-term vulnerability for American society and the American economy today. Substitution of petroleum-based transportation fuels (gasoline and diesel) by non-petroleum-based fuels ("replacement fuels," including alternative fuels such as electricity, ethanol, hydrogen, liquefied petroleum gas, methanol, and natural gas) could be a key means of reducing the vulnerability of the U.S. transportation sector to disruptions of petroleum supply.

EPACT Title V

Centrally fueled fleets are critical to the transportation sector's transition to alternative fuels and vehicles. These fleets are much more amenable to introduction of alternative fuels since they generally refuel at a central facility and operate within a fuel tank's driving range of that central facility. If the necessary infrastructure for alternative fuels is installed at the central facility, the alternative fueling capability could be made available to other parties, including both other fleet operators and the general public. In many cases, the central fueling facility may, in fact, be a commercial station that would be available to the public. Fleet AFV usage could also provide the necessary volume for manufacturers to justify introduction of new AFV models, more options on AFVs and more ready availability in terms of lead time and delivery. Fleet vehicles are generally resold after a few years so that some fleet AFVs could find their way into the general vehicle population. Fleet vehicles typically are driven more than private vehicles, using more fuel and providing more scope for fuel replacement by alternative fuels.

In recognition of the vulnerability of the U.S. transportation system to disruptions of foreign oil supplies and the opportunities for alternative fuel use by centrally fueled fleets, Congress enacted the Energy Policy Act of 1992 (EPACT), including as part of EPACT's core, Title V on the displacement of conventional motor fuel by non-petroleum energy sources, focusing on light-duty motor vehicle fleet operations. While Title V mandates certain fleets to begin acquiring vehicles capable of operating on alternative fuels, these mandates are not intended, in and of themselves, to provide major reductions in U.S. petroleum use or dependence. Rather, these key vehicle operations

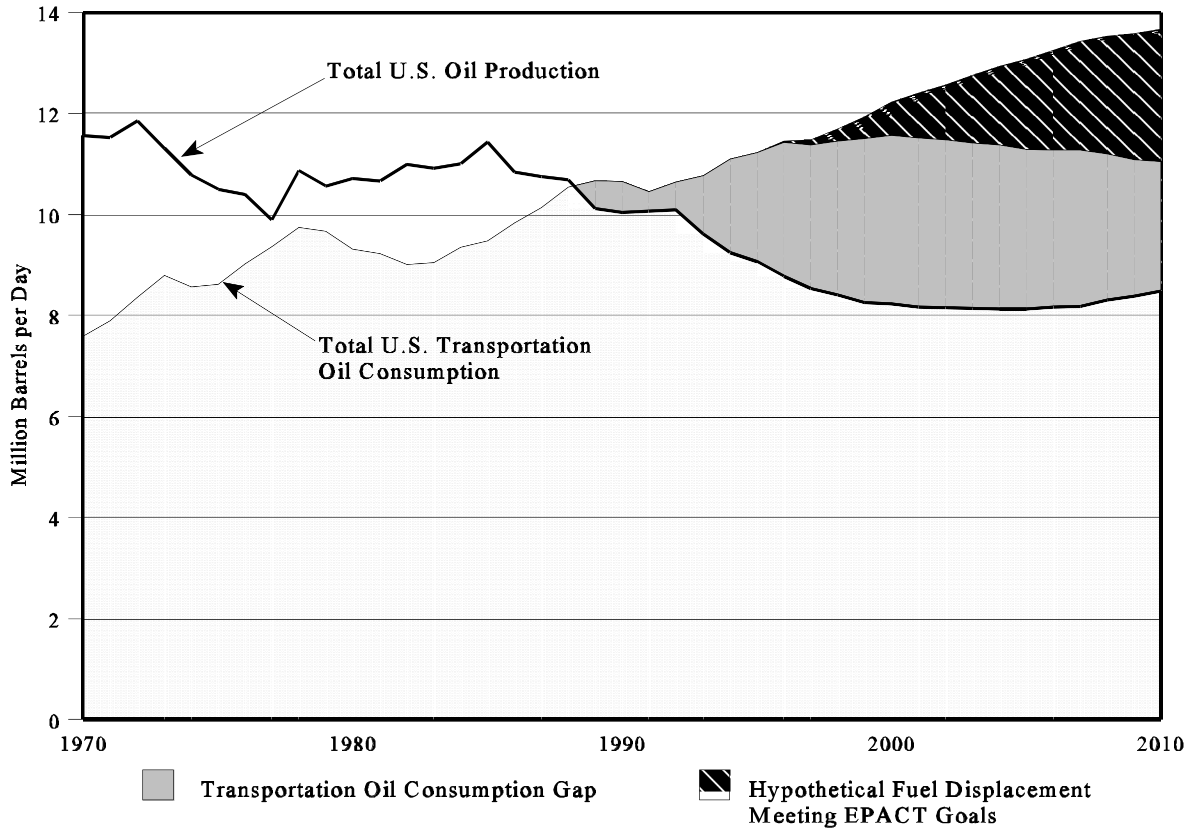

Figure 2. U.S. Transportation Oil Gap

are intended to pave the way for alternative fuel use and fuel flexibility for society at large by demonstrating the in-use practicability of the technology on a substantial scale and to provide the necessary critical mass to catalyze markets into supplying alternative fuels and vehicles with sufficient scale and access. In this way, the Title V programs would plant the seeds for growth of alternative fuel vehicle use.

Energy Trends Since EPACT Enactment

Transportation petroleum consumption has risen from 10.3 million barrels per day in 1992, when EPACT was enacted, to 10.7 million barrels per day in 1994. EIA projects this consumption to rise to 14.0 million barrels per day by 2010. U.S. dependence on imported petroleum has also grown since EPACT enactment, from 41 percent in 1992 to 46 percent in 1995 with growth projected (EIA) to 54 percent in 2000.

The 1995 Annual Energy Outlook (AEO), published by EIA, projects that the oil import gap will have risen 34 percent by 2010, driven mainly by gasoline consumption. Under the AEO 1995 base case, oil imports will account for close to 59 percent of oil consumption by 2010, compared to today's 44 percent. This estimate is based on a projected increase in crude oil prices to about $24 per barrel; if oil prices do not increase to such a level, the import gap is likely to be even larger.

To the extent that dependence of U.S. motor vehicles on imported oil was one of the major driving forces behind congressional passage of EPACT, the imperatives are even stronger now than at the time of passage.

IV. PROGRESS MADE IN ACHIEVING THE GOALS DESCRIBED IN SECTION 502(b)

Section 506(b)(1) of EPACT requires DOE to evaluate in this Technical and Policy Analysis the "progress made in achieving the goals described in section 502(b)(2), as modified under section 504." Section 502(b)(2) of EPACT suggests goals of displacing 10 percent of light-duty transportation fuel with replacement fuels by the year 2000 and displacing 30 percent by the year 2010 with at least half of such fuels being from domestic sources.[5] DOE is making steady progress in carrying out the provisions of EPACT Title V and related programs, which should yield measurable results in replacement fuel and AFV usage in the future. Many of the programs authorized by EPACT have not been in place long enough to allow a credible assessment of program impacts. The statutory requirement for this Technical and Policy Analysis actually precedes the start of implementation for some of the EPACT programs.

DOE supports and coordinates the Federal Fleet Program for AFV acquisition, which had put over 20,000 AFVs on the road or on order by late 1995. DOE's Clean Cities Program promotes voluntary commitments and coordinated action by the key groups within participating city regions for installation of alternative fuel infrastructure and acquisition of vehicles. As of fall 1996, 50 cities and over 1,000 stakeholder organizations were participating. DOE is also carrying out the rulemaking and analytical activities prescribed by EPACT Title V, including its study of the technical and economic feasibility of reaching the 10 percent and 30 percent goals and ongoing reports of the demand estimates and supply information required by section 503. The Research, Development, and Demonstration program has been instrumental in fostering technology development in its two spheres, Advanced Vehicle Propulsion Technologies and Alternative Fuels Research and Demonstration. The latter is now turning its focus to alternative fuels infrastructure technology. DOE is also involved with EPA in Clean Air Act programs that promote use of advanced technology vehicles, including alternative fuel vehicles, for use in certain air quality non-attainment areas.

The paragraphs that follow summarize the status of the key activities and programs that contribute toward the goals suggested in section 502 of EPACT.

Federal Fleet Program

The Federal Government is working aggressively to acquire alternative fuel vehicles for its own vehicle fleets, as intended by EPACT and the Alternative Motor Fuels Act of 1988 (AMFA). EPACT section 303 requires the introduction of light-duty AFVs into Federal fleets in specific incremental percentages over the next several years. President Clinton, in April 1993, issued Executive Order 12844, which increases the acquisition requirements by 50 percent for 1993-95 over the levels required by section 303. President Bush had earlier issued Executive Order 12759 (April 1991) requiring Federal agencies to annually purchase the maximum practicable number of alternative fuel vehicles.

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[5] These suggested numerical goals that DOE is to evaluate are apparently suggestions for what might represent the basic objective described in section 502(a) to "... promote the replacement of petroleum motor fuels with replacement fuels to the maximum extent practicable."

The Department of Energy has the primary responsibility for coordinating Federal efforts on alternative fuels, including implementation of AMFA, EPACT section 303, and Executive Orders 12759 and 12844.

As of the end of 1995, over 20,000 alternative fuel vehicles were either on the road or on order for Federal agencies, including the U.S. Postal Service, the Defense Department, and the General Services Administration (GSA), among other agencies. This program has dramatically increased the use of important classes of AFVs, has prompted automakers to expand AFV availability, and is encouraging the alternative fuel industry to plan and invest in a growing refueling infrastructure.

Vehicle Acquisition Process

The Department of Energy works closely with each agency to identify needs for alternative fuel vehicles. Information acquired includes vehicle types and fuel types needed to meet agency mission requirements. Working with the GSA, a solicitation for vehicles is prepared, normally in the late summer. Bids are received in September; evaluation and award usually take place by October or November. Subsequent to award, agencies can order vehicles from the GSA award list. Agencies can also purchase alternative fuel vehicles directly from the manufacturer. Some agencies, including the Postal Service and the Defense Department typically do not purchase through GSA. Each agency provides full funding for its vehicle purchases, and the DOE reimburses the agency--through an Interagency Agreement established for this purpose--for the incremental cost of the AFV relative to a conventional vehicle.

Alternative fuel vehicles are not a supplement for an agency's conventional fleet, but are replacements for vehicles that are scheduled for retirement due to age or high mileage. Many agencies do not make their vehicle purchase decisions until the second quarter of the fiscal year, depending on individual agency transportation budgets and other factors. In fiscal year 1994 and again in 1995, delays in awards to vehicle providers for requested alternative fuel vehicle types have delayed agency decision making.

Funding History

The Department of Energy has received appropriations of $7 million in fiscal year 1993, $18 million in fiscal year 1994, and $10 million in fiscal year 1995 (after an additional $10 million was rescinded) for the Federal AFV programs. These funds have been used to reimburse Federal agencies for the incremental costs of alternative fuel vehicle acquisition.

Additional funding contributed by GSA, the Defense Department (DOD), and the U.S. Postal Service (USPS) has supplemented the DOE AFV funding. DOD received appropriations, to perform research and development and to acquire natural gas vehicles in the amounts of $10 million for fiscal year 1993, $15 million for fiscal year 1994, and $10 million in fiscal year 1995; it has also received $15 million for electric vehicles in fiscal year 1995. The U.S. Postal Service has also acquired a significant number of AFVs with its own (non-appropriated) resources. GSA provides funding from its revolving fund that is available from vehicle recalls and canceled orders. DOE provides critical support to industry initiatives to provide vehicles to GSA and the USPS. A summary of Federal AFV acquisitions is shown in Table 1.

Table 1.
Federal Alternative Fuel Vehicle Acquisitions

FY	CNG		M-85		E-85		LPG		EV		Total
	Qty	**%** [1]	**Qty**	**%** [1]	**Qty**	**%** [1]	**Qty**	**%** [1]	**Qty**	**%** [1]	
91	104	*37.6*	70	*25.3*	0	*0.0*	103	*37.1*	0	*0.0*	277
92	799[2]	*7.1*	2,520	*90.5*	25	*0.9*	7	*0.3*	35	*1.2*	2,786*
93	2,273	*42.0*	2,974	*54.8*	89	*1.6*	13	*0.2*	78	*1.4*	5,427*
94	4,446	*53.4*	3,727	*44.8*	25	*0.3*	106	*1.3*	17	*0.2*	8,321*
95[3]	4,276	*87.4*	366	*7.5*	250	*5.1*	0	*0.0*	0	*0.0*	4,892
Totals through FY 95	**11,298**	***52.0***	**9,657**	***44.5***	**389**	***1.8***	**229**	***1.1***	**130**	***0.6***	**21,703**
Planned FY 96 Acquisitions											
96	6,142	*77.3*	0	*0.0*	1,352	*17.0*	100	*1.3*	350	*4.4*	7,944
Totals through FY 96	**17,440**	***58.8***	**9,657**	***32.6***	**1,741**	***5.9***	**329**	***1.1***	**480**	***1.6***	**29,647**

* Exceeded requirements of the Energy Policy Act of 1992.

Notes
[1] Percentage of annual AFV acquisition. May not add to 100 percent due to rounding.
[2] Includes 600 Compressed Natural Gas General Motors (GM) pickups recalled by GM.
[3] Fiscal year 95 quantities are based on preliminary acquisition data obtained from Federal agencies.

Clean Cities Program

The Clean Cities Program was initiated by DOE to serve the goals established by EPACT and specifically serves as DOE's mechanism for seeking voluntary commitments from suppliers, providers, and fleet purchasers as required by section 505 of EPACT. Clean Cities is designed to expand the use of alternative fuel vehicles in communities throughout the country and to provide refueling and maintenance facilities for their operation. Through the establishment of locally-based Government and industry partnerships, and supported by Federal guidance and leadership in vehicle acquisitions, Clean Cities seeks to build the foundations for a sustainable, nationwide alternative fuels market.

Goals

The primary goal of the Clean Cities Program is to combine Government objectives for energy security, fuel diversity, air quality, and economic opportunity with commercial objectives and voluntary commitments from fuel suppliers, vehicle suppliers, and fleet owners to form the critical, locally-based partnerships necessary to:

(1) Communicate that valid economic choices exist among transportation fuels and identify the benefits of using AFVs;

(2) Promote the use of domestically produced, clean-burning alternative fuels;

(3) Create commercial opportunities and contribute to economic development, including developing alternative fuel supply infrastructure, vehicle manufacture and conversion, service and maintenance, and domestic fuel production and distribution; and

(4) Improve air quality and support the objectives of the Clean Air Act (CAA), including its 1990 Amendments.

Approach

Clean Cities establishes a systematic process of working with communities to develop local plans for creating an alternative fuels market. The program builds on local initiative, identifies options to local problems, and creates partnerships as the mechanism to develop solutions. Clean Cities works directly with local businesses and governments to shepherd them through the goal-setting, coalition-building, and commitments process necessary to establish the foundations for a viable alternative fuels market. Then, by sharing local innovation along the Clean Cities network "mayor-to-mayor," by relating local issues to State and Federal objectives, and by providing continuous customer feedback to the more than a thousand industry and public stakeholders, DOE can help each Clean City to build an enduring program. Ultimately, the Clean Cities approach demonstrates that the alternative fuels challenge has many solutions--which ease the transition for those communities required to implement EPACT and CAA, minimizing the use of additional regulation while achieving comparable results through market processes.

Accomplishments

By fall of 1996, the Clean Cities program had created partnerships in 50 cities throughout the country. The overwhelming national interest carried the program beyond Secretary O'Leary's 1994 goal of 25 cities. Participating fleet operators within these "pioneer" Clean City programs are operating or planning to be operating approximately 30,000 AFVs within the next two years--helping to reduce dependence on foreign oil and improve air quality. The programs comprise over a thousand stakeholder organizations nationwide, committed to significant increases in alternative fuel vehicle acquisitions and infrastructure investment over the next five years. Currently, the program covers over half of the ozone non-attainment areas, including ten cities in the Ozone Transport Region (Northeastern States sharing a regional ozone problem), and continues to gain momentum.

During 1994 and 1995, DOE awarded $2.145 million in grants to 19 pilot projects submitted by State governments to accelerate the introduction of alternative fuels and vehicles. The grants are closely linked to Clean Cities and will play an important role in developing contributions from States and cities that have previously stepped forward to make alternative fuel commitments to the program. Moreover, by awarding incentive funds to support these projects, DOE is able to provide additional support to local initiatives, and leverage the limited public resources for the expansion of the alternative fuels market.

Metrics

By the end of 1996, the program will likely feature an estimated 50 to 55 Clean City Programs, covering most Metropolitan Statistical Areas and almost all ozone non-attainment areas. Current trends are expected to continue and designated Clean Cities will add stakeholders such that by 1997, over 2,000 stakeholder organizations will be associated with the DOE Clean Cities Program.

EPACT Rulemaking Activities

Regulations governing the Alternative Fuel Provider Mandate (section 501) and the Mandatory State Fleet Programs (section 507(o)) were published in the *Federal Register* on March 14, 1996 (61 *Fed. Reg. 10622*). These programs will require that 90 percent of new vehicles acquired by certain alternative fuel providers be alternatively fueled by 2000 and 75 percent of vehicles acquired by State government fleets be alternatively fueled by 2001. The notice also proposes rules to govern a credit trading program (authorized by section 508) for required AFV acquisitions by covered entities under these mandates.

DOE published a Notice of Proposed Rulemaking for the State and Local Incentives Program under EPACT section 409, March 21, 1995 (60 *Fed. Reg.* 15020). Although no funds have been appropriated for this program specifically, such funding for State AFV programs has been included in the consolidated State Energy Program grants. This consolidated grant program will make funds available to certain States that adopt aggressive and/or innovative policies for AFV deployment and alternative fuel utilization. It earmarked $2,150,000 for such projects in fiscal year 1996, in addition to optional use of other State Energy Program funds.

DOE published an Advance Notice of Proposed Rulemaking as required by section 507(a)(3) for a possible rulemaking under section 507(b) on August 7, 1996 (61 *Fed. Reg.* 41032). Section 507(b) requires DOE to undertake a rulemaking process to determine whether an AFV mandate for private and local government fleets is necessary to meet the EPACT section 502(b)(2)(B) goal of 30 percent motor fuel displacement by 2010, whether that goal is practicable and achievable, and whether various requisite conditions (relating to vehicle and fuel availability) are met. Section 507(a)(3) requires that this process be initiated with an Advance Notice of Proposed Rulemaking for the purposes of:

- Evaluating the progress toward achieving the goals of replacement fuel use described in section 502(b)(2), as modified under section 504;

- Identifying the problems associated with achieving those goals;

- Assessing the adequacy and practicability of those goals; and

- Considering all actions needed to achieve those goals.

DOE's draft Advance Notice requested comments on these issues as well as on issues germane to the rulemaking for the possible future mandate. Hearings were held on the Advance Notice in September and October of 1996 and the public comment period closed on November 5, 1996. DOE was unable to complete a rulemaking to implement an early mandate for private and local fleets by the December 15, 1996 deadline and will proceed with a rulemaking process to determine if such a mandate should be implemented beginning in model year 2002 or thereafter.

<u>EPACT Analytical and Informational Activities</u>

Replacement Fuel Goals

Title V of EPACT suggests ambitious goals for the replacement of petroleum-based motor fuels. DOE is in the process of assessing the technical and economic feasibility of displacing 10 percent of motor fuel by 2000 and 30 percent by 2010. Despite aggressive steps to increase alternative fuel use by State and local governments, industry, Clean Cities, and fleets, it is unlikely that these efforts will be adequate to attain the EPACT goals. As part of the process of assessing feasibility, DOE is investigating additional programs that would contribute toward the goals. For example, DOE is analyzing potential contributions of alternative fuel incentive programs in meeting the motor fuel displacement goals. The Department is encouraging an ongoing public dialog on these issues and will publish proposed programs and determinations in the *Federal Register* providing ample opportunity for public comment.

Replacement Fuel Demand and Supply Program

EPACT section 502(a) requires DOE to establish a program to promote the development and use of domestic replacement fuels in light-duty motor vehicles. The program is to promote the replacement of petroleum motor fuels with replacement fuels to the maximum extent practicable and to ensure availability of those replacement fuels that will have the greatest impact in reducing oil imports, improving the health of the U.S. economy, and reducing greenhouse gas emissions. Development of this program will necessarily be based on the foundations from the other analytical activities including the section 502(b) activities (discussed below) and, particularly, the public dialog DOE expects to be initiated with the section 506 reports.

Under section 502(b), DOE is to determine the technological and economic feasibility of replacing 10 percent of traditional fuels by 2000 and 30 percent by 2010, with at least half of the replacement fuels coming from domestic sources. In addition, DOE is to determine the best means and methods for increasing U.S. production of alternative fuels and to estimate domestic and foreign production capacities for the replacement fuels and AFVs needed to meet the current fuel replacement goals, as well as the effects that the replacement fuels will have on greenhouse gas emissions. The methodology for this study was published in the *Federal Register* on October 4, 1993, (58 *Fed. Reg.* 51622), and partial results have been published as *Technical Report Fourteen* in the DOE Office of Policy's series *Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation*

Sector. Analysis of the feasibility of reaching the goals is continuing through identification of possible transition pathways and construction of a Transition to Alternative Fuel Vehicle model. Views of stakeholders on issues relating to possible transition pathways are also being solicited.

Replacement Fuel Demand Estimates and Supply Information

EPACT section 503 requires DOE to estimate, on an annual basis, the number and geographic distribution of each type of AFV in use in the United States, the amount and distribution of each type of alternative fuel, and the greenhouse gas emissions produced from the use of each alternative fuel.

This activity is being conducted by the DOE Energy Information Administration. Fuel suppliers and AFV manufacturers must provide EIA with information concerning fuel supplies and AFV production. EIA has released three such reports to date. The first, entitled *Alternatives to Traditional Transportation Fuels: An Overview* (DOE/EIA/-0585/0), was issued in June 1994 and the second, *Alternatives to Traditional Transportation Fuels 1993* (DOE/EIA-0585(9)), was released in November 1994. The third, *Alternatives to Traditional Transportation Fuels 1994,* Vol. 1 (DOE/EIA - 0585(94)/1) was released in February 1996. Key data from these documents are summarized in Section V of this report.

DOE Research, Development, and Demonstration Programs

EPACT-mandated research and development is being conducted within the framework of the DOE Office of Transportation Technologies research and development program. This program is split into two major research and development focus areas: 1) advanced vehicle propulsion technologies that will enable substantial increases in vehicle fuel economy, and 2) cost-competitive domestic alternative fuels. Both of these areas will help to achieve energy security and transportation fuel diversity, reduced emissions from mobile sources, and more competitive U.S. vehicle and fuel industries.

Advanced Vehicle Propulsion Technologies

Through strategic partnerships such as the United States Advanced Battery Consortium and the Partnership for a New Generation of Vehicles (PNGV), the advanced vehicle propulsion system development program is pursuing many parallel research efforts in:

- Hybrid propulsion systems;

- Transportation fuel cell development;

- Improved energy storage technology;

- Advanced materials technology; and

- Advanced heat engine technologies.

Alternative Fuels Research, Development, and Demonstration

The alternative fuels program is conducting several research and development projects to:

- Stimulate development of technologies to lower the cost and improve the performance of vehicles that use alternative fuels, particularly natural gas, alcohols, and electricity;

- Assist the introduction of alternative vehicles/fuels that can be competitive with conventional fuels and vehicles; and

- Stimulate development of technologies that provide abundant, cost-effective fuels from domestic resources.

Not all of DOE's work is conducted in the test labs. As a continuation of earlier Alternative Motor Fuels Act of 1988-originated activities, on-road fleet testing is currently being conducted on a cross section of light-duty vehicles, trucks, and buses. These fleet tests encompass several major geographical regions that represent diverse climate and use conditions.

DOE has been instrumental in fostering AFV technology in the U.S. In the 1970s and 1980s, the focus of DOE support was on basic engine and vehicle development. As successes in this area were achieved, demonstrations of the vehicle technology were conducted to quantify their performance. During this time, it became apparent that AFVs had additional potential to reduce the emissions from vehicles that degrade air quality and/or contribute to global warming. In the late 1980s and early 1990s, as the vehicle manufacturers brought AFVs to market, the focus of DOE alternative fuel efforts broadened to include public outreach programs. For instance, working with the private sector, DOE has established a National Certification Program for alternative fuel vehicle training programs for automotive technicians. This should assure that properly trained automotive technicians will be available to service alternative fuel vehicles using proper and safe procedures. DOE has also initiated several public education actions including development of several brochures and the National Alternative Fuels Hotline, where anyone can phone in and ask questions about alternative fuel vehicles. The implementation of these programs illustrates the realization by DOE that alternative fuel vehicles were becoming sufficiently technically mature for commercialization.

Implementation of the Alternative Motor Fuels Act was a turning point away from research to infrastructure development; this paved the way for implementation of EPACT AFV programs. However, it should be noted that research and development is still being supported by DOE in those alternative fuel vehicle technology areas such as fuel cell, hybrid and hydrogen vehicles that have not reached the same level of maturity as methanol, ethanol, natural gas, and LP gas vehicles have to date. Without this continued research and development, AFV technology will not be ready for a program as large and far-reaching as EPACT.

Coordination with EPA Program

Section 246 of the Clean Air Act, as part of the Clean Air Act Amendments of 1990 (Pub. L. 101-549) requires certain fleet operators located in extreme, severe, and serious ozone non-attainment areas to acquire "clean fuel fleet vehicles" for their fleets, beginning in model year 1998. The Environmental Protection Agency has published a series of rules governing this program. Many of the same fleet operators covered by the EPA program will also be covered by EPACT fleet acquisition requirements. Indeed, many of the same vehicles within the fleets could be used to meet the requirements of both programs. DOE believes that the two programs can and should be implemented in ways to complement and reinforce each other. DOE is working with EPA and industry to promote AFVs that will meet the clean fuel fleet vehicle requirements.

It should be noted, however, that there are important differences between the two programs. Significant differences between the two programs include: (1) the primary goal of the EPA program is to significantly improve air quality through reduced emissions of pollutants while the primary goal of the DOE program is to strengthen national energy security by reducing dependence on imported oil; (2) the lists of fuels enumerated in the definitions of "clean alternative fuel" under section 241 of the Clean Air Act and of "alternative fuel" under section 301 of the Energy Policy Act of 1992 are not identical, and the Department's rulemaking discretion to add to the section 301 list is limited by stringent statutory standards; (3) the EPA program applies to fleets as small as ten vehicles while fleets are defined by section 301 as minimum of 20 vehicles operated by an entity operating 50 or more vehicles; (4) the EPA program applies to light-duty motor vehicles (up to 8,500 gross vehicle weight (GVW) rating) and heavier duty motor vehicles (up to 26,000 gross vehicle weight rating) while the DOE program applies only to light-duty motor vehicles (8500 GVW); (5) the States will administer the EPA program while DOE will directly administer the EPACT program; and (6) the EPA program applies only to fleets in 22 ozone or carbon monoxide (CO) non-attainment areas[6] (only about half of which appear likely to implement such programs at this time) while the DOE program applies to fleets in approximately 121 areas, including both non-attainment and attainment areas.

[6] All these areas have a population of 250,000 or more according to the 1980 census. The ozone non-attainment areas are classified as serious, severe, or extreme; the CO non-attainment areas have a CO design value of 16 parts per million (ppm) or higher. Areas are able to opt-out by creating equivalent emissions reductions through their State Implementation Plans; two areas have opted into the Clean Fuel Fleet Program.

V. ACTUAL AND POTENTIAL ROLE OF REPLACEMENT FUELS AND AFVs

While DOE modeling suggests that the potential use of replacement fuels in the U.S. is very high, by 1996 the transportation sector has barely scratched the surface of this potential. The actual use of replacement fuels in 1996 in the U.S. is estimated by EIA to be about 4.6 billion gallons gasoline equivalent (or 3.1 percent of total highway transportation fuel). Of this, 4.2 billion equivalent gallons was oxygenates blended into gasoline (3 percent of highway fuel) and 323 million equivalent gallons was alternative fuel used by AFVs (0.2 percent of highway fuel). The results of phase one of DOE's study of the feasibility of reaching the goals suggested by section 502(b) indicate that the potential use of replacement fuels sustainable by the market could be as high as 30 to 40 percent in 2010 under various scenarios and could ultimately be nearly double that. In order to reach such levels of alternative fuel use, however, major transitional impediments would have to be overcome, including changes in relative fuel/vehicle prices to consumers.

Actual Role of Replacement Fuels and AFVs

As the results of the "Replacement Fuel Demand and Supply Information" required by EPACT section 503, the Energy Information Administration publishes a series of annual reports entitled *Alternatives to Traditional Transportation Fuels*. The most recent edition, *Alternatives to Traditional Transportation Fuels 1994*, was published in February 1996, including actual data (as estimated) for 1994 and projections for 1996. EIA surveyed current use of replacement fuels and existing AFVs in service as of 1994. According to EIA, at least 324,000 AFVs were in use in the U.S. in 1994, with 421,300 expected to be in use in 1996. Of the 1994 inventory, 264,000 were fueled by LPG; 41,200 by CNG; and 5,500 by M85, with the remainder LNG, electricity, M100, E85, and E100. The proportions of the various AFVs by fuel type are shown in Figure 3. Around 86 percent were owned by the private sector, 9 percent owned by State and local governments, and 5 percent owned by the Federal Government (Figure 4). Approximately 82 percent were light-duty vehicles. Alternative and replacement fuels accounted for 1.6 percent of the transportation fuel market in 1992, with 0.17 percent of highway transportation fuels being alternative fuels and 1.4 percent being oxygenates. In 1994, the percentage for replacement fuels increased to 2.2 percent, of which 0.21 percent were alternative fuels and 2 percent were oxygenates. In 1995, the share of alternative and replacement fuels is estimated to have increased to 3.1 percent, of which 0.22 percent is expected to be alternative fuels and about 2.9 percent will be oxygenates [7,8]. Between 1994 and 1996, on-road consumption of CNG is expected to double, of M85 to increase by 50 percent, of LPG to increase by 6 percent and of oxygenates to increase by 45 percent.

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[7] According to the EIA data, the oxygenate 3 percent of total highway transportation fuel represents 4 percent of gasoline used in light-duty vehicles.

[8] The EIA data for replacement fuels exclude natural gas liquids (NGLs - butane, pentane, and some heavier hydrocarbons collected as condensed in natural gas production, transmission, and storage) blended into gasoline. Some blended NGLs could be interpreted to be LPG, which is included in the EPACT definition of replacement fuels, while other NGLs are outside the EPACT definition.

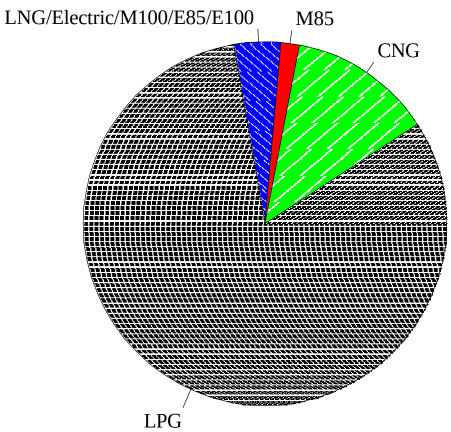

Figure 3. 1994 AFV Inventory by Fuel Type
Source: EIA

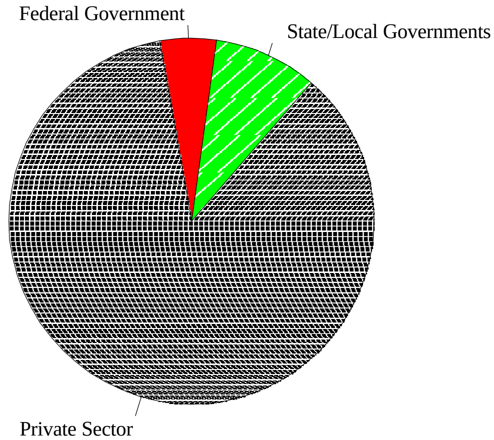

Figure 4. 1994 AFV Inventory by Owner
Source: EIA

<u>Potential Role of Replacement Fuels and AFVs</u>

DOE modeling indicates that the potential role of replacement fuels and AFVs in the U.S. is large. Based on underlying costs, it appears that the market could sustain over 30 percent replacement fuel use in 2010 and eventually could sustain perhaps double that. Even in light of the successful technology development and voluntary programs, the U.S. does not appear to be on the path to such large-scale replacement fuel use, however, and appears unlikely to approach such market shares without significant changes in relative prices to consumers. The unfavorable cost structure reflects partly current market conditions, partly a tax structure that disadvantages key alternative fuels, but most importantly the costs and other impediments associated with a transition from the current petroleum-based transportation system to a multi-fuel system, including associated infrastructure. Even with more favorable costs, considerable perceptual and logistical barriers would have to be overcome.

Other countries' experience with alternative fuel vehicle programs shows that favorable consumer economics is critical but not in itself sufficient for achieving large alternative fuel market shares. The U.S. approach embodied in EPACT is somewhat unique among world programs in its reliance on government-industry research and development partnerships and fleet AFV requirements to help overcome barriers and catalyze initial infrastructure. Fleet AFV use by itself will be insufficient to achieve large alternative fuel market share. Alternative fuel use by EPACT covered fleets, even with the contingent mandates for private and local government fleets, is unlikely to provide more than about 1.5 percent replacement fuel use, with a similar volume expected from State and local programs. Large volumes of AFVs would have to be acquired by the motoring public in order for replacement fuels to reach high market shares. In order to reach 30 percent replacement fuel use by 2010, AFV sales would have to reach approximately 30 to 40 percent of new vehicle sales by year 2000 and stay in that range through 2010. Such rapid market penetration is beyond even the typical pattern for auto industry market introduction of conventional new models or technologies. AFV penetration conforming to more typical market introduction would be consistent with replacement fuel use of 30 percent sometime around 2020 (if market conditions were favorable and transitional impediments were overcome).

The potential for replacement fuel use through substantially greater blending of oxygenates in conventional fuels was not evaluated within the scope of this study, though it could be considerable. Such blending could occur through more widespread blending of oxygenates geographically or possibly through higher blending levels. Energy security benefits, economic costs and benefits, and environmental implications should be studied further in the future.

Market Potential: Analytical Results to Date

DOE has assessed the potential roles of replacement fuels and AFVs most systematically in part one of its study performed under EPACT section 502(b), which required DOE to evaluate the technical and economic feasibility of displacing 10 percent of U.S. motor fuel use by year 2000 and 30 percent by 2010 (published as *Technical Report Fourteen*).[9]

With regard to the year 2000 goal of 10 percent LDV replacement fuel use, although the study projected little increase in use of alternative fuel vehicles beyond the mandated fleet usage by year 2000, it found that the 10 percent goal could be met if NGLs blended with gasoline are counted as replacement fuels (along with oxygenates).[10]

For year 2010, the study simulates a world market based on the underlying economic costs of production, distribution and use of different fuels, and the consumer advantages/disadvantages associated with each. In effect, it assumes that the necessary infrastructure, production capacity, and distribution networks are in place for those fuels that are inherently competitive. In other words, it assumes that transitional problems are solved and that the advantages of "incumbency" currently enjoyed by gasoline (and diesel) are neutralized.

Technical Report Fourteen is based on long-run equilibrium analysis using DOE's Alternative Fuels Trade Model (AFTM) for year 2010. The AFTM determines prices and quantities that balance the interrelated world oil and gas markets based on assumptions about supply, demand, and costs. The model estimates hypothetical future differences in fuel markets that could economically occur with the existence of well-developed infrastructure for alternative fuels, including values for fuel prices,

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[9] U.S. Department of Energy, Office of Policy. *Assessment of the Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Technical Report Fourteen: Market Potential and Impacts of Alternative Fuel Use in Light-Duty Vehicles: A 2000/2010 Analysis*, September 1995.

[10] EIA, on the other hand, does not classify blended NGLs as replacement fuels in its section 503 reports or other publications. If NGLs, representing about 5 percent of light-duty motor fuel, are not counted, it appears unlikely that the ten percent goal would be met. Treatment of NGLs would not necessarily have major implications for the section 502(b)(2)(B) goal of 30 percent replacement fuel use in 2010.

fuel volumes used, fuel imports, international trade flows, greenhouse gas emissions, and other variables of interest. The model also estimates the costs and benefits of alternative fuel use.

The primary focus of this report is the analysis of the economic and environmental implications of substituting alternative transportation fuels for 30 percent of conventional gasoline and diesel fuel used in LDVs in year 2010. The fuels examined are: compressed natural gas (CNG), liquefied petroleum gases (LPG - principally propane), methanol from natural gas, ethanol from cellulosic feedstocks, and electricity (i.e. electric vehicles).

This study focuses on the private LDV market; more specifically, the model applies to privately owned vehicles that are not part of large fleets. EPACT mandates some level of AFV use by Federal, State, fuel provider and possibly private and local government fleets of 20 or more vehicles (operated by entities that control 50 or more vehicles). Several State programs also mandate AFV and/or replacement fuel use in both fleets and personal use vehicles (e.g., the California zero emissions vehicle (ZEV) mandate).[11] Alternative fuel use by private and local government fleets was estimated separately (outside of the model) as part of the non-market fleet population, calculated as if the fleet mandates of EPACT section 507(b) were imposed, although existence of the statutory conditions for those mandates has yet to be determined. The report, thus, primarily deals with the feasibility of EPACT 30 percent replacement fuel goal for 2010 in the market for personal cars and light trucks.

Results from the study indicate that displacing 30 percent of light-duty motor fuel use by 2010 is technically feasible. Analysis of vehicle production decisions and the growth in the vehicle stock indicates that up to 100 million alternative fuel vehicles (or about half of the total stock of LDVs) could be in use by 2010. If demand were sufficiently great, vehicles could be produced in large enough numbers to achieve significant economies of scale. In addition, the fuels could be produced and distribution systems put in place to make the fuels widely available throughout the United States.

The report estimates that the market could support replacement fuel use at 30 percent or more of light-duty motor fuel in 2010, and perhaps this level could ultimately be doubled. The percentage varies for different scenarios analyzed.

The alternative fuels/AFV combinations that appear to be most economical are methanol and propane. The combined vehicle and fuel cost for propane vehicles is estimated to be less than that of all other fuels, and methanol is projected to have both favorable long-term production costs and competitive vehicle costs. However, both fuels are penalized relative to gasoline by current Federal and State excise taxes. These fuels might only be competitive if excise taxes were restructured to place the fuels on an equal footing (on a Btu basis) with gasoline.

Neither CNG nor ethanol appears to be competitive in the broad private vehicle market in the tax neutral scenarios. In the case of ethanol, this is because of its high cost of production. CNG, on the other hand, which is less expensive than conventional fuels on a gasoline equivalent basis, is

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[11] Originally scheduled to begin in 1998 requiring automakers to sell ZEVs in numbers equal to 2 percent of their California vehicle sales, implementation of the mandate was postponed by the California Air Resources Board to begin in 2003 with a requirement of 10 percent EV sales.

disadvantaged principally because of the high incremental vehicle cost. Lengthy and frequent refueling is an additional impediment to widespread CNG use. On the other hand, in scenarios corresponding to current fuel tax ratios, ethanol use rises to 40 percent of alternative fuel use, with methanol and LPG use dropping correspondingly.

Electric vehicles (EVs) are not used in any scenario above their mandated usage of 0.09 million barrels per day gasoline equivalent (based on ZEV mandates in California, New York, and Massachusetts). This is because of the high incremental cost (estimated at $5,000 with future large-scale production, higher for the foreseeable future) and performance characteristics of electric vehicles. It would take a major breakthrough in EV technology to make EVs competitive in the private vehicle market.

The study also considered import substitution effects associated with the displacement of petroleum fuels. It projected that methanol would displace imported petroleum on roughly a Btu equivalent basis. In an unconstrained market equilibrium, all of the vehicular methanol would be imported (just as essentially all incremental petroleum fuel use would be from import sources). Propane use would result in displacement of imported crude oil, but about 40 percent of the vehicular propane would be imported. Much of the propane that is not directly imported could result indirectly in an increase in petroleum imports to substitute for use in applications previously using propane. About half of the imported propane would be produced by petroleum refineries with the other half coming from natural gas. Substantial advantages would be gained from diversification of fuels and sources and flexibility in fuel choice, even where alternative fuels might be imported.

CNG use would displace some petroleum. Because of substitution elsewhere in the economy, a given volume of CNG used would displace a smaller volume (about half) of petroleum on a Btu equivalent basis. CNG use as a motor fuel would lead to some increase in domestic natural gas prices for other uses, including residential heating.

Greenhouse gas emissions are virtually unaffected by alternative fuel use except when a CO_2 emission constraint is imposed. Imposing such a constraint results in substantial costs, which could negate the economic benefits of AFV use. In the current tax scenarios, increased use of ethanol produced from cellulosic feedstocks results in about a 10 percent reduction in LDV greenhouse gas emissions.[12]

In long-run equilibrium, making alternative fuels and alternative fuel vehicles available would provide a net annual economic benefit of up to $10.3 billion in 2010. This level of gain would be achievable in the reference case with tax neutrality. Much of this benefit ($4.2 billion) consists of an increase in consumer satisfaction from the availability of new classes of vehicles and less expensive fuels; the remaining $6.1 billion reflects dollar cost savings from alternative fuel use, mainly through reduced cost of fuel imports. There could also be significant environmental benefits: up to $3.7 billion per annum. However, there could be significant transition costs that must be weighed against these gains. Transition costs are not included in this preliminary analysis but are being estimated by DOE in an

[12] Considerable uncertainty attends the estimates of greenhouse gas impacts from cellulosic ethanol as well as from other fuels. The estimate is, nonetheless, believed to be as reasonable as any available at this time.

ongoing study described below. Such costs include potentially higher fuel production, fuel distribution, and vehicle costs, etc., which will likely exist in the transitional years when AFVs begin to penetrate the LDV market. The report concludes that, while a free market could sustain a large volume of alternative fuel use, it does not appear at present that the market will move toward such a scenario without either Government action to affect the availability of both fuels and vehicles or a sharp increase of oil prices relative to replacement fuel prices.

Transition Analyses

The actual use of replacement fuels and AFVs described above represents DOE's best estimates of current volumes of use, while the potential use of each described in *Technical Report Fourteen* represents volumes that might be used if all the economic and logistical hurdles associated with switching from a transportation system based almost wholly on gasoline for light-duty vehicles to one based on multiple fuels were overcome. Although not specifically requested by section 506 of EPACT, DOE is attempting to provide as meaningful analyses as possible of the likely path between the current replacement fuel use and the potential use described in *Technical Report Fourteen*.

DOE is in the process of developing a transition analysis based on a dynamic market model of AFV use to support DOE analytical activities deriving from EPACT Title V rulemaking determinations and the examination/possible modification of the goals called for by section 504. This model will be used to forecast actual use of alternative fuels by AFVs (including dual-fuel AFVs), impacts from EPACT programs and other programs and policies, response of fuel providers, and infrastructure and any spillover AFV/alternative fuel use from fleets to private households. The initial results of this model could be available by early 1997.

In the absence of the market transition model, which is still under development, DOE has constructed some rough estimates of the magnitudes associated with the transition to a multiple fuel LDV transportation system. DOE is also able to present some perspectives of the pathways such a transition might take and to identify some additional issues that would have to be addressed in the context of pursuing such transition pathways.[13]

AFV Penetration Needed to Reach the 10 and 30 Percent Goals

The EPACT goals are based on the percent of motor fuel used in transportation. For purposes of this analysis, motor fuel use will be defined as the total motor fuel used by light-duty vehicles according to EIA. In 1995, EIA estimates that 98.1 percent of light-duty motor fuel use is gasoline (4.0 percent of which is oxygenates), 0.8 percent is estimated to be alternative fuels (predominately natural gas and propane), and 1.1 percent is diesel fuel. Figure 5 illustrates the projection of total light-duty motor fuel use through 2010, as well as the 10 and 30 percent goals in the years 2000 and 2010, respectively. Total light-duty motor fuel use is projected to rise from 13.5 quads in 1995 to 14.3 quads in 2000, 15.1 quads in 2005, and 15.5 quads in 2010.

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[13] For additional discussion of transition issues, see "Alternative Fuels and Vehicles: Transition Issues and Costs," Mintz, Marianne, and Singh, Margaret K.

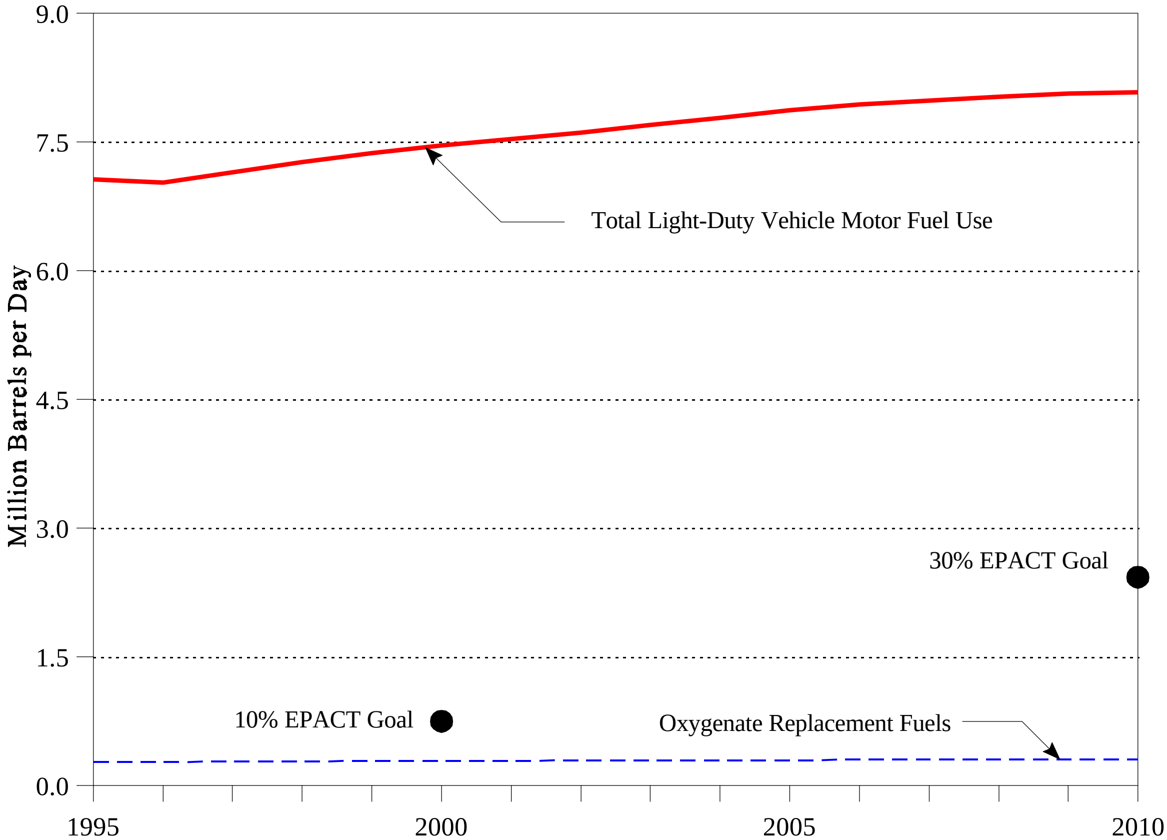

Figure 5. Total Light-Duty Vehicle Motor Fuel Use and EPACT Goals
(Source: EIA 1995 Energy Outlook)

The EPACT goals to displace 10 percent of transportation fuels in the year 2000 and 30 percent in the year 2010 will require that a large number of light-duty AFVs be in operation. Figure 6 illustrates the range[14] of light-duty AFVs that would have to be sold annually in order to meet the EPACT goals for motor fuel displacement (assuming that 4.0 percent of light-duty motor fuel gasoline is oxygenate replacement fuels and assuming that all of the AFVs projected are operated on alternative fuels all of the time).

[14] The range is due to varying estimates of new vehicle sales, fuel efficiency, and vehicle scrappage rates in the future. The upper bound represents the most conservative combination of these variables while the lower bound represents the most optimistic combination.

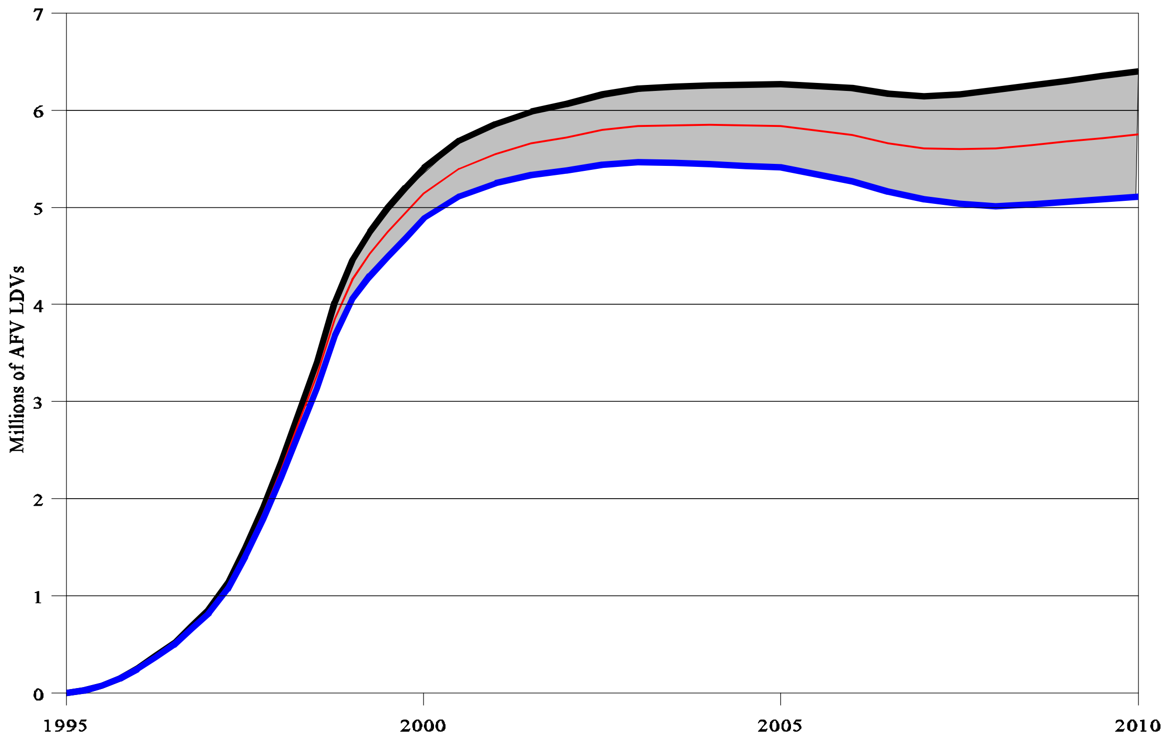

Figure 6. New Light-Duty AFV Sales Required to Achieve EPACT Goals

As Figure 6 shows, a very high rate of AFV sales is necessary to meet the 10 percent goal in the year 2000 (4 percent of the 10 percent being met with oxygenates blended into gasoline and 6 percent being met with alternative fuels used in AFVs). This very rapid build-up is required to get enough AFVs in service to cause the required amount of fuel consumption to occur. Between 1998 and 2000, AFV sales must grow by about 1.5 to 1.9 million per year. To put this task into perspective, the entire production of Ford passenger cars in 1993 was slightly less than 1.5 million. Figure 7 illustrates AFV sales in terms of the percentage of total light-duty vehicles sales. As Figure 7 shows, AFV sales must grow to between 35 and 40 percent of total light-duty sales to meet the 2000 goal and stay in the range of 30 to 38 percent to build an AFV population sufficiently large to meet the 2010 goal. Figure 8 illustrates how the AFV population would grow through 2010 based on the sales curve of Figure 6.

Figure 8 vividly illustrates why AFV sales would have to increase very rapidly and stay at a high level through 2010 to meet the 30 percent EPACT goal. As Figure 8 shows, the AFV population must grow steadily from approximately 1998 through 2010 in order to build a vehicle population sufficiently large to consume 30 percent of the projected amount of light-duty motor fuel in 2010. AFV sales as a percent of total new light-duty vehicle sales level out in the mid-30s to achieve 30 percent displacement because total light-duty motor fuel is projected to increase each year from 1996 through 2010, but vehicle fuel efficiency is also projected to increase each year, requiring more vehicles to achieve a given fuel displacement than the average older vehicle in the conventional LDV population.

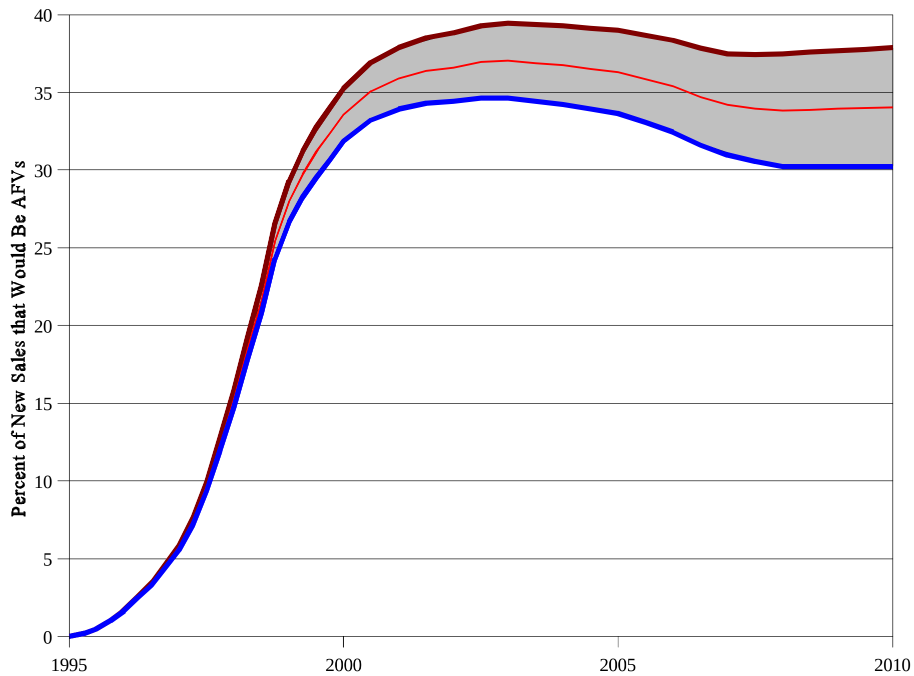

Figure 7. AFV Sales to Meet EPACT Goals as a Percentage of New Light-Duty Vehicle Sales

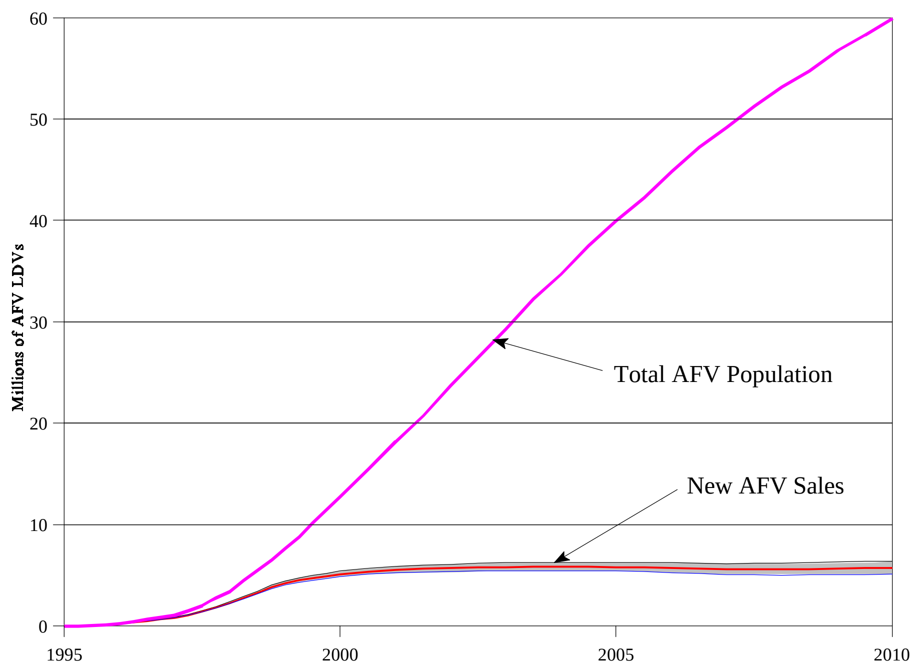

Figure 8. AFV Sales and Population to Meet EPACT Goals for Motor Fuel Displacement

The estimated amount of light-duty fuel displacement by the AFV population illustrated in Figure 8 is shown in Figure 9. (The initial amount of replacement fuel use in 1995 is due to oxygenates in gasoline and existing alternative fuel use by light-duty vehicles.[15]) The slow increase in fuel displacement illustrated in Figure 9 is due to the time needed to build an AFV population that has significant fuel consumption relative to the conventional LDV population. After the AFV population is established and growing at a steady pace, the amount of alternative fuel consumed also grows at a steady pace.

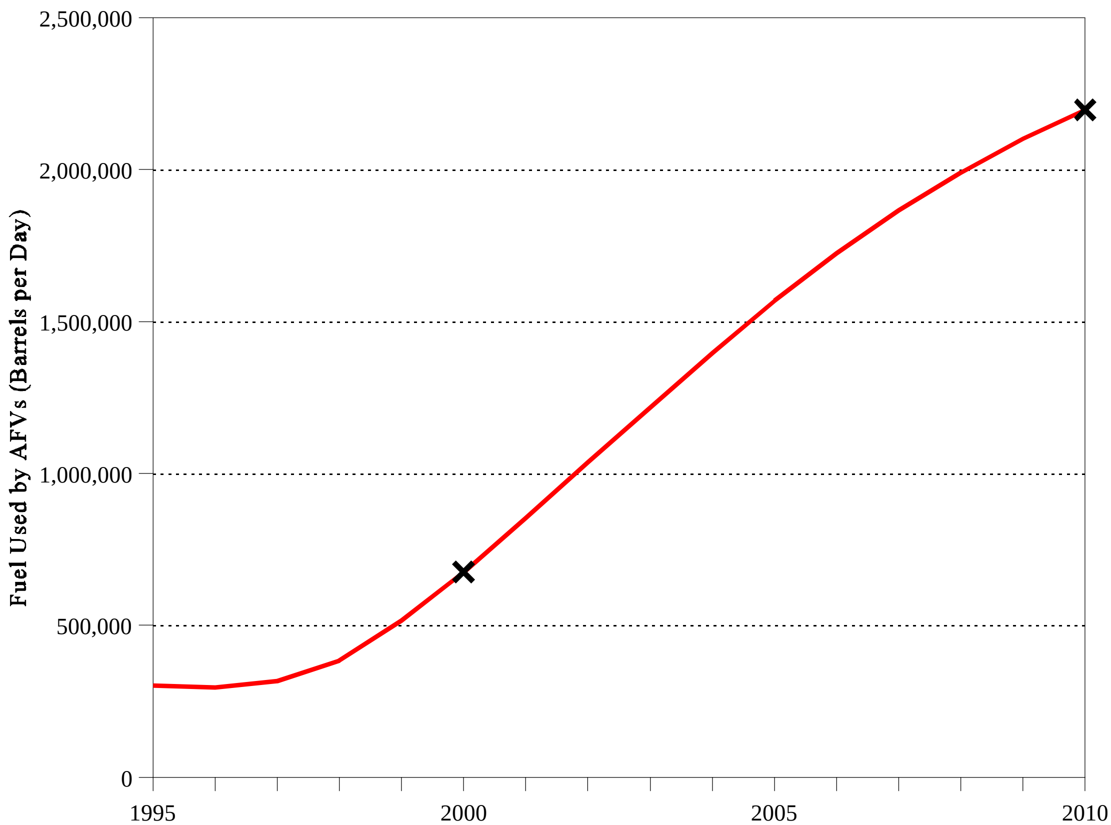

Figure 9. Replacement Fuel Energy Use by AFVs to Meet EPACT Goals

The rapid market penetration depicted in Figure 7 and Figure 8 is beyond even the typical pattern for auto industry market introduction of conventional new models or technologies. An AFV acquisition scenario was also considered that simulates a more gradual phase-in of AFVs over the coming 25 years (the "Reference Growth" scenario). Such a scenario for AFV implementation based on a slower initial growth rate of AFVs is illustrated in Figure 10, Figure 11, and Figure 12. This scenario includes growth of AFV sales in several distinct phases. In the first phase (years 1995

[15] "*Alternatives to Traditional Transportation Fuels, 1993*" Energy Information Administration, DOE/EIA-0585(93), January 1995.

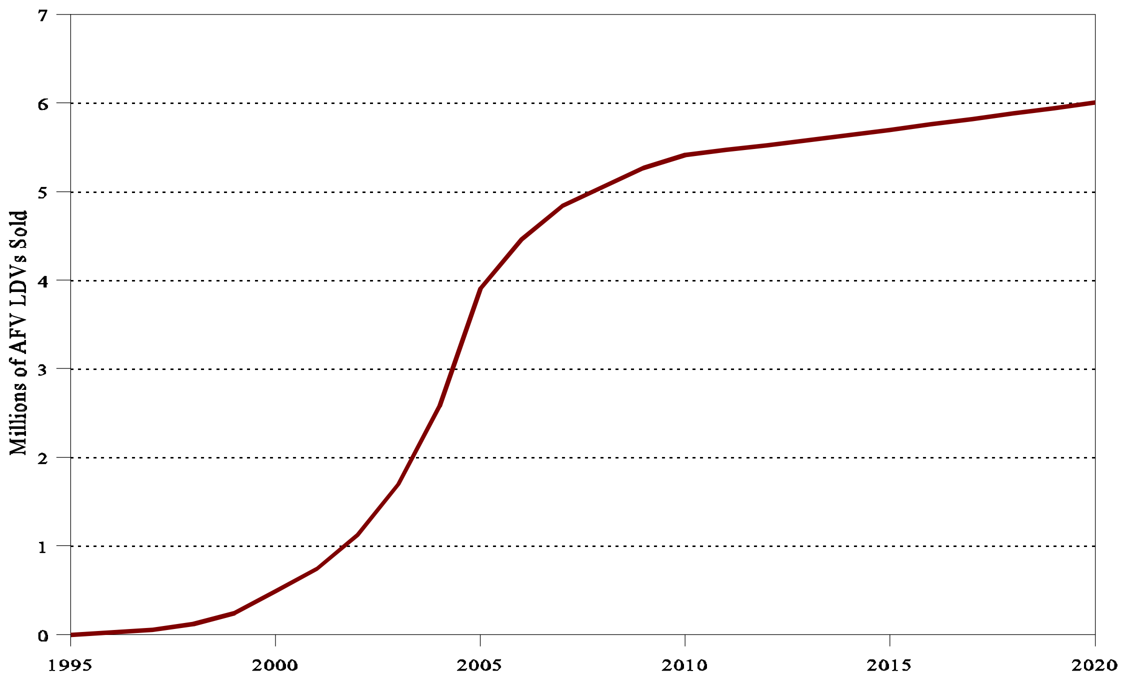

Figure 10. Projection of AFV Sales under the Reference Growth Scenario

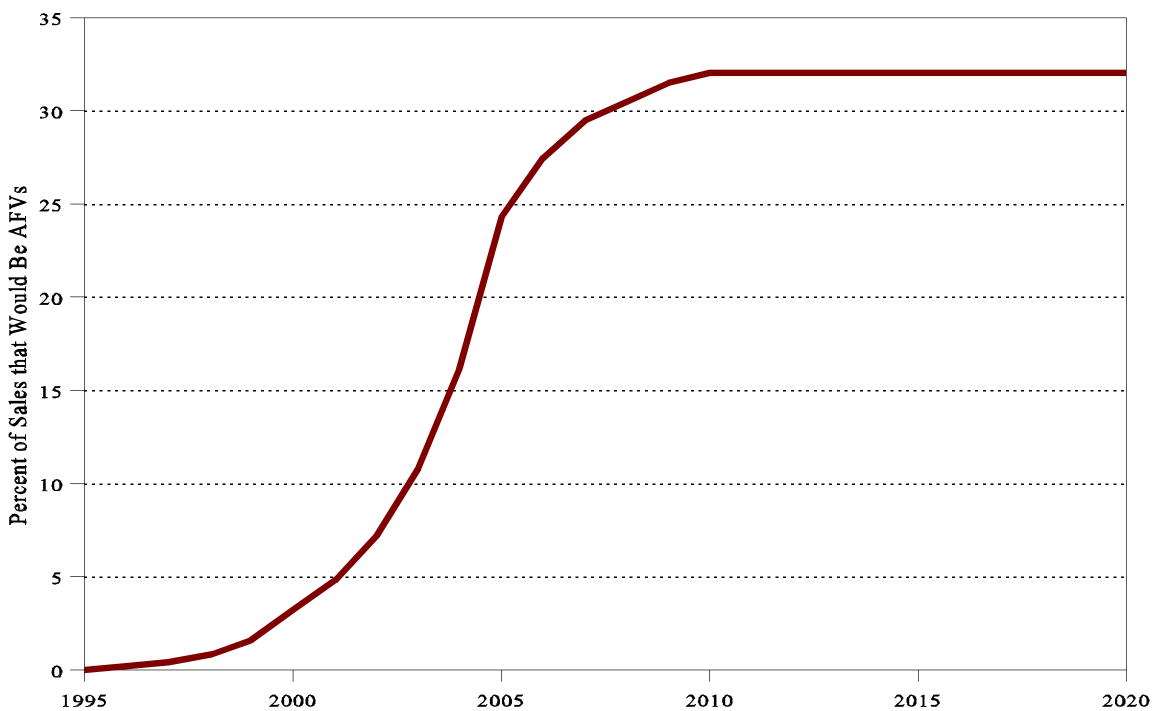

Figure 11. AFV Sales as a Percentage of Total New Light-Duty Vehicle Sales - Reference Growth Scenario

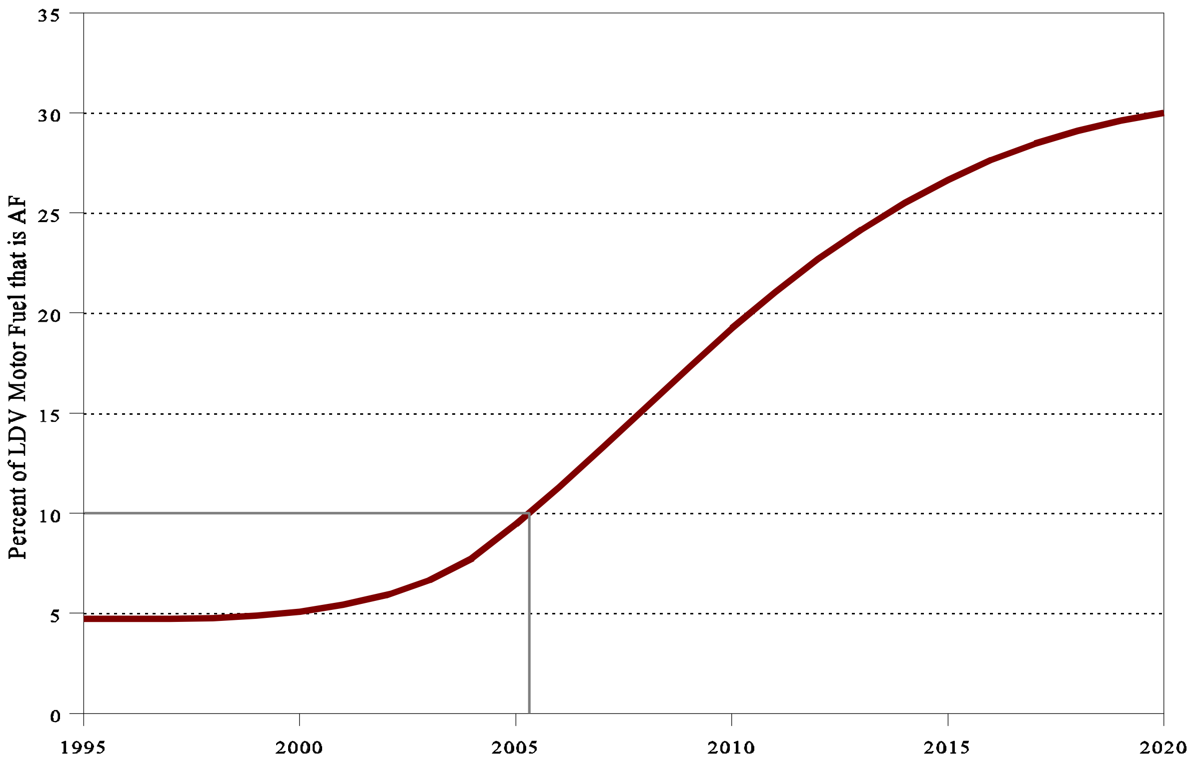

Figure 12. Fuel Displacement as Percent of Total LDV Motor Fuel under the Reference AFV Growth Scenario

through 2000), AFV growth doubles every year, going from approximately 30,000 to 500,000 sales per year, representing production of AFVs across several manufacturers and model lines.

The sales increase in this time period, however, never exceeds 250,000 vehicles per year. In the period from 2001 through 2005, AFV sales increase by 50 percent per year, representing a period of sustained high-growth of AFVs sales. In the year 2005, total AFV sales would be 3.9 million. After the period of sustained high-growth, AFV sales growth in the period of 2005 through 2010 is assumed to decrease steadily so that by 2011 sales of AFVs remain at a constant 32 percent of total LDV sales (Figure 11). If AFV sales are then constant from 2011 through 2020 at 32 percent of all LDVs, the AFV population in 2020 (ten years later than the EPACT 30 percent goal) will be large enough so that 30 percent of LDV motor fuel will be alternative fuel plus oxygenates in conventional vehicle fuel (Figure 12). (Note that the initial fuel displacement in Figure 12 is due to oxygenate and alternative fuel use in 1995.[16]) In this scenario, the original 10 percent displacement goal is essentially met in 2005, five years later than the original EPACT goal date. This scenario ends up with a larger population of AFVs (67 million, Figure 13) than the previous calculation of AFV population to meet the EPACT goals (60 million, Figure 8). The difference is due to the fact that the LDV population in the U.S. is projected to continue to grow, and that new LDVs will be more

[16] Range due to varying estimates of new vehicles sales, etc. (see footnote 7).

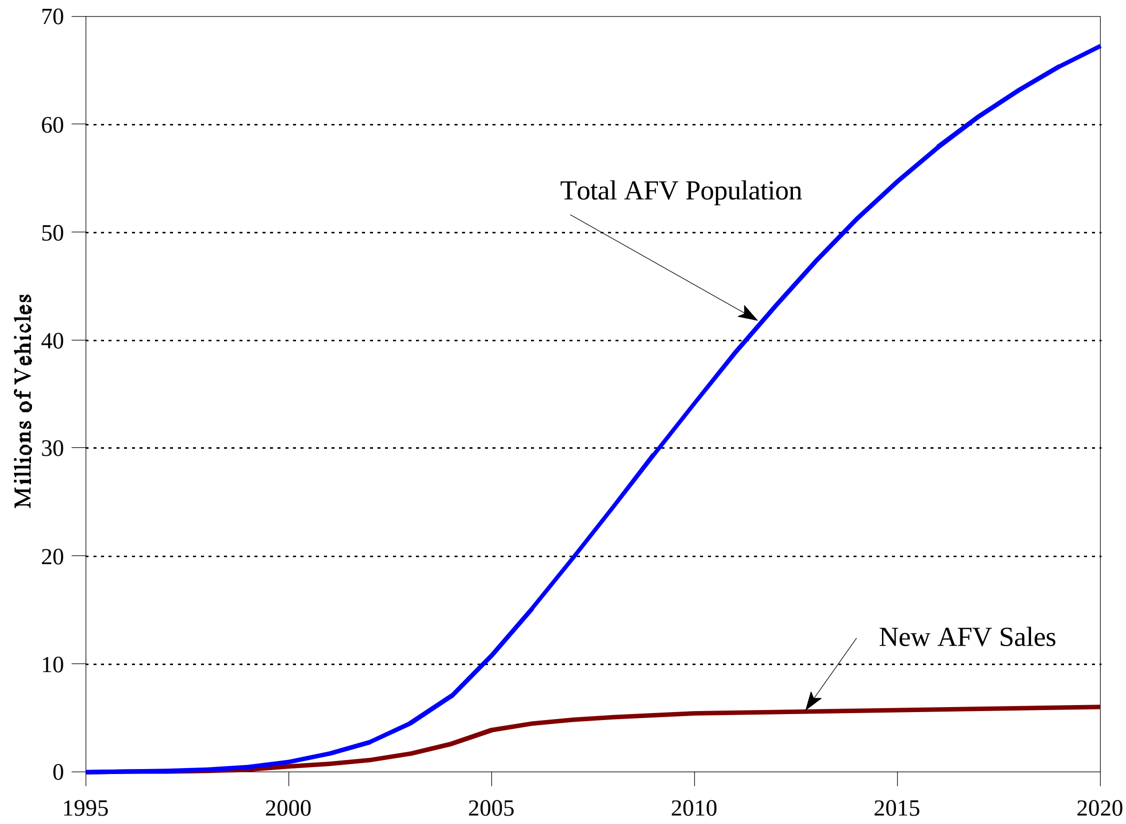

Figure 13. AFV Sales and Population for the Reference Growth Scenario

fuel efficient than previous ones, requiring more new AFVs to achieve the same level of fuel consumption as older vehicles.

To meet the 10 and 30 percent goals in EPACT requires a very rapid increase in vehicle sales followed by sustained sales at a high level without large increases in sales growth. This type of market behavior is not typical. More likely would be slower initial sales increases followed by long periods of sustained sales growth. Without some constraint on sales, and assuming economic reasons for purchasing AFVs, it is difficult to envision a scenario that would result in rapid growth that levels off when 30 percent fuel displacement is achieved. More readily conceivable would be that the 30 percent fuel displacement level would be just one point along a path to some higher equilibrium of AFVs versus conventional vehicles. (Alternatively, if AFV growth were to reach a maximum of only 30 percent fuel use, the time to reach 30 percent would be more gradual.) The Reference Sales Growth Scenario has this characteristic in that sales growth is positive when 30 percent fuel displacement is reached on the way to higher AFV sales in the future.

This Reference Growth Scenario is believed to be generally more representative of new vehicle market introduction than the growth paths reflecting the EPACT goals. Sales growth rates of new technologies such as AFVs, however, typically do not follow such smooth and consistent patterns.

Sales may very well increase faster than depicted here at some phase in the process. A major difference between this scenario and the previous ones discussed in this section is that this scenario was not constrained to meet the 10 and 30 percent transportation fuel displacement goals by 2000 and 2010, respectively. The reference growth scenario, however, would still represent an extremely ambitious change for the U.S. economy and society, and it is by no means clear that market conditions and/or policy programs are conducive to embarking on such a path in the near-term.

DOE generated estimates of the numbers of vehicles covered by the various EPACT fleet mandates, and State and local AFV programs, which can be compared and contrasted with the projections of numbers of AFVs necessary to meet the 10 percent and 30 percent goals suggested by EPACT. These estimates indicate that the various Federal and State programs could result in as many as one million AFVs in operation by 2000 and five million by 2010, counting only those vehicles directly covered by mandatory programs, exclusive of the Clean Cities voluntary program and any spillover effects on non-covered vehicles. These estimates do count private and local government fleets that would be covered by a possible early fleet program under section 507(b). These estimates are presented by program in Table 2 and Table 3. A more detailed description of the estimates can be found in *Estimates of Alternative Fuel Vehicle Use from Federal, State and Local Programs*, Margaret Singh, Argonne National Laboratory, background paper prepared at the request of DOE.

The five million AFVs potentially deployed as direct results of these programs alone could displace approximately 220,000 barrels per day of motor fuel or roughly 3 percent of the LDV transportation fuel use projected by EIA for 2010. Replacement fuel in the form of oxygenates can be expected to contribute an additional 4 to 6 percent of LDV fuel use.

It can be seen from the above estimates that a large gap exists between the AFV penetration likely to result from Federal and State programs by themselves and that necessary to reach or approach the EPACT section 502(b)(2)(B) goal of 30 percent fuel displacement by 2010. At the same time, *Technical Report Fourteen* suggests that the market could support 30 percent fuel use by then. This gap between the level of AFV use that could be supported by the market and that projected to result directly from EPACT mandates raises the questions of whether and how a transition to such alternative fuel use might occur. Could some threshold of use be reached by some of the alternative fuels that would provide for sufficient economies of scale in production and use of the fuels and vehicles, including accessability and convenience of refueling? Would motorists perceive and respond to such a threshold if it is reached? Would the fleet programs provide sufficient critical mass for such economies and accessability and the necessary perceptions on the part of the motoring public? While answers to these questions are not yet available, DOE has considered relevant issues from various perspectives, as are summarized below.

Lessons from International Experience

A number of other countries have implemented policies to promote AFV use in recent decades. To the extent that these programs have been in place for some years, the market reactions could provide valuable indications of likely responses to EPACT programs, not withstanding the considerable differences in the nature of the programs and in the markets themselves.

Table 2. Year 2000 Estimates of AFVs in Operation by Program
(thousands of AFVs)

PROGRAMS	VEHICLES Passenger Cars	Light-Duty Trucks	Heavy-Duty Trucks	Transit Buses	School Buses	Totals
EPACT						
- Federal	65	81				146
- State	58	16		2		76
- Fuel Provider & Private	353	114				467
Total EPACT	476	211		2		689
STATE/Local/ Private						
- State/Local	51	20		5	38	113
- Private	59	24	17			100
Total State/ Local/Private	110	44	17	5	38	213
ZEVs (NY)	9	46				55
All Programs	595	301	17	7	38	958
National Vehicle Stocks	149,000	60,680	2,508*	58*	526*	212,772
Percent National Vehicle Stocks	0.4	0.5	0.7	12.1	7.2	0.5

* Projections not available, stocks based on latest available information.

Table 3. Year 2010 Estimates of AFVs in Operation by Program
(thousands of AFVs)

	VEHICLES					
PROGRAMS	Passenger Cars	Light-Duty Trucks	Heavy-Duty Trucks	Transit Buses	School Buses	Totals
EPACT						
- Federal	80	120				200
- State	174	79		32		285
- Fuel Provider & Private	1,440	564				2,004
Total EPACT	1,694	763		32		2,489
STATE/Local/ Private						
- State/Local	50	19		3	52	125
- Private	149	58	57			264
Total State/ Local/Private	199	76	57	3	52	389
ZEVs	2,023	195				2,219
All Programs	3,916	1,034	57	35	52	5,095
National Vehicle Stocks	156,000	77,740	2,508*	58*	526*	236,832
Percent National Vehicle Stocks	2.6	1.3	2.3	60	9.9	2.2

* Projections not available, stocks based on latest available information.

About one percent of the world's vehicles are powered by alternative fuels. In every country where AFVs have penetrated the market significantly, the national government has played a critical role establishing effective prices for alternative fuels of one-third to two-thirds the prices of gasoline and/or diesel fuels through tax and/or subsidy policies (Canada, New Zealand, Netherlands, Italy, and Brazil). In some cases, subsidies for purchase of new AFVs or conversion of conventional vehicles and/or for refueling infrastructure were also provided (Canada and New Zealand). Even in these five countries, AFV penetration has not been more than 15 percent, except for Brazil. When tax/subsidy policies have been subsequently altered, reducing the fuel/vehicle price differential, conversion of vehicles to alternative fuels and sales of new AFVs have dropped dramatically (New Zealand, Canada, Italy and Brazil). It is clear from the experiences of the countries that have made substantial efforts to convert to alternative fuel use that strong, consistent, and multifaceted national policies are required in order for alternative fuels to have any chance for success, particularly for long-term success.

Strictly in terms of penetration levels, the world's most effective AFV program is clearly Brazil's. There, a combination of tax, subsidy, mandates, and para-statal marketing resulted in an (ethanol) AFV market share of approximately 30 percent, along with another 22 percent gasoline substitution through ethanol blending at the peak levels (1989). Cost effectiveness, however, puts the Brazilian experience in a much different light. The program has often been cited as a substantial contributing factor to runaway inflation and economic disruption. It also resulted in shortages of other fuels (diesel) and even in imports of high-cost ethanol from the U.S. Brazil has had to reduce its subsidy programs as part of its anti-inflationary policies, bringing the whole program into constant reassessment. As relative prices have changed over time, domestic ethanol producers have shifted their emphasis to other products, such as sugar. In the early 1990s, sales of ethanol vehicles plummeted, and their future market share is difficult to predict.

Aside from Brazil, the Netherlands has the most effective policy. LPG displaces about 15 percent of the gasoline that would otherwise be used by the light-duty fleet. The Dutch policy is tax based; there are no mandates. It has been relatively consistent for two decades; its biggest difficulty lies in keeping the vehicle use tax and the relative gasoline/LPG and diesel/LPG price ratios responsive to changing prices among the factors that together make up the net LPG incentive. Because of lead and lag times, the share of LPG vehicles drifts up and down somewhat, but is not in danger of drifting down so far as to make the fuel delivery infrastructure economically marginal. The policy includes close cooperation with the LPG supply and distribution industry to meet demand, to locate LPG stations at safe locations, and to design and install refueling equipment that is convenient (self-service is allowed), safe, and similar in design to gasoline refueling equipment.

Experience in the other countries shows that governments can cause AFVs, particularly LPG-fueled AFVs, to penetrate the market through combinations of taxes/tax incentives, loan programs, and educational programs. It also shows, however, that, at least over the past 20 years, subsidies continue to be necessary and that governments find it very difficult to maintain the political will to continue the subsidies at large enough levels to generate the desired response. Various countries' experience suggests that the political will to support alternative fuel programs with financial incentives is greatest when oil prices are at peak levels. When the incentives are most critical to sustaining alternative fuel momentum, at the low end of the oil price cycle, governments have often been least committed.

Even where the subsidies have been maintained, lack of governmental attention may cause programs to stagnate, as in Italy. This suggests that the Government role in alternative fuel transition must include many actions beyond the purely economic role of preferential tax treatment for alternative fuels and/or tax credits for AFVs alternative fuel infrastructure.

Penetrations of the various alternative fuels in motor vehicle use in Brazil, the Netherlands, New Zealand, Italy, Japan, Canada, and Australia are shown in Figure 14.

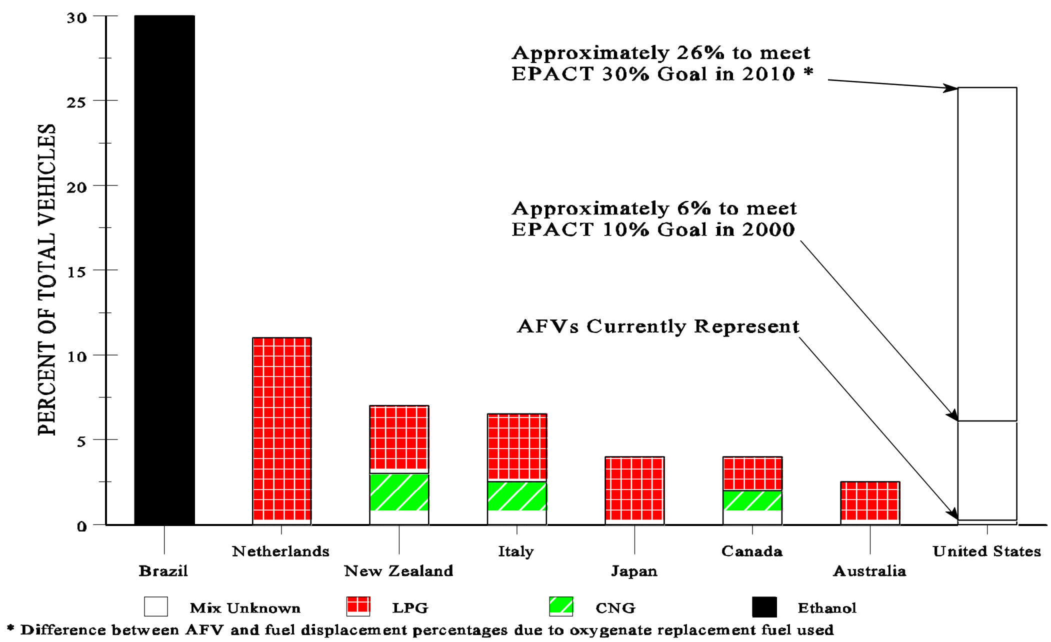

Figure 14. AFVs as Percentage of Total Vehicles in Selected Countries

New Zealand's experience with gas-to-methanol-to-gasoline in the 1980s, as well as U.S. experience with synthetic fuels over the same period, shows that large volume subsidies to a small number of large, high-technology companies are politically vulnerable -- more vulnerable than a large number of small subsidies, which, it has been shown, are also vulnerable when government budgets get cut. The vulnerability is increased when the technologies used are inadequately proven.

Unlike the countries whose policies have been discussed, the United States has chosen a policy route based primarily on Government-industry research and development partnerships, along with mandates and regulations, with economic incentives playing only a marginal role.[17] Also unlike the other countries, the U.S. fuel tax structure penalizes all the alternative fuels other than compressed natural gas, ethanol, and electricity, a reality that sometimes works against the AFV policies that Federal, State, and local governments are now implementing for all the other alternative fuels. Experience

[17] Brazil falls somewhere in-between the U.S. and other country programs, relying on a combination of economic incentives and mandates, principally on the para-statal oil monopoly. Some other countries (Japan, India and Korea) have imposed mandates on taxicabs operating in certain cities.

with mandated programs is very limited. The international policy experience considered does not address the potential direct impacts of the EPACT fleet mandates. It does suggest that spillover into voluntary use of alternative fuels and AFVs in non-mandated sectors is likely to be determined by the relative economic costs and benefits during each stage of the transition, including (at least for dedicated AFVs) some differential to compensate for future uncertainty and for the operational disadvantages of dedicated AFVs. Merely putting in place novel and limited infrastructure networks is likely to be insufficient in generating high levels of spillover to non-mandated motorists, even in conjunction with cognizance of societal benefits and potential future widespread availability unless and until some change in the overall economics, access, and convenience factors occurs or is perceived to be imminent.

More detailed descriptions of the individual country experiences are included within a paper prepared for DOE: *Summary of Domestic and International Experience with Alternative Transportation Fuels* by David E. Gushee, R.F. Webb Corp.

Transition Scenarios and Necessary Measures

DOE's main analysis of transition pathways, issues, and measures to achieve the 30 percent goal is being undertaken in conjunction with development of the dynamic market model and geared toward potential realization of the market solution suggested by *Technical Report Fourteen*. In the absence of the results from that analysis, DOE has reviewed existing studies of possible transitions and policy measures. DOE has identified as the best and most pertinent of these a series of studies commissioned by the Congressional Research Service (CRS) in response to a request of the U.S. Alternative Fuels Council, published in April 1992. CRS commissioned five studies to identify the types of policy levers that would be necessary to cause the desired transitions to a marketplace where vehicles using five fuels would achieve market penetrations of 5 percent each, the costs of the various policies, and the rates at which the vehicles and fuels could be expected to appear.

The five fuels considered included methanol, ethanol, natural gas, LPG, and electricity. A broad array of policy levers was identified as necessary for each of the fuels to achieve the 5 percent goal. To provide adequate supply and retail availability, each fuel was believed to require subsidies/tax credits of over $3 billion except for LPG, which was believed to require $1 billion in subsidies to achieve 15,000 new stations. The 5 percent share for ethanol would be achieved through 10 percent blending in half of all U.S. gasoline, would require a mandate for such blending in addition to the existing tax exemptions, and additional investment tax credits. There would be no certainty that the 5 percent shares for the various fuels would be reached even with the levels of subsidies identified (representing costs incremental to conventional fuels), because total investment would be much greater than these amounts.

EPACT does not target market shares for particular fuels; nor does there appear to be any interest in the U.S. in setting such targets or in designing programs toward fuel-specific goals. Such was not necessarily the intent of the CRS study series. Rather, comparing and contrasting the relative hurdles faced by the different replacement fuels helps shed light on a number of issues which must be considered in conceptualizing, let alone designing, a coherent and effective approach to promoting transition to substantial replacement fuel use.

These studies all concluded that, under existing price relationships, public policy intervention would be necessary in order for alternative fuels to substantially penetrate the light-duty vehicle market. That intervention would have several dimensions:

- Subsidies to vehicle purchasers;
- Subsidies to fuel providers for infrastructure development;
- Subsidies to fuel purchasers; and
- Governmental support
  - Information programs,
  - Research and development, and
  - Technology transfer.

Mandates could, conceivably, serve as substitutes for subsidies; the CRS study used subsidies as a mechanism to estimate the amount of effort required to make the transition.

The results of the CRS studies indicated that the different energy forms would require different kinds of policy prescriptions with differing costs, differing mixes of social, energy security, and environmental benefits, and differing rates of response. These conclusions are summarized in Table 4. Although some particulars of Table 4 regarding tax treatments and vehicle costs are out of date,[18] the conclusions are still indicative of the key policy issues that must be resolved and the energy and environmental effects to be expected from the various policy options. (Some vehicle costs have been updated from the original CRS table.)

The studies made clear the critical factors for each alternative fuel:

- For methanol, fuel price and infrastructure development are the big barriers; vehicles are priced the same or slightly more than the same models with gasoline power.
- For natural gas, whether compressed or liquefied, vehicle price and range and service station costs are the big barriers. Both are long-term problems.

[18] EPACT introduced tax incentives for alternative fuel and electric vehicles and for construction of service stations, while the Omnibus Budget Reconciliation Act of 1993 modified fuel tax rates somewhat.

Table 4. Critical Path to 5 percent Penetration for Each Fuel
(California Phase II gasoline is taken as the competitive reference point)

OBSTACLE	METHANOL (M85/M100)	ETHANOL (E10/E85)	NATURAL GAS (Dedicated)	PROPANE (Dedicated)	ELECTRIC
Fuel Cost	Without transitional subsidy, incremental methanol primarily from imports. 50 percent investment tax credit for investment in domestic methanol capacity (about $2 billion). Temporary subsidy of 15 to 30 cents per gallon seems needed (about $2 billion) for price reduction pending economies of scale. Subsequently self-sustaining	Priced about 20 cents/gal. more than competitive octane sources. 25 percent investment tax credit suggested for new ethanol capacity; $2.5 billion. Over 10 years, $3 billion increased consumer fuel cost (fuel standard replaces blender tax credit). Subsequent cost path uncertain but promising	Has price advantage of 30 to 45 cents/gal. at "city gate" (depends on distance of city from gas source). Price may rise slightly from additional demand but not enough to dissipate advantage	Price advantage of 30 to 45 cents per gallon at "city gate." Price will rise some with added demand but not enough to dissipate advantage. Some investment tax credits probably necessary to induce increased domestic supplies	Batteries cost a lot and have short lifetimes. Utility ownership and rate basing for several years, followed by subsidy declining year by year in percentage, suggested. About $24 billion involved, including costs of recharging (see below). Subsidy would be about $4 billion. Possibly self-sustaining thereafter
Vehicle Cost	Currently $100-$300 for M-85. For M-100 currently around $2500 per vehicle, estimated to decline rapidly and perhaps disappear as production scale increases.	No change for E-10. For E-85, same as for M-85.	Currently up to about $2500 per car higher. $800 to $1000 higher in volume production. Assistance in start-up costs or subsidy to vehicle buyer indicated	Currently $800 to $1200 per car higher. Perhaps half that in volume production. Assistance in start-up costs or subsidy to vehicle buyer indicated	EVs (less batteries) initially cost up to $10,000 more than gasoline vehicles, declining over time. Subsidies of 25 percent of the incremental cost would total about $3 billion over 10 years. Subsequently self-sustaining
Fuel Transportation Cost	Two gallons needed per gallon gasoline replaced. About 5 percent expansion of system needed. Not viewed as a critical obstacle	Refinery, pipeline, and/or terminal practice must be modified. About $3 billion investment needed, with investment tax credit of about $600 million suggested	No change	Tankage at terminals to be expanded.	Not expected to be critical except perhaps in some local situations
Retail Distribution Cost	Service station receptivity an issue. Incremental cost ranges up to about $75,000. Assistance with low volume start-up indicated. About $1 billion, to support up to 25,000 service stations in affected areas at $40,000 each. Subsequently self-sustaining. Methanol federally taxed at gasoline Btu equivalency	No Change Ethanol currently has Federal tax waiver of 54 cents per gal. 5 percent target and investment tax credits would substitute for tax waiver	Service station costs estimated at up to $300,000 more than gasoline for equivalent volume. Like methanol, will have start-up problems at low volumes. Would take about $4.5 billion for 15,000 stations. Currently not subject to highway tax	Service station costs about the same as methanol, unless local safety rules add cost, but current practice includes high mark-ups except for fleet sales. Most existing outlets must be upgraded to become attractive to drivers. Currently taxed per gallon as gasoline (1.18 times Btu equivalency)	Recharging infrastructure must be developed. Subsidies included under Fuel Cost. Not subject to highway tax
Research and Development	Formaldehyde emission catalysts	Reduce ethanol production cost. About $230 million	Onboard fuel storage.	Emission catalysts, onboard storage	Batteries, motors, converters, control systems. Several billion dollars could easily be spent

- For propane, fuel price stability and fuel safety (fuel heavier than air) are the big barriers. Both appear to be resolvable.

- For ethanol, fuel price is an even bigger problem than it is for methanol. It was concluded that adding ethanol to gasoline would be a better path than making ethanol an alternative fuel.

- For electricity, vehicle price, range, and battery replacement cost are the big barriers. All appear to be long-term problems.

The studies showed that both propane and methanol appeared to be able to capitalize on temporary subsidies in the range of $10 billion each to become self-sustaining in the marketplace after 10 to 15 years. Whether the methanol and propane would be produced from domestic resources or imported would depend on favorable investment tax benefits during capacity expansion. Ethanol's future depends on technological developments to reduce costs of conversion of biomass to ethanol. Natural gas could become self-sustaining but would require more support ($25 to $30 billion) and a longer timeframe than methanol or propane because the economic hurdles for both vehicles and retail fuel delivery are higher. The technical and economic hurdles faced by electric vehicles are the highest (more than $40 billion) of all the alternative fuels examined.

VI. ACTUAL AND POTENTIAL AVAILABILITY OF AFVs AND REPLACEMENT FUELS

Alternative fuel vehicle technologies are available for the principal alternative fuels believed most likely to play major parts in any transition to substantial alternative fuel use. Natural gas, LP gas, and alcohol vehicle technologies are sufficiently developed for such vehicles to be introduced into the market on large-scales if the other factors, currently marginal, including cost, convenience, and infrastructure, were favorable. Electric vehicle technology per se is also close to market-ready but battery cost and range probably stand in the way of general market acceptance between now and 2010.[19] Hybrid electric, fuel cell, and hydrogen vehicle technologies are in various stages of development and could be available in the future but would probably not play major roles in an alternative fuel transition, particularly in the period up to 2010.

A number of types of vehicles are currently available for purchase from original equipment manufacturers by the public and fleets but not the whole range of vehicles in each of the alternative fuels. One full-size passenger car is available for use with 85 percent alcohol/15 percent gasoline mixtures or any mixtures down to straight gasoline at the same price as the same conventional model. A pickup truck may be available for 85 percent ethanol use in two to three model years. Light-duty vehicles for 100 percent alcohol operation are not currently available. A full-sized sedan is available for dedicated CNG operation and others may follow. Pickup trucks, vans, and mini-vans are available for dedicated CNG use. CNG vehicles (bi-fuel and dedicated) may also be obtained by conversions of conventional vehicles by many small conversion firms. Costs for dedicated CNG vehicles are generally $3,000 to $5,000 more than conventional models. Bi-fuel CNG/gasoline or LP gas/gasoline light-duty vehicles are not available as new vehicles from manufacturers, but manufacturers are providing vehicles specially configured for addition of CNG and LP gas fuel systems by aftermarket suppliers. Electric vehicles are expected to be available in model year 1997 in subcompact passenger car and small pickup models but at prices that could limit their market to the mandated zero emissions vehicle areas.

Most of the major alternative fuels are available at national and regional levels in volumes that are significantly greater than current transportation use. Only CNG would currently be available from domestic sources in volumes corresponding to the section 502(b) goal of 30 percent replacement fuel use for 2010. LPG could be available in sufficient quantities to play a major role in a transition but perhaps 40 percent of it would be imported from outside North America. New methanol plant capacity would be needed for any substantial transportation fuel market. Under open market conditions without domestic investment incentives, much of the additional methanol to be used for vehicle fuel would probably be imported. Ethanol production for substantial alternative fuel use would be from cellulosic feedstocks and production processes that are currently under development. Taken together, the alternative fuels could be available as a transition proceeds with at least 50 percent being produced domestically.

[19] The California Air Resources Board recently concluded that EV technology is not yet ready for general market acceptance and, accordingly, chose to postpone initiation of ZEV mandates from 1998 until 2003.

None of the alternative fuels are currently available at retail for vehicle refueling in adequate networks to support widespread use. Adequate refueling sites could be available as the transition proceeds but would involve additional capital costs.

Actual and Potential Availability of AFVs

The alternative fuel vehicles (AFVs) targeted by EPACT Title V are light-duty vehicles represented by passenger cars, pickup trucks, and vans. The following sections discuss the present and near-term availability of AFVs that could be used to satisfy EPACT requirements. Medium-duty and heavy-duty vehicles are also available as AFVs but are not included in this discussion.

Current AFV Technologies

The currently available AFV technologies can be grouped into five distinct categories:

- natural gas;
- LP gas;
- methanol;
- ethanol; and
- electricity.

Each of these are at different stages of technology development and explained in the following sections.

Natural Gas

Natural gas vehicle technology includes two distinctly different technologies — engine fuel metering technology and fuel storage technology.[20] Engine fuel metering technology has evolved to be essentially the same level as that of gasoline fuel systems, i.e., multipoint fuel injection, which facilitates advanced driveability and efficiency and reduced emissions. Detail improvements in natural gas fuel metering systems are likely in the future, though they are not necessary for natural gas AFVs to be competitive with conventional vehicles operating on gasoline or reformulated gasoline. Natural gas storage technology has made significant improvements over the last few years resulting in lighter storage tanks for compressed natural gas (CNG). Research is ongoing to further improve CNG storage systems, though natural gas vehicles are viable with current technology storage systems. Natural gas can also be stored as a liquid (LNG) that improves its storage density, though the focus of LNG use for vehicles has been for heavy-duty vehicles and not the light-duty vehicles targeted by EPACT Title V. While storage of natural gas as LNG on light-duty vehicles is possible, problems

[20] Engine fuel metering technology includes the fuel system components that prepare and meter the fuel for use in the engine. Fuel storage technology includes the tank where the fuel is stored and associated equipment needed to move the fuel to the fuel metering system on the engine.

such as boil-off[21] have yet to be solved sufficiently for public use or for use in fleets typical of those that would be covered by EPACT programs.

While natural gas vehicle technology is evolving, it is currently at a level that should not deter prospective customers from purchasing natural gas vehicles. Of more importance is fuel availability and cost, and the initial cost of natural gas vehicles relative to conventional fuel vehicles. Also important is the development of a natural gas refueling infrastructure. The equipment to prepare CNG is expensive, and while natural gas refueling facilities are being established, achieving wide-scale coverage will take time and a large amount of investment.

Liquefied Petroleum Gas

Like natural gas, LPG vehicle technology includes both engine fuel metering and fuel storage technologies. LPG fuel storage technology is well-developed and there appears to be little or no demand for improved storage technology, probably since storage pressures are only a nominal 160 pounds per square inch (psi). LPG fuel metering technology has focused on systems that can be added to existing gasoline fuel systems making the vehicle a bi-fuel vehicle. Because of this focus, these LPG fuel systems have not advanced to offer the same level of vehicle performance, driveability, and emissions capabilities that current gasoline or natural gas multipoint fuel injection systems offer. However, the overall performance of current LPG fuel systems should not impede the use of LPG as an alternative fuel. The vast majority of LPG vehicles now on the road are bi-fuel, converted from gasoline vehicles; the very limited numbers of LPG vehicles sold by auto manufacturers to date have all been dedicated. Regardless of the type of fuel system, LPG vehicles have demonstrated the capability to have low emissions with driveability and performance comparable to conventional gasoline vehicles.

LPG vehicle technology is relatively mature and should not deter prospective customers from purchasing LPG vehicles. It is likely that prospective LPG customers will base their purchase decisions primarily on issues such as fuel availability, range, vehicle and fuel prices, vehicle warranties, and resale value rather than LPG vehicle technology.

Methanol

The current technology for using methanol (M85[22]) is largely the same as used for gasoline vehicles. The only significant difference is that some of the fuel system components are made of materials compatible with methanol. Most current methanol vehicles include a sensor that measures the percent

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[21] LNG storage tanks must be highly insulated to keep the LNG at temperatures colder than -258ºF. However, even the best tanks eventually allow enough heat transfer so that natural gas must be vented to prevent pressure build-up that would damage the tank. The natural gas that is vented from LNG tanks is referred to as “boil-off.”

[22] M85 is a mixture of 85 volume percent methanol and 15 volume percent gasoline. The gasoline is required for cold-start capability in current technology vehicles and also provides flame luminosity benefits important to fuel use safety.

methanol in the fuel, allowing compensation for mixtures of methanol and gasoline. This sensor allows current methanol vehicles to use either methanol or gasoline as fuel, in the same tank. Vehicles with this capability are generically referred to as "flexible fuel vehicles" or FFVs. FFVs have the same performance and driveability as conventional vehicles, with emission levels that are the same as or better than their gasoline-only counterparts. Without the constraint of having to be able to operate using gasoline, methanol vehicles could be further optimized to improve efficiency, power, and emissions. However, present FFV technology is completely adequate for consumers to use methanol fuel, with the only drawback being reduced operating range compared to using gasoline. The low incremental cost of FFVs relative to other alternative fuel vehicles is an additional incentive for their use. Methanol vehicle technology is mature and adequate to meet consumer needs as an alternative fuel vehicle.

While methanol can be stored and dispensed using essentially the same components as for gasoline (with materials changes), it is currently not widely distributed in large quantities. However, under certain conditions, service stations can upgrade existing tanks and dispensers for methanol. It is readily transported via truck or railcar to almost anywhere in the U.S. Currently, methanol is available through only a very sparse network of stations, which would have to be expanded significantly to support large numbers of methanol vehicles.

Ethanol

FFVs designed for methanol have been found to work equally well with ethanol with minor changes in materials and reprogramming of the engine fuel system computer. One benefit of ethanol vehicles is that their range is better than methanol vehicles (but still less than when operating on gasoline). Ethanol faces the same fuel storage and dispensing hurdles as methanol, though not to the same extent.

Electricity

Electric vehicles (EVs) represent a radical change in vehicle technology. EVs are commercially available only in very limited numbers. Much intense development is currently ongoing on EV batteries, motors, drivetrains, and vehicle structures. Several auto manufacturers claim that they will have EVs available by 1997, though their price may be high, which will certainly discourage high sales.

One advantage to EVs is that the electric grid is ubiquitous; EVs can be recharged from households if enough time is available for recharging (as much as 8 to 16 hours). However, for EVs to become widely accepted, fast-charge recharging facilities will need to be established at public locations in addition to slow charging facilities at personal residences or the locations where EVs are parked overnight. Fast rechargers are just now being developed and there is uncertainty as to how expensive such units might be in large production quantities and whether certain battery technologies can handle fast charging.

Potentially Available Technologies

There are several AFV technologies that are in the research and development phase of development that may be available in the future. Of these, the most promising are hybrid electric and fuel cell vehicles, while hydrogen vehicles are also noteworthy.

Hybrid Electric Vehicles

Hybrid vehicles are vehicles with batteries and electric motor drives (which makes them very much like electric vehicles) and auxiliary combustion engines to recharge the batteries and/or provide power to the drivetrain. By not being limited to the range available with batteries, hybrids are envisioned to be much more appealing to the public. Hybrids also provide advantages to infrastructure development relative to electric vehicles because there would be less need for fast-charge facilities. They could substantially reduce the requirements for the most costly component of the pure electric vehicle, the battery package. The auxiliary engine could be designed to operate on other alternative fuels, if such fuel(s) are readily available for refueling, rather than gasoline.

Series configuration hybrid electric vehicles use only electrical power for the drive. The battery power source is supplemented with additional electrical energy provided by an engine-driven generator. A typical series design is envisioned to be able to travel for 30 to 60 miles on battery power only, which should be enough to satisfy a large percentage of vehicle trips. After that time, the engine would come on to provide additional driving range.

Parallel configuration hybrid electric vehicles, by contrast, supplement the battery-electric motor system with a combustion engine that is mechanically connected to the drive wheels. In this configuration, the battery provides the high energy needs of the vehicle (such as for acceleration and moderate speed driving conditions), while the engine satisfies the high power demand function (e.g., for extended acceleration and highway driving conditions), and simultaneously recharges the batteries.

While hybrids are not zero emission vehicles, as electric vehicles are considered, their emissions are expected to be well below even the California standards for Ultra Low Emission Vehicles (ULEVs). Consideration is being given to adjusting the ZEV standard to allow hybrid vehicles to qualify.

Fuel Cell Vehicles

Fuel cells are electrochemical devices that convert the chemical energy of a fuel and an oxidant directly into electrical energy (without combustion). Fuel cell vehicles have the potential to be two to three times more efficient than today's vehicles. While fuel cell vehicles operating on hydrogen are zero emission vehicles (ZEVs), emissions from fuel cell vehicles operating on conventional and alternative fuels are expected to be well below the California ULEV standards. They differ from batteries in that they will continue to provide electricity as long as the fuel and oxidant are fed to them. Fuel cell vehicles are essentially electric vehicles with reduced battery storage and addition of a fuel cell. The primary advantage of fuel cell vehicles over electric vehicles is that fuel cell vehicle range is only constrained by the amount of fuel carried onboard. However, fuel cells are not yet developed sufficiently to be used in vehicles. The introduction of electric or hybrid vehicles should nicely pave the way for fuel cell vehicles when they are commercially ready.

The simplest fuel of choice for fuel cells in hydrogen. Because hydrogen fuel infrastructure is not well developed, an on-board fuel processor may be used initially that would reform gasoline, ethanol, methanol, and natural gas for fuel cell use. (Prototype processors have been developed and demonstrated in DOE's fuel cell RD&D program.) Although on-board reformation adds significant complexity to the fuel cell system, it has the advantage of using the existing gasoline infrastructure and developing alternative fuel infrastructures. Therefore, fuel cell vehicles using gasoline, ethanol, methanol, and/or natural gas could contribute to EPACT goals by early in the next century. Fuel cell vehicles using stored hydrogen on-board the vehicle may be too far in the future to contribute to the 2010 EPACT goal.

Hydrogen Vehicles

Hydrogen could be a very good fuel for transportation vehicles because it can be made from non-fossil sources and its only combustion product is water vapor when used in fuel cells or water vapor and modest amounts of oxides of nitrogen when used in internal combustion engines. The major drawback to using hydrogen as a fuel is that it is very difficult to get enough onboard for a practical operating range. Until the energy storage density of hydrogen is improved significantly, it is not likely to be considered a practical transportation fuel.

Another major hurdle facing hydrogen vehicles is large-scale hydrogen production and distribution. It has been demonstrated that hydrogen can be distributed using much the same technology as for natural gas, but establishing hydrogen pipeline distribution networks would take a significant period of time and represents a large capital investment. Perceived safety issues would also have to be addressed.

Availability by Vehicle Type

U.S. automakers are offering a variety of passenger cars for use with compressed natural gas, ethanol (E85), and methanol (M85). Light-duty trucks and vans are offered with CNG fuel systems, both bi-fuel and dedicated. Electric vehicle development continues for all three light-duty vehicle types. No U.S. auto manufacturer currently offers bi-fuel or dedicated propane light-duty vehicles, though Ford has offered a dedicated medium-duty truck with propane power through the 1996 model year.

New AFV Passenger Cars

Until recently, the auto manufacturers focused on M85 flexible fuel vehicles (FFVs) for passenger cars. Ford offered M85 FFV Crown Victorias in 1989, switching to their Taurus model in 1991. Ford has offered M85 Taurus FFVs since 1991. GM offered an M85 Lumina FFV in 1991 and 1993, but not since then. Dodge offered M85 Spirit FFVs in 1992 through 1994, and offered an M85 Intrepid FFV in 1995. Dodge does not currently offer any M85 FFVs.

M85 FFVs paved the way for similar E85 models. Ford has offered an E85 Taurus FFV since 1993 and continues to offer this model today. GM offered an E85 Lumina FFV in 1992 and 1993 and plans to offer one again in 1997. No other auto manufacturer has offered E85 FFVs in the U.S.

Ford began offering a dedicated CNG version of its Crown Victoria in 1996 and will offer it again in 1997. Ford will also offer a bi-fuel CNG version of its Contour in 1997.

Honda, BMW, and Daewoo have demonstration or prototype CNG passenger cars. Honda has announced that it will offer a CNG version of its Civic in 1998. BMW has indicated that it will sell its CNG vehicles first in Germany - an initial quantity of 1,000 is planned. Daewoo has indicated a desire to offer a CNG passenger vehicle (a sports sedan) in the U.S. in 1998.

The development of electric vehicles (EVs) has lagged other AFVs because of high vehicle and battery costs and limited operating range. At present, GM is testing 50 of its two-seater EV1 passenger car EVs in cities around the U.S. GM has indicated that it will lease the EV1 in southern California, Phoenix, and Tucson in 1997 based on a value in the range of $30,000 to $35,000. GM believes that the market for the Impact is for use as a second or third vehicle in up-scale, non-fleet applications. Honda, Toyota, and Nissan are all testing electric versions of their compact and subcompact passenger vehicles with electric power. Honda plans to offer a subcompact passenger car EV late in the 1997 model year. Toyota plans to offer an EV version of its popular RAV4 sport utility vehicle in the 1997 model year for lease to fleets only. In France, Microcar, SEER/Volta, Renault, and Peugeot all offer subcompact EVs for sale, though there is no indication that they plan on selling these EVs in the U.S.

New AFV Light Trucks and Vans

Unlike passenger cars, auto manufacturer interest in AFV light-duty trucks and vans has focused on CNG. Ford has produced some M85 FFV vans for test and demonstration, but it has not indicated that they will be made available as production units in the future. GM, however, has just recently announced that it will offer and build up to 100,000 ethanol FFV light-duty pickups, possibly starting in the 1997 model year.

Ford is planning to offer pickups and vans in dedicated CNG configuration in the 1997 model year. In the interim, Ford has developed a program to certify dealerships and other companies to produce dedicated and bi-fuel natural gas and LPG vehicles starting with pickups. A van and a passenger car are planned to be added to the program in the future. Ford will sell nearly completed vehicles to these qualified companies who would add their own natural gas or LPG fuel systems. The engines in these vehicles have modifications to make them more durable and better suited to gaseous fuel operation. Ford would warrant the basic vehicle and the converter would warrant the fuel system. Ford calls this the qualified vehicle modifier (QVM) program. Ford is targeting Texas as the first application of the QVM program, with the Atlanta area next, followed by California and then the rest of the U.S. At present, the Ford QVM program has been established in Texas.

GM produced 2,600 dedicated CNG pickup trucks since 1992 but has since stopped offering them because of CNG cylinder failures in two vehicles where the CNG cylinders were exposed to battery acid from old batteries carried in the truck beds. GM claims that it will offer CNG pickups in the future in both dedicated and bi-fuel versions, but it has not yet set a firm timetable for doing so.

Chrysler started offering a dedicated CNG version of its full-size van in 1992. In 1994, it added dedicated CNG minivans and Dakota compact pickup trucks. The Chrysler CNG vans are the cleanest AFVs yet certified. The large van has been certified as a LEV (even though it meets ULEV standards), while the minivan has been certified as a ULEV. Chrysler has announced that it is suspending CNG vehicle sales until demand increases beyond current levels, which it characterizes as insufficient (it sold less than 800 in 1996).

Ford, Chrysler, and GM have all developed electric versions of selected vans. The Ford version, called Ecostar, is a small van based on a European Ford vehicle. The Ecostar is currently undergoing test by several utilities, but it is not available for sale. Ford started offering an electric version of the Ranger compact pickup in the 1996 model year through a conversion company that adds the electric vehicle components. In 1998, Ford plans to offer the electric Ranger as a new Ford vehicle without going through a vehicle converter. The GM EV van, called the G-Van, is a full-size van that has also been tested by utilities, but is also not available for sale. The Chrysler EV is based on its minivan and is said to be available for purchase at around $100,000. Chrysler plans to sell 1,000 EVs in 1996, 2,000 in 1997, and 5,000 in 1998 and 1999, presumably at prices lower than $100,000.

Table 5 presents the AFVs offered for sale by the auto manufacturers to date and their plans for offering AFVs in the near future. Table 5 illustrates that the number of AFV models has expanded over the years to include a wider range of manufacturers and fuel types. Those fleets that must comply with EPACT should find choices available among vehicle types, alternative fuels, and manufacturers. (Table 5 does not show the AFVs built before 1989, which were mostly research and development or demonstration vehicles, such as the 600 methanol Escorts built by Ford for the California Energy Commission. The only AFVs previously commercially available from OEMs in the U.S. were the propane passenger cars offered by Ford in 1982-84 of which only a few hundred were sold.) Note that the vehicle offerings are complete only through 1996 - given the uncertainties of market demand, manufacturers typically do not confirm AFV model availability more than one model year in advance.

Converted Vehicles

There are many aftermarket vehicle converters throughout the U.S. that install natural gas and LPG fuel systems on conventional fuel vehicles. Almost any light-duty vehicle can be converted to run on natural gas or LPG, though most favor bi-fuel operation because it is difficult to install sufficient gaseous fuel storage capacity without compromising cargo carrying space or load carrying capacity. New models, however, are becoming increasingly more difficult to convert because of the complexity of fuel and emissions control systems.

There are also a few dozen companies that convert conventional fuel vehicles to electric operation. Vehicles converted to EVs have the economic disadvantage of having to remove the conventional fuel power train and replace it with an EV power train. Vehicles converted to EVs tend to have

Table 5. History of AFV Vehicle Model Availability

Year	CNG Pass. Car	CNG Light Truck	M85 Pass. Car	M85 Light Truck	LPG Truck	E85 Pass. Car	E85 Light Truck	EV Pass. Car	EV Light Truck
1989			Ford Crown Victoria		Ford F600/ F700				
1990					Ford F600/ F700				
1991			Ford Taurus Chev. Lumina		Ford F600/ F700				
1992		Dodge Vans Chev. PU[1] Trucks	Dodge Spirit	Ford Vans	Ford F600/ F700	Chev. Lumina			
1993		Dodge Vans	Ford Taurus Chev. Lumina Dodge Spirit		Ford F600/ F700	Chev. Lumina Ford Taurus			
1994		Dodge FS[2] and Mini Vans	Ford Taurus Dodge Spirit		Ford F600/ F700	Ford Taurus			
1995		Dodge FS and Mini Vans, Dakota PU Ford PUs and Vans[3]	Ford Taurus Dodge Intrepid		Ford F600/ F700	Ford Taurus			
1996	Ford Crown Victoria	Dodge FS and Mini Vans, Dakota PU Ford PUs and Vans[3]	Ford Taurus		Ford F600/ F700; Bifuel Pickup	Ford Taurus			Ford Ranger Chrysler Minivan
1997	Ford Crown Victoria and Bifuel Contour	Ford Pickups and Vans	Ford Taurus	NS[4]	NS	Ford Taurus GM Lumina[5]	GM S-10[5]	GM EV1 Honda EV	Ford Ranger GM S-10 Chrysler Minivan Toyota RAV4
1998	Honda Civic	NS	NS	NS	NS	NS	GM S-10	GM EV1 Honda EV	Ford Ranger GM S-10 Chrysler Minivan Toyota RAV4

[1]Pickup
[2]Full-size
[3] Bi-fuel vehicles
[4] Not yet specified
[5]Planned

limited operating range and compromised load carrying capacity because of the weight of the batteries required.

With regard to potential or long-term availability of AFVs, automobile OEMs have always held that they would produce AFVs in sufficient volumes and models to satisfy demand as long as demand is adequate to justify production runs.

Actual and Potential Availability of Replacement Fuels

National Availability

Currently, total production of all of the major alternative fuels (natural gas, LPG, methanol, ethanol, and electricity) far exceeds the volumes of the fuels utilized as alternative transportation fuels. All of these fuels have other uses both within and without the transportation sector. In some cases, these other uses would limit the availability of the existing production capacity for high volume use in AFVs.

Throughout much of 1994, methanol was in short supply both in the U.S. and in world markets because of rapid growth of demand for it in production of methyl tertiary butyl ether (MTBE), demand for which has grown dramatically due to oxygenated fuel and reformulated gasoline requirements of the Clean Air Act Amendments of 1990, and because of unanticipated temporary loss of some production capacity. Because of this, from the middle of 1994 through early 1995, methanol prices considerably exceeded any level that would make methanol use in AFVs competitive with gasoline. The 1994 prices were also far above costs of production, however, and are not an indication of long-term prices. U.S. and global supplies of natural gas, essentially the only feedstock necessary for production of methanol, are abundant. Methanol production technology is well-developed and plant construction is available from any number of providers. There are no fundamental constraints to methanol production capacity rising to keep pace with any demand that might be generated by alternative fuel use. World class methanol plants, however, are very large and require enormous capital investment. (Historically, world class plants have been in the range of 1,000-2,500 tons-per-day. Today's designs for low cost production facilities are often in the 5,000 ton-per-day range and by 2010 technologies for 10,000 ton per day plants are expected.[23]) Investment and supply are, therefore, considered "lumpy." Finance sources are reluctant to commit to investment on such scale merely in anticipation of uncertain new demand.

Technical Report Fourteen forecast prices for alternative fuels as well as conventional and reformulated gasoline in 2010 under various scenarios relating to tax treatment, regulatory constraints, ethylene demand, and domestic and international supplies of natural gas. Methanol is forecast to be priced competitively with conventional gasoline on an energy equivalent basis, although in some scenarios it is priced slightly higher and fails to provide the margin of price advantage that might be necessary to overcome consumer uncertainty and inconvenience factors. Methanol prices are lower than reformulated gasoline prices on an energy equivalent basis in all but

[23] Each 5,000 ton per day plant would represent supply for approximately 600,000 light-duty vehicles in normal use.

a few scenarios.

Liquefied petroleum gas is also available in sufficient quantities to supply the transportation market for the foreseeable future, at least up to LPG's market share in *Technical Report Fourteen*'s scenarios (10 to 15 percent under most scenarios). Reformulated gasoline and other EPA fuel volatility regulations result in substantial reductions in blending of butanes and other LPG in U.S. gasoline, which could be turned to use in AFVs (though most LPG vehicles in the U.S. are currently designed to run only on propane). LPG prices have historically fluctuated from substantially less to slightly more than gasoline on an energy equivalent basis, which makes LPG quite viable given that the incremental vehicle cost can be as low as $400, if adequate vehicle production volumes are realized. *Technical Report Fourteen* shows LPG costing less than both reformulated and conventional gasoline on an energy equivalent basis in all of the market scenarios for the year 2010.

Availability of domestically sourced methanol and LPG is a different matter. Under *Technical Report Fourteen*'s market simulations, virtually all of the incremental methanol supply to the U.S. for transportation use would be imported. It displaces petroleum imports on a one-for-one energy equivalent basis, meaning that there are no secondary effects that result in additional petroleum imports. About 40 percent of the incremental LPG for AFV use would be imported from outside North America, of which about half would come from petroleum refineries and half from gas processing. However, much of the domestically produced propane to be used in AFVs would be diverted from other uses. This would create additional demand for other fuel sources to fill the vacuums, which would be met largely by petroleum imports, offsetting much of the reduction in transportation demand.[24]

Natural gas abounds in the U.S. far beyond the volumes that would be utilized in the transportation sector under the EPACT goals. The pipeline price of natural gas is below that of gasoline, but the infrastructure to deliver it as CNG to vehicles is more costly than the comparable gasoline infrastructure. In addition, the operating costs to compress natural gas to CNG pressures typically adds about $0.10 to each gallon equivalent of CNG. Typical retail prices of CNG are below those of gasoline, but in many cases these prices do not fully reflect the capital costs of the CNG infrastructure that are being rate-based by utilities or offset by other means. CNG is also taxed at a lower rate at the Federal level (5.6 vs. 18.4 cents per gallon) and many States have reduced tax rates for CNG as well.

Electricity to recharge EVs is in plentiful supply if off-peak power is utilized. Using off-peak power, the per-mile cost of electricity to power EVs is considerably less than the gasoline cost of operating gasoline vehicles. However, when the cost of chargers and replacements of current technology batteries are taken into account, the per-mile operating cost of EVs is now typically higher than the cost of gasoline for gasoline vehicles.

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[24] EPACT defines energy imports as supplies from outside of the North American Free Trade Agreement (NAFTA) countries, as reflected in *Technical Report Fourteen's* estimates of imports. The study does not break out the specific country sources of import supply outside North America. For example, the import share of the Persian Gulf countries is not determined.

Oxygenates (alcohols and ethers blended into conventional fuels) are also classified as replacement fuels under EPACT. Although there were predictions of oxygenate shortages to attend the initiation of the EPA reformulated gasoline program in December 1994-January 1995, no substantial shortages did, in fact, occur.

Regional Availability[25] [26]

Methanol is not expected to be distributed in petroleum pipelines but to be distributed from methanol plants and marine terminals by tanker truck and rail car. Since gasoline is currently distributed by truck within ranges of 100 miles, distribution of methanol should be competitive within 100 mile radiuses of production facilities and marine terminals. Of the 50 largest metropolitan areas in the U.S., 31 have marine terminals and 11 others are within a 100 mile range of a marine terminal. These areas contain most of the population of the U.S. and over 75 percent of vehicle miles traveled in the U.S.

An existing network of natural gas distribution pipelines serves all States in the U.S. except for Alaska, Hawaii, and Vermont. (Vermont is connected to Canadian pipelines.) Local utilities operate low pressure distribution networks around cities, towns, and surrounding regions. All major population centers in the 48 States with transmission lines have natural gas service and some 51.5 million households and firms have such service. While some excess capacity exists in the national grid, the additional loads may require expanding some interstate transmission pipelines for peak loads, including rerouting of flows, addition of compressors, looping of the lines at strategic bottlenecks, and some strategic storage capacity. No new regional transmission lines are expected to be required even for displacement of one million barrels per day equivalent. Adding new areas that previously had no access, however, will require distribution lines and connections to transmission lines, both of which are costly. The most significant constraint will be providing availability to remote stations along interstate highways, most of which are outside distribution networks and will require dedicated pipelines. DOE has estimated the cost for such dedicated pipelines to be $200,000 per mile. For the scenario to displace one million barrels of oil per day, the total cost of dedicated pipelines was estimated to be over $1 billion. Costs of all the other upgrades to gas transmission and distribution networks to serve regular stations was estimated at $604 million.

The existing LPG network includes 860 natural gas plants and 190 refineries that produce LPG, over 70,000 miles of cross-country pipelines (13 major pipelines with capacity of over 20 billion gallons per year), 12,700 railway tank cars, 60 barges and tankers, 26,000 transport and delivery trucks,

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[25] This text is drawn substantially from *Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector*, Technical Report Four: Vehicle and Fuel Distribution Requirements, August 1990, U.S. DOE Office of Policy, Planning and Analysis, DOE/PE 0095P except where otherwise noted.

[26] Infrastructure cost estimates are provided as indications of the potential availability of the alternative fuels. The studies drawn on did not estimate any savings from additional transmission and distribution infrastructure for expanded volumes of petroleum products, which might otherwise be required. DOE is not aware of any existing studies which investigated the potential for such savings.

9,000 storage and distribution terminals, 16 import terminals, and 16 billion gallons of underground storage capacity. The pipeline network provides low cost transportation to terminals in 25 States. Expansion of the system to accommodate a substantial increase in LPG volume for transportation purposes would require significant investments in storage and distribution infrastructure in addition to any expansion of the network to other regions such as California and other Western States.[27] DOE had a contractor perform an assessment of LPG infrastructure for motor vehicle use in 1992.[28] The study estimated the infrastructure necessary for use of 13.7 billion gallons of LPG per year (10.05 billion gallons gasoline equivalent per year or 655,300 barrels per day gasoline equivalent) by light, medium, and heavy duty vehicles. It estimated the costs for additional transportation and storage capacity at $2.43 billion to $2.51 billion. *Technical Report Fourteen* included both scenarios with less LPG use than the 1992 report's 655,300 barrels per day equivalent and scenarios with greater LPG use, but all of the scenarios that resulted in high fuel displacement by replacement fuels included higher LPG use. The scenario that projected exactly 30 percent replacement fuel use in 2010, for example, showed 866,000 barrels per day gasoline equivalent LPG use. Scaling the cost estimates from the 1992 study up proportionately to the increased volume of the 30 percent replacement fuel use scenario would give LPG distribution cost estimates of $3.21 billion to $3.31 billion.

It is not anticipated that any significant expansions to electrical transmission or distribution infrastructure would be required even if substantial numbers of electric vehicles were to be used in the U.S. Several million electric vehicles in daily use (up to 5 percent of total light-duty vehicles) would only be expected to increase electricity needs by less than one percent.[29] Most recharging of vehicles would probably occur at night, during off-peak power usage and generation intervals. [30]

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[27] *Investigation Regarding Federal Policy Actions for Encouraging Use of Liquefied Petroleum Gas as a Motor Vehicle Fuel*, April 1992, prepared by R.F. Webb Corporation for Congressional Research Service.

[28] *Assessment of LPG Infrastructure for Transportation Use*, Final Report, September 1992, prepared by EA Energy Technologies Group for Oak Ridge National Laboratory.

[29] *Electric Vehicle Policy Perspectives and Pathways to the Year 2010*, April 1992, prepared by EA Engineering, Science and Technology for Congressional Research Service, p. 4.

[30] Experience with GM's EV-1 program indicates that, currently, EV motorists are strongly inclined to top off batteries whenever they return home, at least during their early experience with EVs. If electric rate differentials are substantial enough, however, electric motorists should adjust over time to their actual needed recharging while taking advantage of the lower night rates to the extent possible.

Availability of Refueling Sites

The potential availability of alternative fuel refueling infrastructure is dependent on numerous technical and economic variables. All the alternative fuels being considered in this report can be distributed and retailed nationally without any constraints due to the need for development of new technology. However, the cost of providing the refueling infrastructure varies widely among the alternative fuels. For instance, M85 infrastructure costs are relatively small since much of the existing conventional liquid fuel infrastructure can be used. On the other hand, the infrastructure cost for CNG is high because of the high cost of compression equipment. For electricity, costs are high because of the diffusion of sites, while the basic concept of "refueling" infrastructure is indeterminate and not comparable to that for combustion fuels since the normal recharging unit is part of the vehicle.

But infrastructure cost alone will not determine which alternative fuels will become available at retail service stations. Prerequisite to private investment is a high probability of adequate return to justify the risk. Alternative fuel infrastructure development is likely to follow preferences for alternative fuel vehicles (as expressed in the market) and the cost of the fuel for those vehicles. While the cost of alternative fuel infrastructure to the consumer can be accounted for in the retail price of the fuel, vehicle performance and convenience factors such as the time for refueling and operating range will be major factors determining the alternative fuel or fuels most preferred. It is possible that one or more alternative fuels may become available on a national basis, and that certain regions of the country may have different concentrations of distribution and retailing infrastructure for one (or more) alternative fuel(s) relative to other regions.

As above for regional availability, refueling infrastructure cost estimates are shown below as factors of the potential availability of refueling sites. All of the previously cited studies assumed that the alternative fuel would displace one-third of the gasoline dispensed at existing stations, reducing the stations' gasoline capacity proportionately. In many of the key urban areas, limited queuing space would likely dictate such a substitution, while, in other cases, the alternative fuel capability could be incremental to the existing facility or could be at a new (possibly separate) facility altogether. In any event, overall fuel demand is not expected to grow between now and 2010 at a rate that would approach the (alternative fuel) refueling capacity which would be added if the EPACT 30 percent goal were to be met, so that some existing capacity would be made redundant. The impact of substantial alternative fuel capacity on existing station fuel capacity has not yet been adequately assessed, making it problematic to adequately incrementalize the infrastructure costs by netting out other cost savings.

Methanol/Ethanol Stations

DOE's Alternative Fuels Data Center identified 86 methanol refueling sites and 41 ethanol refueling sites in operation in the U.S. in 1996 (see Figure 15). Fifty-eight of the methanol stations are in the State of California and most are retail service stations available to the general public while only a very few are exclusively central refueling sites for fleet vehicles. The New York State Thruway Authority operates nine methanol refueling sites across New York along the New York Thruway for its 45 methanol vehicles. Washington, D.C., New York City, Colorado, Georgia, Illinois, Maryland,

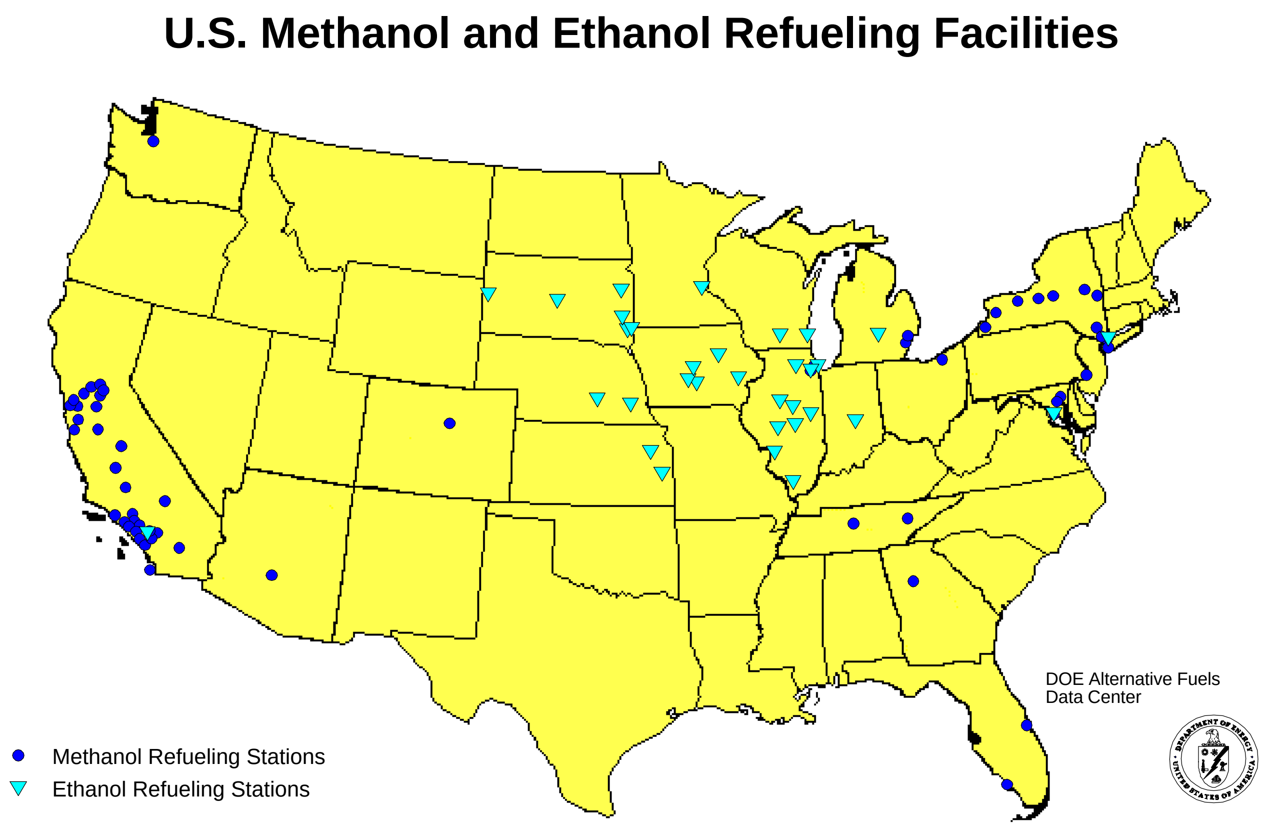

Figure 15. Methanol and Ethanol Refueling Facilities in 1996

Michigan, Pennsylvania, and Washington State each have one or more commercial methanol refueling stations. The ethanol sites are virtually all in Midwestern States.

In a 1990 Technical Report, DOE's Office of Policy, Planning and Analysis estimated the number of refueling stations necessary to deliver 2.4 million barrels per day of M85 to motorists using a formula based on assumed size of service stations and an average volume of each fuel dispensed per station, assuming that M85 would be dispensed along with two grades of gasoline in roughly equal proportions.[31] (The calculations could also be applied to E85 or to some combination of M85 and E85 stations.) This analysis resulted in an estimate of 91,000 required refueling stations or roughly half of all stations in the U.S. to dispense M85. This volume of M85 is considerably greater than that projected by any of the scenarios of *Technical Report Fourteen* and other studies; however, and the percentage of stations is also greater than other estimates of what would be required. Under *Technical Report Fourteen*'s 30 percent replacement fuel use scenario with equal tax treatment, 774,000 gasoline equivalent barrels per day of M85 are projected to be used, which represents 1.35 million barrels of M85 per day. Using the same volume per station as in the 1990 DOE study, approximately 51,500 stations would be required. This is also more consistent with the 1992 Congressional Research Service study, which found that approximately 25 percent of stations would

[31] *Assessment of Costs and Benefits*, Technical Report Four, *DOE- OPPA*, *supra*, p. 23.

have to carry methanol in order to win customer acceptance, citing marketing studies by Ford.[32] The 51,500 stations would be more than 25 percent of all stations in the U.S. and would be considerably more than 25 percent of the stations in the regions of methanol AFV penetration.

The cost of making each station compatible with methanol was estimated by the DOE 1990 Technical Report as $45,000 if an existing system was removed at each station installing the M85 capability. If methanol compatible tanks were instead installed during the course of normal renovation or replacement or in response to regulatory requirements, the cost could be much lower, possibly as low as $5,000. (Many of the tanks being installed as replacements today are already methanol compatible.) The total station cost if all of the 51,500 stations incurred the full $45,000 cost would be approximately $2.3 billion dollars. If 25 percent of these stations installed methanol capacity when they would otherwise be replacing tanks, the total cost would be approximately $1.8 billion.

CNG Stations

In 1996, there were just over 1,200 CNG stations established across the U.S. (see Figure 16). Of these, just over half offer open access for CNG sale to the public or sell CNG to the public by arrangement.[33]

There are two basic types of CNG refueling stations: time-fill and fast-fill. The time-fill system uses a lower powered compressor and little or no storage capacity and would typically be used for overnight refueling at fleet facilities (or private homes). The fast-fill system includes storage of a substantial volume of natural gas already compressed as well as a more powerful compressor and can refuel vehicles in approximately eight minutes.

The 1990 Technical Report (*supra* fn. 9) made cost projections based on typical station capacities and designs for both regular public stations and truck stops. The regular public refueling stations were designed to handle an average of 300 vehicles per day with four nozzles, fueling each within eight minutes, with a peak capacity of 30 per hour in two 2-hour continuous peak demand periods. The average cost for installing CNG capacity at these stations was estimated at $320,000, which does not include any distribution cost for constructing pipelines to stations not in areas otherwise served by natural gas. The per vehicle cost for this station installation based on the capacity was estimated at $177 for the public stations.

The Technical Report estimated requirements for dispensing CNG to displace one million barrels per day (bpd) of gasoline, including both the regular public stations and truck stops for refueling medium- and heavy-duty vehicles. The regular public stations accounted for approximately 675,000 bpd equivalent of this, dispensing 42.3 bpd at each of 16,000 stations. None of the scenarios in

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[32] *Federal Policy Actions for Encouraging Methanol Use*, April 24, 1992, prepared by Acurex Environmental Corporation for Congressional Research Service.

[33] *Alternatives to Traditional Transportation Fuels, 1994*, op. cit., p. 35, based on data from DOE's Alternative Fuel Data Center.

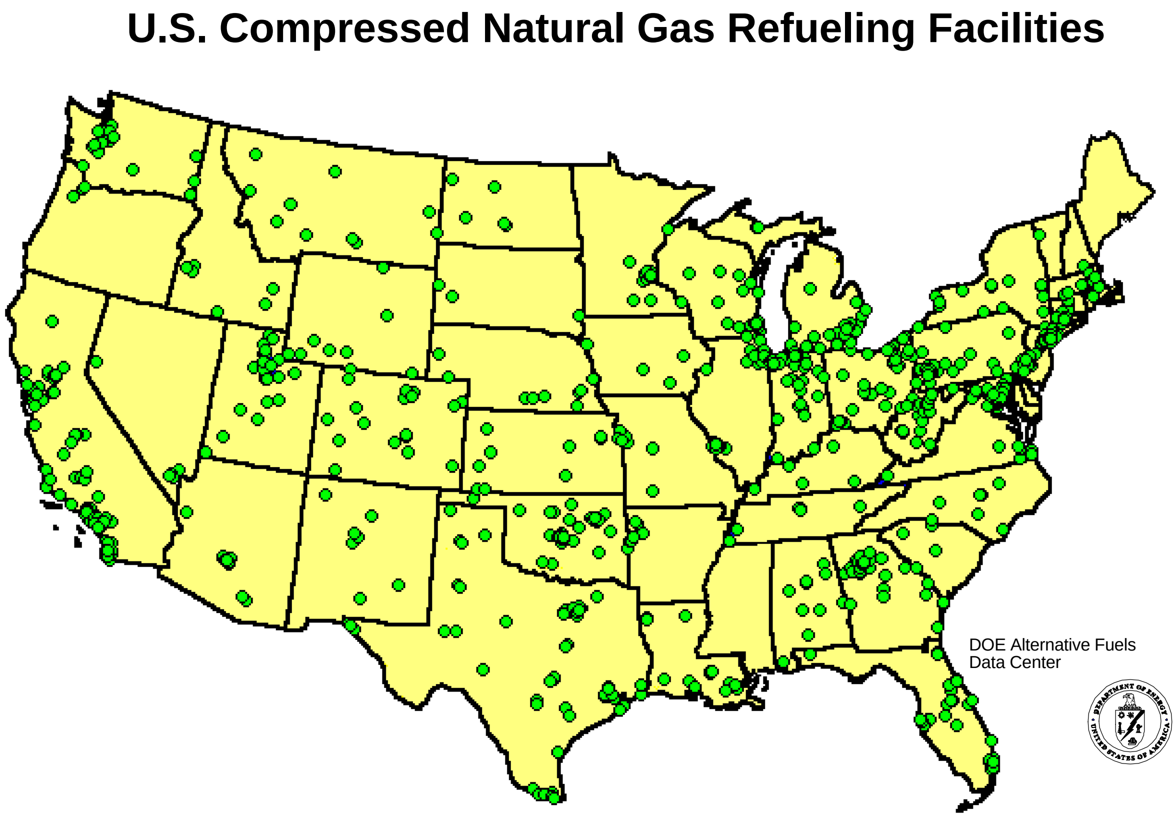

Figure 16. CNG Refueling Facilities in 1996

Technical Report Fourteen projected volumes of CNG use this large (estimates ranged from 40,000 bpd to 546,000 bpd gasoline equivalent). Assuming 400,000 bpd gasoline equivalent of CNG were used, which is far more than projected in most of *Technical Report Fourteen* scenarios, the analysis of the Technical Report would indicate that around 9,450 stations would be required. At a cost of $320,000 per station, the total station conversion costs would be $3.02 billion.

LPG Stations

DOE's Alternative Fuel Data Center estimated there are about 3,300 LPG refueling stations in the U.S. in 1996 (see Figure 17). LPG can be dispensed and sold using systems very similar in appearance to those used for gasoline and it is assumed that LPG would be sold in this manner in the future when volumes are large enough to support selling LPG at gasoline retail facilities or in facilities dedicated to selling LPG for vehicle use.

The 1992 DOE contractor's report on LPG infrastructure[34] also evaluated the necessary availability of refueling sites. It assumed that the typical high-volume stations dispensing 150,000 gallons per month of gasoline would install LPG capacity and that these would each sell LPG equal to one-third of their total volume or 50,000 gallons per month gasoline equivalent (69,000 gallons of LPG).

[34] *Assessment of LPG Infrastructure for Transportation Use, supra.*

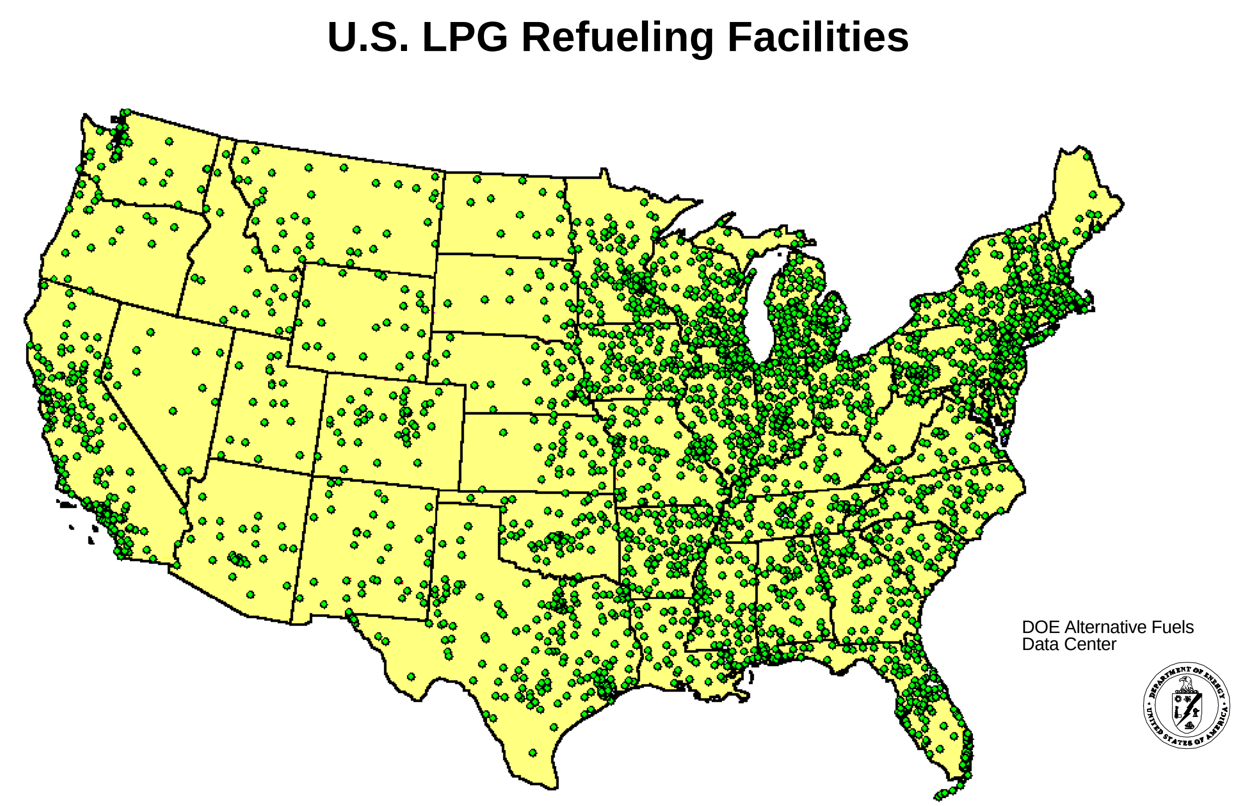

Figure 17. LPG Refueling Facilities in 1996

Thus, each would displace one-third of their gasoline throughput or 50,000 gallons per month of gasoline. The study derived typical station configurations and estimated costs for installing the LPG capability on a per station and national basis. The total fuel displacement estimated by the 1992 study was 13.7 billion gallons per year or 655,300 barrels per day gasoline equivalent, including heavy-duty vehicles refueling at truck stops and school buses being refueled at private facilities, each of which had a different estimated cost structure.

Using this displacement target, being met completely by light-duty motor vehicles at ordinary commercial service stations and assuming the per station 50,000 gallon gasoline displacement per month (39 barrels per day), 22,205 such stations would be required to dispense LPG to reach the volume projected by *Technical Report Fourteen*'s 30 percent replacement fuel use scenario (866,000 barrels per day gasoline equivalent). This compares with 12,537 such stations estimated by the 1992 study itself, along with the truck stops and school bus refueling sites.

The incremental cost of installing LPG infrastructure at the existing stations estimated by the 1992 study was $192,800 per station. Applying this cost estimate toward the 22,205 stations estimated to be necessary to reach *Technical Report Fourteen* fuel displacement target (in the 30 percent total replacement fuel scenario) gives a total estimated cost of refueling infrastructure of $4.3 billion.

Electric Vehicle Recharging Stations

Electric vehicle recharging is expected to be performed primarily overnight at the home of the vehicle owner or at fleet facilities for fleet electric vehicles. However, there is also strong interest in providing public recharging facilities at commuter parking lots, shopping malls, and other public facilities where EVs would be partially recharged during the day. Electric utilities are likely to provide substantially lower rates for nighttime recharging as electric demand and capacity usage is lowest then. Some additional charging stations might also be provided to extend the range and flexibility of use of electric vehicles, including metered outlets in parking lots and work places. Faster recharging facilities might also be used but are not likely to predominate. Most normal driving use would only partially discharge electric vehicles batteries over the course of a day so that overnight recharging would be an option for many motorists. Commercial recharge facilities would probably be priced higher to cover the higher daytime rates, even higher costs for fast-charge equipment and additional charges for facility use. Electric vehicles are not, in the near future, likely to be an option for motorists without individual parking facilities of some sort, for those using vehicles heavily at night, or for extended highway driving.

Installation costs for a recharging unit at a typical home are estimated in DOE's Technical Report at \$400-\$600.[35] Commercial fleet station costs would be the same except that fleets would be more likely to install a 50 amp outlet for somewhat faster charging at an additional \$30 to \$90. Private households would also have the option of the 50 amp charging for additional cost. *Technical Report Fourteen* projects a total population of approximately 2.5 million electric vehicles in 2010 (all of which would be required for environmental programs). Assuming that greater numbers of charging stations than vehicles were required might support an estimate of 4 million charging stations. Using a median of the cost estimates of \$500, the total cost of the charging infrastructure would be approximately \$2 billion. This number is not truly comparable to the cost estimates for other alternative fuels in that the actual recharging unit will generally be part of the vehicle rather than the station, except for fast-charge stations, and is reflected in the extremely high expected cost of electric vehicles in general. Moreover, the actual fuel use occurs in the generation of the electricity at power plants.

[35] This is the estimated cost of a 240 volt branch circuit plus a safety device and load management device. The actual battery charger would be installed on the vehicle and forms part of the vehicle cost.

VII. KEY ISSUES AND PERSPECTIVES

As can be seen from the above analysis, a great deal of uncertainty attends many aspects of a possible transition to an automotive transportation system in which alternative/replacement fuels play significant roles. In addition, a number of elements of information and analysis critical to evaluation of replacement fuel goals and design of policies remain to be substantively addressed. In some cases, meaningful answers may be obtained only through future experience with AFV implementation and policies. DOE is developing information and analysis and will be able to better address some of these questions in the second Technical and Policy Analysis. Among the many unanswered questions are the following:

- What preferences among the AFV fuel and vehicle types will prevail among consumers?

- When and to what extent could economies of scale be reached during a transition to substantial alternative fuel use? What would the effect of scale economies be on a transition?

- What market interactions would occur at various stages of a transition, with particular regard to the role of expectations and uncertainties?

- What levels of commitment and staying power would the critical stakeholder groups demonstrate?

- What would be the actual costs of the possible transition pathways? Will the replacement and alternative fuels be available at reasonable costs as necessary for a transition? What portion of the alternative fuel infrastructure cost is truly incremental and what portion represents a necessary expansion of fuel capacity that would have to be made irrespective of whether alternative fuel or conventional fuel were used?

- What impacts would widespread use of alternative fuels for transportation have on markets for those fuels for other uses?

- What impacts would a transition to widespread use of alternative fuels according to a timetable like the EPACT suggested one have on U.S. petroleum production and refining?

- What roles could replacement fuels and AFVs play in contingency planning and responses to potential oil shocks? To what extent could capability for fuel switching be a substitute goal for actual alternative fuel use?

- What will be the relationship between energy efficiency and replacement fuel use? How should superior efficiency AFVs be counted toward the EPACT fuel displacement goals?

- In a future U.S. market with substantial alternative fuel use, how much of the alternative fuels would be imported and how much produced domestically? How much shifting of energy imports from the transportation sector to other sectors would there be? How much value to U.S. energy security would there be from a multi-fuel transportation sector if the non-petroleum fuels used did not result in a substantial net reduction in energy imports? What policies might be adopted to favor domestic sourcing?

In the paragraphs that follow, some additional areas calling for further investigation are introduced along with some perspectives.

Fleet to Household AFV Spillover

No clear basis exists for estimating the extent to which fleet use of AFVs will generate multiplier effects through acquisition of AFVs by private households. It is possible to identify a number of ways in which widespread fleet AFV usage could facilitate household AFV use and reduce impediments to it. Large numbers of fleets using AFVs could provide sufficient critical mass for development of alternative fuel distribution and refueling infrastructure, including commercial stations available to the public. They could provide impetus for further technological development and for original equipment manufacturers to offer a wider range of AFV models with more options and on more attractive terms than currently available. Widespread fleet AFV use could also demonstrate to the public the viability of using alternative fuels and the advantages of such use including energy security, environmental, and, in some cases, economic advantages. But these effects may not be sufficient to spur substantial AFV acquisition by the public.

Experience of other countries (Netherlands, New Zealand, and Brazil) suggests that spillover will, at the initial stages of a transition, occur only if a significant and discernible economic incentive exists for households to purchase AFVs and to use alternative fuels. Currently, U.S. tax policy is unfavorable to all alternative fuels other than ethanol, natural gas, and electricity. Ethanol costs make its use in AFVs considerably more expensive than gasoline even with its favorable tax treatment. Natural gas, which has to date been the fuel of choice for most fleets using alternative fuels, is less expensive than gasoline at current prices but the substantial extra cost of natural gas vehicles and refueling infrastructure make its use uneconomic except for motorists driving high annual mileage. Currently available OEM natural gas light-duty vehicles are dedicated rather than dual-fuel, which will inhibit their acquisition by households until refueling infrastructure is quite widespread and concerns about the permanence of its availability have been erased. Electric vehicles' costs and range limitations probably limit their role for the foreseeable future.

Recent market research suggests that behavior of U.S. households in regard to AFVs will not be qualitatively different from that of the other countries which have promoted transitions.[36] Surveys of U.S. vehicle consumers show that most place high value on range and on fuel availability but also on emissions reduction. Targeting levels for these three factors in the survey at levels likely to prevail during a transition, the survey indicated that the average consumer would require substantial price discounts in order to purchase an AFV. With fewer than 50 percent of stations dispensing the alternative fuel, less than 250 miles in driving range, or less than a 65 percent emissions reduction, the discount would have to be over $2000 per vehicle. In order to be purchased at prices equivalent to conventional vehicles, the AFVs must have ranges of at least 300 miles, reduce emissions by 90

[36] See Mintz, Marianne, and Singh, Margaret K., op cit., Appendix B, citing Golob, T., et al., Institute of Transportation Studies, University of California, presented at the Electric and Alternative-Fuel Vehicle Demand Forecasting Project Workshop, Laguna Beach, CA, (Nov. 4-5, 1993).

percent, and fuel must be available at 80 percent of all service stations in the driving area, according to respondents. While such survey data often diverge from actual purchase decisions, particularly after consumers have had time to familiarize themselves with and analyze the decision factors, the survey may be the best available indication of consumer preferences. It seems clear, at least in regard to dedicated vehicles, that consumers will have to be confident not only that AFVs will become a permanent feature of the automotive market, but also that a particular vehicle/fuel combination will be available five, ten, or even fifteen years in the future.

DOE will be evaluating potential spillovers into the household sector under various cost scenarios using its transition model and expects to have results available in early 1996.

Fuel Neutrality of Policy Options

The CRS studies summarized in Section IV showed that different alternative fuels would have different optimal policy mixes, costs, and energy security and environmental benefits. Recognizing that the different fuels face different mixes of relative obstacles and have different optimal sets of policies for overcoming the obstacles, it might be inferred that policy approaches that are nominally fuel neutral, actually favor certain fuels more than others.[37] For example, generous AFV purchase incentives such as the maximum $2,500 tax deduction provided by EPACT benefit natural gas vehicles more than alcohol vehicles because the incremental cost of the alcohol vehicle is substantially less than the allowable deduction. In addition, the incentive is greater for dedicated than dual-fuel vehicles and no dedicated alcohol vehicles are currently being offered for sale. Similar differential effects could apply to incentives for infrastructure installation and for investments in production facilities. Moreover, the CRS studies show that equal outcomes have unequal costs and vice-versa. This is not to suggest, however, that it would be impossible to devise incentive policies that are truly neutral between the different alternative fuels. Excise tax incentives on an energy equivalent basis would seem to be neutral by reasonable measures. Whether such policies would be sufficient to meet EPACT goals or whether more directed policies will be called for is a question that may have to be addressed at some point.

AFV Technology and EPACT Timetables

The current level of alcohol and gaseous fuel AFV technology development should be sufficient to allow auto manufacturers to build AFVs that are acceptable to consumers in large enough quantities to meet EPACT requirements. Consumer perception, however, may diverge substantially from technological reality. Electric vehicles are not at the same stage of development. They probably will not reach such a level within a time frame that would allow them to contribute significant numbers of AFVs under EPACT. The auto manufacturers and other interested parties are continuing

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[37] On the other hand, certain measures which might have indirect effects favoring some fuels over others would still have to be considered fuel neutral by virtue of their nature as measures of general application. For example, fuel economy improvements that are not fuel-specific (weight or friction reductions, etc.), whether or not policy induced, could be seen as favoring those fuels which are more expensive on a per-mile basis than gasoline and penalizing fuels that are less expensive than gasoline.

development of these AFVs and improvements should be forthcoming. Large-scale implementation of current technology AFVs should not diminish the prospects for more advanced technology AFVs such as fuel cell vehicles if they satisfy fleet operators and consumers. A market failure of AFVs at the early stages of EPACT would make implementation of more advanced AFVs more difficult. However, a strategy of waiting for more advanced AFVs before implementing EPACT would likely result in little or no AFV penetration in the interim. Assuming a large-scale switch to alternative fuel use between now and 2010, it remains uncertain which technologies will be available for such a transition.

Macroeconomic Impacts[38]

It is now generally accepted that oil shocks precipitate recessions. In seven of the ten years since 1910 when real oil prices increased more than 25 percent, recessions occurred in the following year (Figure 1, page 13). In addition to the direct impacts of the price increases, abrupt changes in vehicle technologies have followed the price shocks. These abrupt technology changes have adverse impacts on vehicle sales and aggregate economic activity for several years. While *Technical Report Fourteen* estimates the equilibrium benefits of 30 to 40 percent alternative fuel use at approximately $10 billion dollars annually, it does not include the economic benefits of avoiding an oil shock or recession, which could be much greater. These can be calculated in two ways. The first treats the diminished economic activity as temporary, with the economy subsequently making up for lost time and reaching the same level of economic activity as it would have reached without the recession within about a three year interval. In the second scenario, the economy simply resumes the rate of growth it would have experienced without the recession but never makes up for the losses. Assuming a 2.5 percent full employment growth rate and a recession starting with a 1.5 percent shortfall from this natural growth rate in its first year (i.e. a 1 percent growth rate), a 3 percent shortfall in year two (absolute decline of 0.5 percent) and a 1.5 percent shortfall in year three (1 percent growth), the magnitude of the economic loss can be envisioned.[39] Under the temporary loss scenario, the loss of economic activity would be $600 billion dollars over three years. Under the permanent loss scenario, the losses would be about $3 trillion over 15 years, using a discount rate of 10 percent.

A switch to substantial replacement fuel use would, presumably, not involve a discrete switch from one technology to another but would involve a gradual progression to various market niches. The faster the transition and the more severe the measures to bring it about, the more likely will be the adverse impact on the economy through the automotive sector. The slower the transition, the more

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[38] Discussion drawn largely from *Macroeconomic Implications of Transition to AFV Use*, Danilo Santini, Argonne National Laboratory, background paper prepared at the request of DOE.

[39] These GNP loss assumptions appear to be consistent with estimates using 14 major economic models to predict the effects of a 50 percent oil price shock sustained indefinitely. The average estimates for economic losses were 1.8 percent in the first year, 2.7 percent second year, 2.5 percent third year and 2.3 percent fourth year. Energy Modeling Forum, "International Oil Supplies and Demands," EMF Report 11, vol. II, April 1992, Stanford University. See also Greene, David L., and Leiby, Paul N., "The Social Costs to the U.S. of Monopolization of the World Oil Market, 1972-1991," Oak Ridge National Laboratory, March 1993, ORNL-6744, pp. 35-40.

likely will be a future oil shock induced recession.

Impact of Oil Price Cycle on Transition to Alternative Fuels

While EPACT provides a number of specific mechanisms for promoting AFV use by fleets, reaching substantial levels of replacement fuel use will depend on penetration into the motoring public — the household vehicle sector. The key to this penetration will be some economic incentive to households to make the shift. Such an incentive might occur in any one of a number of ways. It would not necessarily have to represent a Government incentive program. Increasing petroleum prices could well imply shifts in relative prices between gasoline and a number of alternative fuels, resulting in natural fuel switching if the preconditions for such switching are in place.

Such potential fuel switching could help mitigate the effects of the oil price spike and reduce the magnitude of the spike. Indeed, a major goal of EPACT is to help prevent future oil crises or mitigate their effects. Nonetheless, future movements in oil prices, including erratic movements, can be expected. To the extent that current price relationships inhibit the actual immediate use of alternative fuels, policies to establish preconditions for fuel switching in future situations could partially substitute for immediate alternative fuel use and might play similar preventive roles.

Investigation of historical crude oil prices, indexed for inflation, shows a somewhat consistent pattern from early in this century to the present: a "sawtooth" with periodic sharp abrupt rises followed by more gradual and prolonged downward trends lasting two to two-and-a-half decades (sometimes including erratic movements within these downward trend periods). This pattern is presented in Figure 1 (page 13). As can be seen from Figure 1, crude prices have been on the downward part of the cycle since the early 1980s, suggesting that, if history is a guide, another price spike might be expected in the next seven to fifteen years.[40] Current empirical evidence could be seen as consistent with this. Economic growth in Asia has been accompanied by growth of energy use, which could be outstripping growth of world oil production, and could lead to tight market conditions in the seven to fifteen year time frame. Various observers have also pointed to underlying conditions that could give rise to political instability in major oil producing countries in the same time period.

Historical movements in prices for alternative fuels and feedstocks relative to petroleum are shown in Figure 18 and Figure 19. Crude oil, natural gas, methanol, ethanol, and LPG are included in Figure 18 (wholesale price data). Electricity is included in Figure 19 along with gasoline, natural gas, and fuel oil no. 2 (consumer price data). The most clear divergences in relative price

[40] The oil price jolt of late 1989 following the Iraqi invasion of Kuwait does not represent a major upward price movement according to this pattern but only part of an erratic downward trend since 1982 or so. The last major upward jump encompassed the 1973-74 oil crisis and the 1979-82 oil shock.

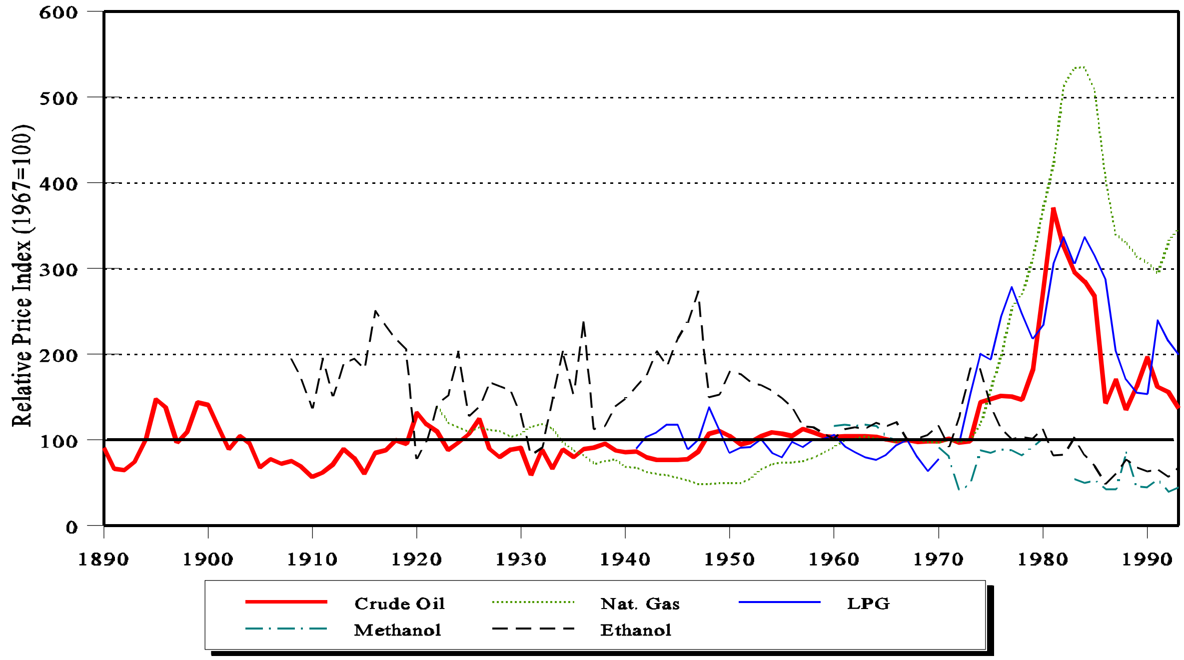

Figure 18. Relative Wholesale Prices for Fuels/Raw Materials
Compiled by Argonne National Laboratory

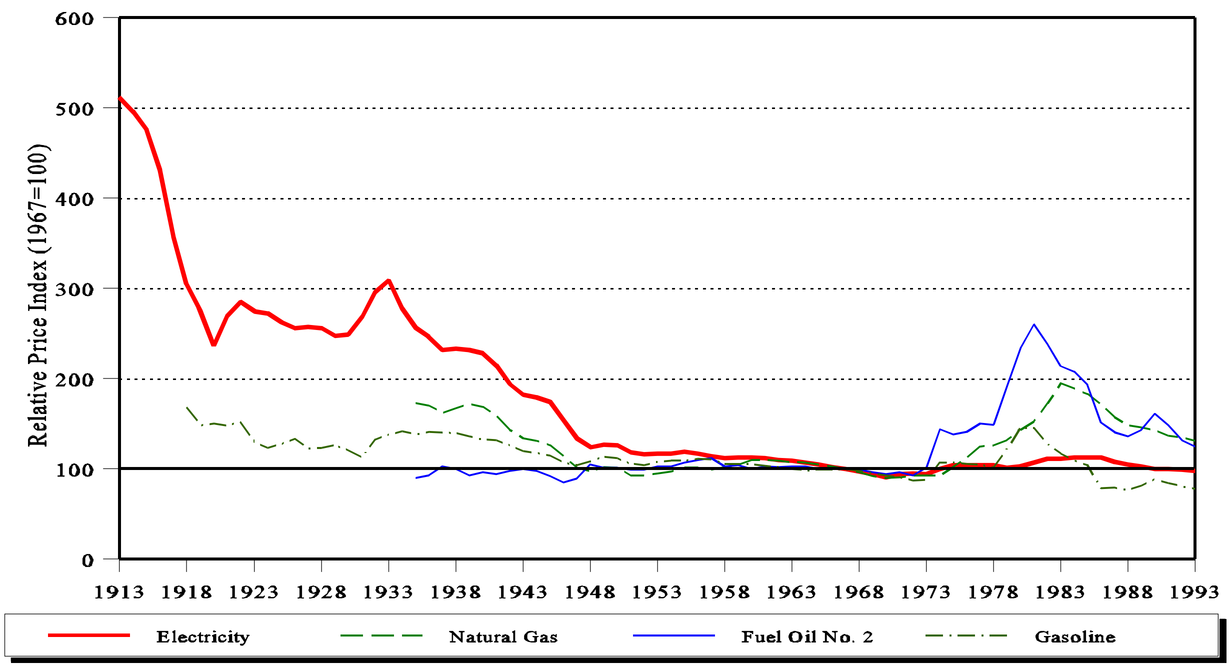

Figure 19. Relative Consumer Energy Prices, Fuel and Electricity Prices
Compiled by Argonne National Laboratory

movements from gasoline and crude oil are for methanol, ethanol, and electricity. As can be seen, although electricity and ethanol prices are influenced by the jumps in oil prices, the resulting price increases for these forms of energy are not nearly of the same degree as for oil. Methanol prices have historically moved independently from petroleum prices. Natural gas prices seem to have moved largely independently of oil prices during the post-war period through 1960 but have moved in close lock-step with them since that time. This is due to the substitutability of natural gas and petroleum fuels in many non-transportation applications and to the deregulation of natural gas prices in the mid- to late-1970s.[41]

Moreover, in the event of an actual oil crisis with real shortages and gas lines, consumer convenience factors could shift decisively in favor of alternative fuels. Rather than requiring a price premium for switching to alternative fuels, motorists might well be willing to pay a premium for the option of refueling with a fuel less susceptible to shortages. This effect might transcend the period of actual oil shortage for a period of some years thereafter while the sense of insecurity persists.

There is probably no way of reliably assessing the impact of a future price hike on the effectiveness of EPACT programs. On the other hand, it does appear possible to infer from prior experience that such a hike is unlikely to result in major fuel switching in the transportation sector in the absence of certain preconditions relating to the availability of AFVs and alternative fuel infrastructure, which EPACT Title V begins to address. It should be noted that most of the fuel switching in Brazil and the Netherlands, the two countries where AFV programs were most effective, occurred after an oil shock that had been preceded by more modest programs promoting the alternative fuel to which the country partly switched after the shock.

Impact of EPACT on Potential Oil Crises[42]

Intuitively, it would be more desirable to have a slow rise in oil prices supporting efficiency enhancing or fuel switching efforts already underway rather than to have a sharp rise in oil prices cause belated and hurried implementation of technologies that could technically have been introduced before the shock. The historical record, however, does not give any comfort that the U.S. will have the option of such gradual and presumably efficient substitution. EPACT is a unique piece of Federal legislation in that it provides incentives to restrain rising oil demand before it leads to run-up in oil prices of the nature of those highlighted in Figure 1 (page 10). Provisions of the Clean Air Act Amendments, including gasoline reformulation, also have the effect of displacing crude oil from gasoline, potentially preventing some of the pressure for a rise in oil prices. Whether these effects will be powerful enough to prevent a future world oil price run-up is far from clear.

EPACT programs could also reduce the likelihood or magnitude of a future oil shock in another way. One potential benefit of developing a fuel switching capability is the potential to alter the behavior

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[41] Future prices of any fuel(s) that come into widespread use in light-duty vehicles could be expected to move more closely with gasoline/crude oil but this would occur mainly after the fuel had gained a competitive advantage. Ample divergences in price movements could remain.

[42] Ibid.

of primary fuel suppliers. If viable competing fuels are available, the likelihood of restriction of oil prices will be diminished. Since OPEC members know the long-term consequences of a spike in oil prices are subsequently declining and depressed prices, they should give strategic consideration to how high prices can go and how long they can be sustained before causing the introduction of substitutes and conservation. In fact, some OPEC members have been known to base their positions on pricing and production on just such considerations. EPACT has the potential to shorten the time lag between an oil price shock and the oil use reductions following it and to magnify such reductions in the key transportation sector, precisely the sector where they have been least substantial up to now. The better the perceived potential of the U.S. to introduce alternatives in the event of an oil price increase, the less the likelihood and/or magnitude of the price increase likely to be sought by OPEC members in the event of a supply disruption.

This deterrence effect, of course, assumes that OPEC member governments are rational actors in control of crude oil pricing and production within their respective countries. The deterrence might be less effective in the event of some major instability in one or more of the major oil producing countries.

It is also possible that a well designed EPACT initiated process of fuel switching could avoid or reduce the magnitude of problems involved with the relatively abrupt technological transitions in transportation that historically follow oil shocks and that have also characterized historical fuel switches. Alternative fuel technologies are considered more developed at the present than other transportation and energy related technologies have been, largely due to DOE RD&D programs. Alternative fuel transportation systems could be even riper for widespread deployment and the American public could be more amenable to fuel switching as results of EPACT fleet demonstrations, infrastructure, and AFV availability.

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