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Effectiveness and Efficiency of Policies to Promote Alternative Fuel Vehicles[1]

by

Paul Leiby*[2]

and

Jonathan Rubin[3]

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[2]Oak Ridge National Laboratory, 4500-N Bethel Valley Road, Oak Ridge, TN 37831-6205. Phone (865) 574-7720, leibypn@ornl.gov.

[3]University of Maine, Margaret Chase Smith Center for Public Policy, and Department of Resource Economics and Policy, 5715 Coburn Hall, Orono, ME 04469-5715. Phone (207) 581-1528, jonathan.rubin@umit.maine.edu.

Effectiveness and Efficiency of Policies to Promote Alternative Fuel Vehicles

Abstract

Alternative motor fuels have been advocated in the name of energy security, regional air quality, greenhouse gas emission reduction, and even economic savings. The Energy Policy Act of 1992 sets a goal of replacing 30 percent of conventional fuel use with alternative fuels by the year 2010. Earlier analysis using a single-period equilibrium model demonstrated the feasibility of EPACT's replacement goals. This earlier analysis, however, assumed mature markets: large-scale vehicle production and the widespread availability of alternative fuels at retail stations. These conditions are not currently attained. To better assess what may be necessary to achieve mature, large scale, alternative fuel and vehicle markets, we use the Transitional Alternative Fuels and Vehicles (TAFV) Model. We simulate market outcomes for the use and cost of alternative fuels and vehicles over the time period of 1996 to 2010, considering possible transitional barriers related to infrastructural needs and production scale. Prices and choices for fuels and vehicles are endogenous. The model accounts for dynamic linkages between investments and vehicle and fuel production capacity, tracks vehicle stock evolution, and represents the effects of increasing scale and expanding retail fuel availability on the effective costs to consumers. Various policy alternatives are evaluated, including fleet vehicle purchase mandates, fuel subsidies, and tax incentives for low greenhouse gas emitting fuels.

1.0 INTRODUCTION

Since the energy crisis of 1973 the United States has explicitly sought to moderate the consumption and importation of oil. Initially the concerns were energy conservation and energy security. While these concerns continue today, additional impetus comes from the environmental concerns of urban air pollutants and greenhouse gases.

The transportation sector now represents about 27% of total domestic energy use (Davis, Table 2.4). Of the total amount of transportation energy used in the United States the demand is overwhelmingly met by petroleum, supplying 96.8% of total transportation energy in 1996. As Greene (1996) points out, the almost complete dependence of the transportation sector on petroleum persists today despite the market upheavals of the 1970's and early 1980's. In 1973 at the height of the Arab embargo, the U.S. transportation sector was 95.6% dependant on oil, about 1% less than today.

There are three ways to reduce the amount of petroleum use by cars: reduce the amount of driving per year; increase the average fuel efficiency of the vehicle fleet; and, substitute alternative fuels for gasoline. The fuel substitution approach is advocated by Section 502(b) of the Energy Policy Act of 1992 (EPACT), and is the focus of this paper. EPACT provides incentives to introduce alternative fuel vehicles (AFVs) and requires that the U.S. Department of Energy (DOE) to estimate the technical and economic feasibility producing sufficient alternative and replacement fuels to replace, on an energy equivalent basis, at least 10 percent of gasoline use by the year 2000; and at least 30 percent by the year 2010 (EPACT, 502(a), 502(b)). Petroleum is displaced by the use of neat alternative fuels as well as through the use of reformulated and oxygenated gasolines which contain natural gas, hydrogen, and alcohol and ether-oxygenates.[4]

In 1996, DOE published the results of their initial analysis of EPACT'S goals, using the Alternative Fuels Trade Model (AFTM, USDOE 1996, Leiby 1993). This study determined, among other things, that (p. xii): "For the year 2000, 10 percent replacement of light-duty motor fuel use with alternative and replacement fuels is feasible and appears likely with existing practices and policies." The USDOE report further states: "Displacing 30 percent of light-duty motor fuel use by 2010 appears feasible. However, this estimated feasibility is based upon a number of assumptions that may not be realized without additional alternative-fuel initiatives." Consumption in 1998, however, of alternative and replacement fuels is estimated to account for 2.6 percent on a gasoline-gallon-equivalent (GGE) basis, of on-road transportation fuel use in the light-duty sector (EIA, 1997a, Table 10). This is despite the spate of announcements from Ford, GM and Chrysler who collectively pledged to build more than 250,000 AFVs (NYT, October16, 1997, Chrysler 1997, GM, 1998). It is clear that little of the 10 percent displacement goal for the year 2000 will be achieved by alternative fuels. Similarly, as described in detail below, it is also quite unlikely that the 30 percent displacement goal for the year 2010 will be met.

As recognized in DOE's own analysis, past studies of the alternative fuel (AF) and AFV penetration either assumed mature markets with large-scale vehicle production and the widespread availability of alternative fuels at retail stations, or assumed immature markets and small scale production. These past studies of the AFV market can be grouped into those which are static, single-

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[4] Replacement fuels, loosely speaking, are those portions of gasoline which are not gasoline (such as oxygenates) and other non-gasoline fuels that are not alternative fuels (such as gasohol, which is a blend of 10% ethanol and 90% gasoline).

year snapshots (Sperling, 1988; Fraas and McGartland, 1990; Lareau 1990; National Research Council, 1990; Walls, 1992; USDOE, 1996), and those which are dynamic, multi-year analyses (Fulton 1994, Rubin 1994, and Kazimi 1997a, 1997b). Obviously, the static analyses are limited in that they cannot assess the feasibility or cost of a transition to the new long-run equilibrium. Furthermore, in many cases their conclusions, as well as those of most dynamic models, reflect exogenous assumptions regarding fuel and vehicle prices and/or AFV penetration rates. For example, Kazimi's work stands out by addressing vehicle introduction and use by a sophisticated micro-simulation of household vehicle demand. However, Kazimi's work takes as exogenous vehicle and fuel availability, and fuel and vehicle prices.

The earlier work has provided critical foundations for this analysis. Still, none of the earlier studies focus on what we believe are they key transitional issues at the heart of the AFV debate. These transitional issues involve changes in the fuel and vehicle infrastructure necessary to take us from a market characterized by small-scale, high-cost AFV penetration to one in which AFV's and their fuels have a sizeable market share and realize the economies of scale typical for conventional gasoline vehicles. The transitional barriers include: vehicle and fuel production scale economies; consumer costs of low retail fuel availability; limited AFV model choice; consumer uncertainty about fuel and vehicle performance and reliability; and, the slow turnover of durable capital equipment and vintaged vehicle stock. These transitional barriers may delay or even prevent the adoption of alternative fuels and vehicles.

The Transitional Alternative Fuels Vehicle (TAFV) Model (Leiby and Rubin 1997), whose structure and results are discussed in this paper, simulates the use and cost of AFs and AFVs over the time frame of 1996 to 2010. As the model's name suggests, the TAFV model is specifically designed to examine the transitional period of alternative fuel and vehicle use. It also explores the effectiveness of policies authorized under EPACT, the Alternative Motor Fuels Act of 1988 (AMFA), and other potential policies that could be used to stimulate the AFV market. Welfare analysis of allows us to place dollar amount on the quantities of fuel displaced by the various policies. Since any environmental or energy-security gains or losses are generally excluded from the decision calculus of private agents, they are not reflected in the market outcomes or welfare analyses reported here. Policy makers must decide whether it is in the national interest to displace oil with alternative fuels to achieve these social goals, given a realistic appraisal of the market costs of doing so *and* taking into consideration the transitional barriers that currently exist.

In a broader context, this paper presents a methodology for simulating the market introduction of new technologies where economies of scale and endogenous feedback effects are important. It is our belief that explicitly modeling these dynamic effects is very important and cannot be ignored for a wide variety of economic and environmental questions that involve substantial investments in capital.

2.0 THE GENERAL MODEL STRUCTURE

The overall objective of the TAFV model is to maximize consumer and producer surplus (well-being) from transportation services provided by the light-duty vehicles (cars and trucks). The TAFV model characterizes interactions among fuel providers, vehicle producers, fuel retailers, private vehicle purchases and fleet vehicle programs. A schematic of these interactions is shown in Figure 3.[5]

[Figure 1 Here]

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[5]Further details on the general model structure can be found in Leiby and Rubin 1996, 1997.

As is shown, new vehicles and vintaged on-road vehicle stocks are tracked. Also tracked are vehicle production capacities and utilization, fuel production, and fuel retail production and capacity.

2.1 Cost Function Representation of Supply Modules

Each of the supply modules shown in Figure 3 is represented by a single-period cost function defined for each time period, region, fuel, and vehicle type. Examples include: vehicle production costs; fuel production or conversion costs; fuel retailing costs; raw material supply costs; and sharing or mix costs associated with vehicle and fuel choices. The sharing costs reflect the welfare loss due to the distortion of choice from the ideally preferred mix of fuel and vehicle non-price attributes, given unequal market prices of fuels and vehicles (Small and Rosen 1981, Anderson, de Palma and Thisse 1988, Leiby and Greene 1995). The cost functions summarize the way in which changing levels of activities, inputs, and outputs affect the costs for each supply module, and implicitly define the cost-minimizing behavioral relationships among the model's variables.

In some cases the supply module involves investments in fixed capital stocks with long-lived (multiperiod) costs and benefits. If so, the module cost function includes the net cost of current activities plus the costs of current investments minus the estimated discounted future value of all remaining capital stock at the end of the last period. Estimated future capital values are determined taking into account depreciation, discounting, and expected future use value.

2.2 Market Balancing Conditions

In each year fuel and vehicle markets must be balanced by equating consumers' demand and producers' costs of producing transportation services. This means that we wish to assure that the following short-run conditions are met: the marginal cost of producing each commodity equals its price;

the marginal benefit of each demand equals its price; the marginal profitability of each intermediate conversion (e.g., converting gasoline and ethanol into E85) activity is zero (unless constrained, in which case short-run profits can be positive or negative); and, the marginal current period value of investment equals the price of capital minus the discounted expected future value of the equipment from the next period.

We require incremental investment in technology-specific capital to be non-negative. If new investment is zero, the profitability of existing capital is insufficient to motivate new investment, and the last stated condition is not met. Disinvestment may be desired, but is not allowed. This later constraint comes into play in our ‘oil price shock’ scenario where we unexpectedly change the price of fuels such that the investments in fixed infrastructure are no longer optimal.

The partial equilibrium solution is calculated with GAMS (Brooke, Kendrick and Meeraus 1992) and yields market clearing supplies, demands, trade, and conversion process levels. It requires that supplies, plus net output from conversion activities plus net trades between regions must be greater than or equal to demand. Final demands and basic commodity supplies are "price responsive" in that their quantities will depend on market prices in each period.

2.3 Vehicle Services Demand for New and Used Vehicles

Benefits in this model come from the satisfaction of final demand for transportation services as determined from projections of light-duty vehicle fuel use (excluding diesel) for 1996 to 2010 given in the Annual Energy Outlook 1998 (AEO98, EIA, 1997). The total demand for light-duty fuel is satisfied by the use of existing (used) vehicles and the purchase and use of new vehicles. The use of older vehicles is limited by the stock of each vehicle type given a fixed, age-adjusted use profile.

Each year, to the extent that existing vehicle stocks are insufficient to satisfy the demand for transportation services, a mix of new vehicles is purchased. New vehicles are chosen according to a nested multinomial logit (NMNL) choice formulation, whose parameters come from (Greene, 1994). Vehicle choice is based on up-front vehicle capital costs, non-price vehicle attributes and expected lifetime nested fuel choice costs. In this way, long-lived investment consequences are reflected in vehicle choice. Fuel choices must be made for the vehicles that are dual or flexibly-fueled.

Since vehicle and fuel choice is endogenous, it is important to specify which fuel and vehicle characteristics are considered in the fuel and vehicle choice sub-modules, and which characteristics are endogenously determined. These characteristics are shown in the Table 1.

Table 1: Factors Influencing Fuel and Vehicle Choice		
Factors considered in Fuel Choice	**Endogenous**	**Exogenous**
Fuel Price	X	
Fuel Availability (fraction stations offering fuel)	X	
Refueling Frequency (based on range)		X
Refueling Time Cost		X
Performance Using Fuel (HP:weight ratio changes)		X
Factors Considered in Vehicle Choice	**Endogenous**	**Exogenous**
Vehicle Price	X	
Fuel Cost	X	
Performance (changes in HP-to-weight ratios)		X
Cargo Space (loss due to space required for fuel storage)		X
Vehicle Diversity (number of models offering AFV technology)	X	

2.4 Principle Assumptions and Data

The important assumptions and data sources can be broken down into the following general areas: wholesale fuel supply curves for gasoline, natural gas, ethanol (from corn and from cellulosic biomass), LPG, methanol, and electricity; wholesale fuel conversion costs and input-output coefficients; vehicle production cost curves, motor fuels taxes; retail fuel supply curves; and, fleet sales subject to AFV mandates. In general, (except for ethanol) these data are based on EIA sources and projections in AEO98. Ethanol feedstock supply curves are based on Walsh et al (1997), Perlack (1997), and Kimbill (1996). For details, see Leiby and Rubin 2000.

3.0 KEY TRANSITIONAL PHENOMENA MODELED

From preliminary analysis and discussions with experts, we identified key areas that could strongly affect the transition to alternative fuels and vehicles. These include the costs to consumers of limited retail availability of alternative fuels; scale economies for vehicle production and fuel retailing; limited AFV model diversity; and any costs to consumers from being unfamiliar with a new technology. Because of their potential importance, all these transitional barriers, except for those related to consumer unfamiliarity, have been explicitly modeled. We did not model the costs of consumer acceptance for new technologies since we had little information to make realistic parameter estimates. As our results below suggest, not including this cost would not likely change any of our qualitative results, since the AFV market has a difficult time getting started given the transitional barriers that we do include.

3.1 Effective Costs of Limited Retail Fuel Availability

Most alternative fuels are currently available at only very few retail stations. First principles, and evidence from surveys of diesel car buyers (Sperling and Kurani, 1987) suggest that fuel availabilities below 10% can impose large implicit costs on consumers. There is, however, little empirical evidence as to the possible size of these costs. Our approach is to use work by Greene (1998) who asked the following question in two national surveys:

> "Suppose your car could use gasoline or a new fuel that worked just as well as gasoline. If the new fuel costs 25 (10, 5) cents LESS per gallon but was sold at just one in 50 (20, 5) stations, what percent of the time would you buy this new fuel?"

Greene used a variety of function forms to estimate a random utility, binomial logit choice model.

Besides issues of fit, we have chosen to use his exponential functional form because our intuition tells us that at 50% fuel availability (every other gas station) the cost penalty ought to be small. For the exponential functional form, the cost penalty at 50% availability is 2¢ per gallon. At 0.1% fuel availability the cost per gallon, using the exponential functional form, is 35¢, see Figure 4.

3.2 Vehicle Manufacturers' Costs per Model

The TAFV model is designed to estimate the costs of vehicle production for the following alternative fuels: LPG, CNG, alcohols, and electricity. The vehicles are either dedicated to a particular fuel type or are capable of using both gasoline and the respective alternative fuel.[6] AFV costs (shown in Table 2) are calculated from engineering-economic estimates of the incremental cost of each AFV fuel technology compared to conventional vehicle technology (EEA, 1995c). EEA believes that AFV technologies that we model, except for electric vehicles, are mature. Here "mature" means that, for a given production scale, further production experience will not reduce per-unit production costs at a rate significantly faster than those of conventional vehicles. There do exist, however, substantial per-unit cost savings with larger scale production.

We therefore model per-unit vehicle production costs as a declining function of the installed production capacity available in each year. The volume of production in any given year is constrained by the level of cumulative capacity investment less capacity decay. This means that vehicle prices and manufacturing capacity are endogenous variables. This has the advantage of admitting the positive feedback effects from policies that encourage the early adoption (and hence larger scale production) of

[6]The one exception is electricity. Hybrid electric vehicles are currently not characterized in the model since their costs and performance are highly dependent on their configuration, something over which there is no current consensus. We do we plan to include them in the future work.

AFVs.

Table 2: Cost Data for Vehicle Production and Fuel Retailing			
Incremental Vehicle Production Costs (Capital and Variable, Compared to a Gasoline Vehicle)*			
	Plant Scale (Vehicles per Year)		
Vehicle Type	2,500 per year	25,000 per year	100,000 per year
Alcohol Dedicated	$2,038	$363	$223
Alcohol Flexible	$1,911	$409	$284
CNG Dedicated	$5,349	$1,841	$1,548
CNG Dual	$5,792	$2,015	$1,701
LPG Dedicated	$3,745	$972	$741
LPG Dual	$3,778	$1,109	$887
Electric Dedicated (1996)	$42,125	$11,060	$8,471
Electric Dedicated (2010)	$29,627	$5,974	$4,003
*For large passenger vehicles and passenger vans.			

3.3 Endogenous Vehicle-Model Diversity and the Effective Cost of Limited Diversity

Consumers contemplating buying a new gasoline-fueled car are offered a wide variety of makes and models with a huge number of features to choose among. The attractiveness of an alternative fuel technology will depend on the diversity of vehicle models for which it is available. Offering, for example, methanol fuel technology on only a single model will put methanol vehicles at an disadvantage compared to gasoline vehicles, all else equal. At the same time, offering methanol capability on several different models is expensive because it lowers plant scale for any overall level of production.

Rather than predetermining the number of makes and models offered with alternative fuel capability, we endogenize the level of model diversity by balancing the additional production costs off against the additional consumer satisfaction. This is accomplished by defining a variable that represents the number of makes and models for each vehicle-fuel type produced. On the vehicle production side we divide the total industry production capacity for each vehicle-fuel type by this diversity variable; on the consumer side we incorporate the diversity variable into our multinomial choice framework.

The value of diversity depends on the order in which vehicle manufacturers introduce AF technology to their existing model lines. This is because different models have market penetrations that vary from a few thousand for specialty cars to over one hundred thousand for some popular pickup trucks. If alternative fuel capability is introduced "randomly" on different vehicle models, then we estimate the cost to be $2080 per vehicle. When manufacturers add the AF technology to the most popular model line first, the cost is $727 per vehicle; when AFVs have the same richness of models as gasoline vehicles, then the cost is $0 per vehicle. In the simulation model we assume that the AF technology is offered on the most popular model first.

4.0 SIMULATION RESULTS

To assess the importance of transitional barriers, we first examine the model's implications for alternative fuel use in the absence of any new policies, without and with the inclusion of transitional barriers. In the base case and elsewhere, unless specifically noted, fuel production costs vary over time, reflecting AEO98 projections as described in Section 2. Alternative fuel taxes reflect current law, with a phase-out of the ethanol incentive by 2007.

There are two existing federal AFV policies which we model explicitly: EPACT's currently mandated purchases of AFVs by fleets, and CAFE credits for producers of AFVs. Existing EPACT fleet mandates represent less than one-half of one percent of new vehicle sales (As is seen in the lower curves of Figure 5). A second important policy driver included in the base case is the favorable treatment received by AFVs pursuant to the Alternative Motor Fuels Act of 1988 (AMFA) in the calculation of each manufacturer's Corporate Average Fuel Economy (CAFE). When calculating a vehicle manufacturer's CAFE for the purposes of complying with the CAFE standards, AFVs are treated as highly fuel-efficient. Based on avoided penalties, we use an estimated value of CAFE credits of $686 and $343 per dedicated or flexible AFV, respectively (Rubin and Leiby 2000). We also estimate that 0.5% to 1.0% of new vehicle production could be devoted to AFVs eligible for the credit.

[Figure 5 Here]

4.1 Base Case

This case characterizes the possible market evolution starting from the current limited alternative fuel availability and low AFV production scale. The initial higher costs of smaller scale AFV production, the current limited retail availability of alternative fuels and the relatively low cost of gasoline present substantial hurdles to the penetration of alternative vehicles and fuels. In fact, our results (see Figure 6) project that in the absence of any new policy initiatives combined AFV sales from now through 2010 will be just under 1% of new vehicle purchases, with the majority (70%) of the AFVs being alcohol FFVs. Moreover, the alcohol FFVs are running on gasoline rather than alcohol. In fact, AF use is only 0.12% with gasoline displacement (mainly from reformulated gasoline) at 9.2% by 2010.

[Figure 6 Here]

This AF and AFV use is consistent with the subsidies received by AFVs due their favorable treatment under CAFE regulations which require the vehicles to be sold, but for the case of FFVs, not actually use a non-petroleum fuel. Indeed, in the base case, the maximum number of CAFE credits are, in fact, used.

These results are in marked contrast to USDOE's 1996 long-run analysis, which concluded that if the necessary infrastructure for a mature alternative fuel and vehicle industry were present, then "alternative fuels, as a group, appear likely to sustain a 30-percent market share under equilibrium conditions." (USDOE 1996:13). However, the modeling results here suggest that the necessary infrastructure may not evolve smoothly, and fuel and vehicle prices may not benefit from economies of scale in the absence of additional policies. Therefore, AF use and gasoline displacement may be very limited.

4.2 Base Case Fuel Prices with No Transitional Barriers

It is useful to assess what level of AFV and AF penetration might be expected if there were no transitional barriers to their introduction, other than the usual gradual turnover of vehicle stock. The no transitional barriers case explores what would happen if alternative fuels and vehicles were produced at large-scale costs, and fuel availability and vehicle diversity pose no effective costs to consumers. This case projects a 15% displacement of gasoline by alternative fuels in the year 2010, using base case fuel prices. Of this, 8.5% displacement is by blends and only a 6.5% displacement by neat alternative fuels M85 and CNG, and LPG. Other fuel price assumptions increase this displacement level. With the EIA High World Oil Price (HWOP), assumptions, petroleum displacement rises to 18% by 2010. If lower LPG costs are also available, then in the absence of transitional barriers, we find that petroleum displacement would be 25%. Thus, absent transitional barriers, and given plausibly higher oil price assumptions, EPACT's 2010 fuel displacement goals would be essentially attainable.

These results of these first two base cases (without and with transitional barriers) demonstrate the vital importance of modeling transitional barriers when examining new, emerging technologies.

Static, long-run equilibrium analyses ("snapshots") are likely to lead to misleading results when technologies and infrastructures are evolving. Transitional barriers are likely to prevent the attainment of EPACT's 2010 fuel replacement goals, even given favorable fuel price assumptions. In other experiments we find that transitional barriers also promote specialization of the market in at most one or two alternative fuels. That is, in cases where oil displacement is finally achieved as a result of large alternative fuel subsidies, a sustained oil price rise, or mandates, the efficient market outcome is for the displacement to be achieved by only one or two alternative vehicle/fuel technologies (see Leiby and Rubin 2000 for details). The convenience and cost savings attainable with specialization of vehicle production and fuel infrastructure outweigh the benefits of diversity of fuel and vehicle types. This is a new result, and differs from earlier comparative-static studies in which multiple AFV types were often projected to each sustain a substantial share of the mature market.

4.3 EPACT Private and Local Rule Making

The USDOE has the authority under EPACT to require private fleets and those of state and local governments (P&L) to purchase AFVs totaling about 2% of total vehicle sales (shown in the upper curves of Figure 5). The outcome of imposing the P&L 2% fleet mandate is that private (non-fleet) vehicle owners are induced to purchase an additional 2.9% of AFVs by 2010. Thus, under the late rule a total of 4.9% of new vehicle sales are AFVs by 2010. Thus, the P&L fleet rule does help reduce transitional barriers by lowering the cost of AFVs. Unfortunately, the vehicles chosen are mainly alcohol FFVs; which use very little alternative fuel given its high cost. Furthermore, the fleet and private demand for AFVs encouraged by the EPACT mandates crowds out induced value of the CAFE credits. That is, the AFV demand induced by the fleet mandate far exceeds the number of

AFVs eligible for the CAFE credit, and the credit value falls to zero. As with the base case, fuel price sensitivity analysis shows this results to be quite robust.

4.4 Retail Fuel Mandate

The Retail Fuel Mandate case requires that sufficient alternative fuels be sold to meet EPACT 2010 displacement target. (We are silent about exactly how this might be implemented, we simply impose it as a retail fuel sales constraint). What makes this case of interest is not that it achieves mandated oil displacement, but the freely chosen mix of fuels and vehicles which comprise the mandated mix. In addition, the net cost to consumers, fuel producers and vehicle manufacturers of attaining this goal is important. Given base and high oil prices, M85 in dedicated AFVs is the predominant way that this mandate is achieved. Interestingly, AFVs make up about 42% of new vehicle sales by 2004 in order for the light-duty vehicle fleet to displace 30% of petroleum by 2010.

4.5 Continued Ethanol tax credit and Low GHG Fuel Tax Credit Policies

Other than the AF sales mandate policy, the policies that are most effective in inducing the displacement of petroleum are a policy to continue the ethanol tax credit and a Low-GHG Fuel tax credit policy. Both of these policies rely on substantial subsidization of ethanol ($0.54 per physical gallon), and the second subsidizes other low GHG fuels in proportion to their full-cycle GHG reduction. Given base case fuel price projections, however, these policies are still not sufficient to induce noteworthy AF penetration. Given High World Oil Prices (HWOP cases), however, these policies can be effective, *particularly* if the tax credits are adjusted for inflation to maintain their real value.

As a policy case we simply assume that the current ethanol tax credit, due to be terminated in

2007, will be continued in its current form through 2010.[7] The tax credit is denoted in nominal dollars since it is set by legislation, it therefore declines in real value at an assumed 3% per year. We also examine the impact of maintaining this tax credit in real dollars at $0.54 per physical gallon ($0.68 per GGE for E85).

As might be expected, extending the credit for only a few additional years has virtually no effect on AF and AFV use given base or high world oil prices (HWOPs). On the other hand, when the ethanol credit is maintained constant dollars then the year 2010 AF use and gasoline displacement are 2.5% and 10.9% respectively given base prices, and 10.6% and 16.5% given HWOPs. The fuel of choice is E85 used in dedicated vehicles. No other AF is encouraged.

The Low GHG Fuel tax credit is structured to give alternative fuels a credit (or tax) in proportion to the degree which their production and use reduces GHG emissions compared to gasoline. Cellulosic ethanol is considered a nearly zero-GHG fuel, and receives a credit equal to what is currently given ethanol, i.e., $0.54-per-physical gallon. Gasoline receives no credit. All other alternative fuels receive prorated between these values. Given HWOPs, the Low-GHG tax credit induces petroleum displacement from 9.3% to 11.3% by 2010. If, in addition, low GHG fuel tax credit is also inflation-adjusted, 22% of petroleum can be displaced by 2010.

4.6 Welfare Calculations

In determining the national cost of policies it is very important to determine an appropriate baseline. We measure the incremental net benefits of the various policy cases compared to the base case, which reflects the policies now in place (see Table 3). When comparing the cost per GGE it is

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[7]The ethanol tax credit is $0.54 per physical gallon, or $0.68 per GGE for E85.

important to make the distinction between the costs in terms of tax dollars foregone and the costs per GGE to the nation's economy after subtracting out transfers that benefit the fuel and vehicle producing sectors. In all cases, we present the market costs after netting out transfers, and only refer to the costs for the United States (even though these policies also affect the welfare of oil and gas exporting countries). These costs do not include any valuation of the possible external effects in the areas of energy security or the environment.

5.0 CONCLUSIONS

Overall, the market barriers to significant alternative fuel and vehicle use are substantial. We find that in the absence of any new policy initiatives, it may be difficult for the alternative vehicle and fuel markets to get started. The base case yields almost no AF and AFV penetration. For the AEO98 base oil price path, current policies (i.e., current EPACT fleet mandates, ethanol tax credit, and CAFE credits for AFVs), appear inadequate to induce any significant alternative fuel use, or any AFV purchases beyond the minimum mandated by the law. More remarkably, if the base case oil price projections from AEO98 hold true, even some substantial new AFV and AF incentives may have only limited effect. For example, the continuation of the ethanol tax credit beyond 2007 may be inadequate to induce ethanol (or other) AF use, unless it is adjusted to maintain its value in the face of inflation.

Table 3 summarizes some of the fuel displacement results given the base-case assumptions on fuel prices. As can be seen, the effectiveness and average cost of the various policies varies widely. In each of the cases The welfare cost is the discounted sum of consumer and producer surplus net of any taxes or subsidies over the 1996-2010 time horizon plus any costs or benefits associated with the terminal period, relative to the base case or current policy.

Table 3: Summary of Fuel Displacement and Costs Across Scenarios

AEO Base, Higher LPG Cost

Policy	Gasoline Displacement in 2010*	Total Displacement 1996-2010	Welfare Cost**	Incremental Displacement Cost***
Units	Percent	Billion GGE	Billion $96	$/GGE
Base (No Policy)	9.2%	178.82	0.000	NA
Late Private (P&L) Rule	9.2%	178.80	1.721	NA
Late Private Rule with 50% Fuel Mandate	9.7%	183.18	3.944	1.56
Continued Ethanol Tax Credit	9.2%	178.88	0.038	0.46
Low-GHG Fuel Subsidy	9.3%	179.07	1.267	0.44
Increased CAFE Standards	9.2%	178.85	0.309	0.36
Retail Alternative Fuel Sales Mandate	30.0%	343.40	26.567	0.29
No Transitional Barriers (Long-Run)	14.9%	224.20	NA	NA
P&L Rule Plus Continued Ethanol Tax Credit	9.3%	179.16	1.804	8.35
P&L Rule Plus Low-GHG Fuel Subsidy	9.3%	179.59	1.904	4.07
P&L Rule Plus Increased CAFE Standards	9.3%	179.35	2.371	3.10

* This includes displacement from both alternative fuels and replacement fuels, including the replacement fuel content of gasoline.

**The welfare cost is the discounted sum of consumer and producer surplus net of any taxes or subsidies over the 1996-2010 time horizon plus any costs or benefits associated with the terminal period, relative to Base/current policy.

*** The cost per gallon is the discounted welfare cost divided by the discounted sum of fuel displacement over the 1996-2010 time horizon plus any costs, benefits and displacement associated with the terminal period.

These results lead us to several observations. First, in a market economy where vehicle manufacturers, fuel suppliers, and consumers all make independent decisions, the efficacy of government policies to reduce the dependence of the United States transportation sector on petroleum is highly dependent on the world price of petroleum. Second, the penetration of alternative fuels and AFVs depends on the fuel retail infrastructure, the extent of adoption of AFVs, and other transitional barriers. Third, governmental policies, if sufficiently large, can effectively reduce these barriers and can allow alternative fuels to compete in the marketplace with gasoline. However, given the current and expected low price of petroleum in the world today, doing so would be costly. Finally, absent major new government policies to promote alternative fuels or reduce greenhouse gases, it is unlikely that the United States will achieve or even approach EPACT's 2010 displacement goals.

Lest we appear too definitively negative about the transition towards AFs and AFVs, we would like to make a few cautionary notes. First, we have been looking only at a subset of possible vehicle and fuel technologies, focusing on well-established alternatives. In particular we have not yet examined hybrid-electric and fuel cell vehicles. These vehicle types may be far more successful than current AFVs in displacing oil use and reducing emissions, and they are a high priority for our subsequent work.[8] In addition, we have tried to model the existing vehicle market within the current and possible future regulatory context. Growing energy security or environmental concerns could motivate sufficiently strong policies to achieve the transition. For example, were the United States to ratify the Kyoto protocol and require reductions in greenhouse gases from the transportation sector on the order of 20% by 2010, then the whole price regime for transportation would be fundamentally altered, potentially allowing AFVs to better compete.

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[8]Nor do we evaluate the relative merits of vehicles with new emissions control technologies (e.g. SULEVs) or using conventional gasoline reformulations, compared to AFVs for at least the goal of reducing criteria pollutant emissions.

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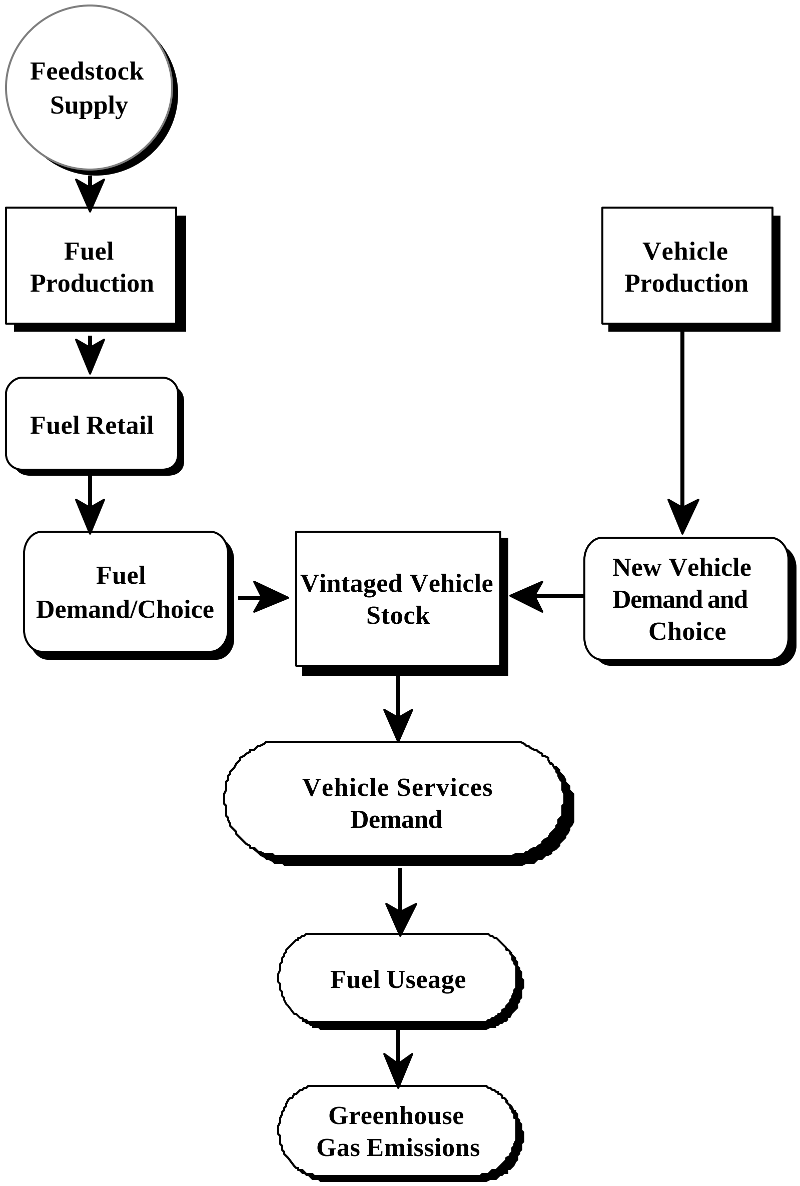
Figure 3: Conceptual Diagram of TAFV Model



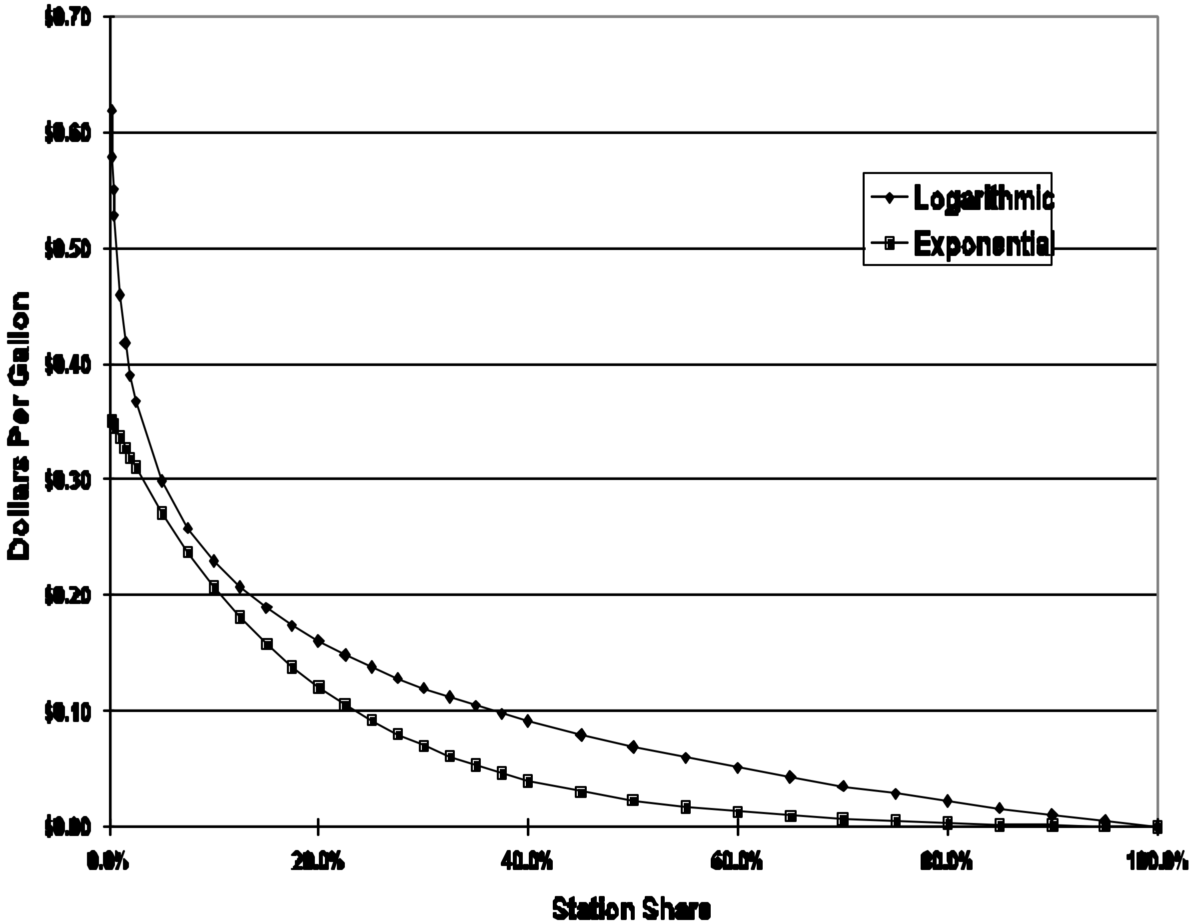


Figure 4: Costs of Limited Retail Availability

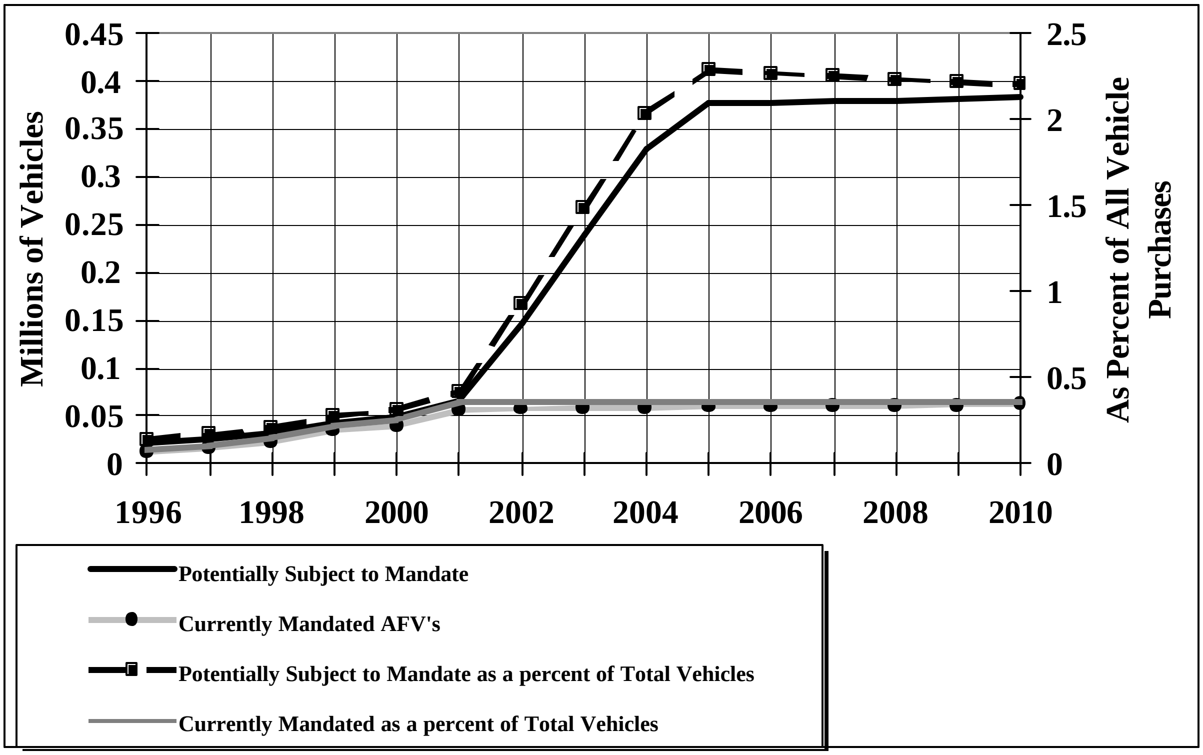


Figure 5: EPACT Fleet Mandates

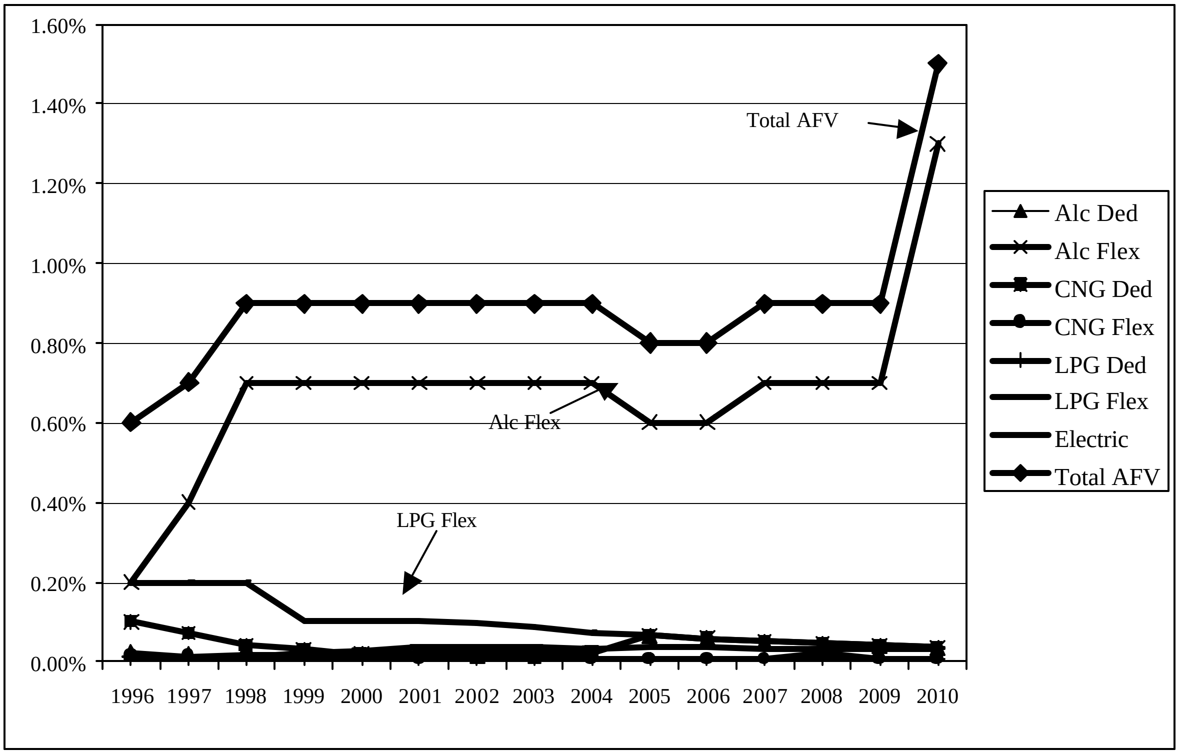


Figure 6: Base Case AFV Shares