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IMPACTS ON HOME HEATING COSTS OF INCENTIVES FOR ALTERNATIVE FUELS VEHICLES

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Office of Policy, Planning and Analysis
U.S. Department of Energy
Washington, D.C.

November 1989

Abstract

The Alternative Motor Fuels Act of 1988 offers incentives in the form of fuel economy credits to manufacturers who produce vehicles capable of using natural gas or alcohol fuels. Substitution of these fuels for gasoline in the transportation sector is likely to affect the prices of natural gas and distillate oil, important sources of energy for home heating. The Act calls for a study to determine whether including alternative fuel credits in calculating corporate average fuel economy is likely to increase the average price of home heating to residential consumers. This report presents an analysis of that question. Assuming that manufacturers take full advantage of the alternative fuel credits available by building compressed natural gas (CNG) or methanol compatible vehicles, projections through the year 2013 are developed for the additional demand for natural gas and reduced demand for gasoline. It is assumed that all natural gas comes from domestic sources and that all methanol for transportation is imported. In scenario I, 10% of alternative fuel vehicles use CNG, 90% methanol (as M85, 85% methanol, 15% gasoline). In this case the price impacts are small: 1) natural gas price increases 5 to 6 cents (1988 dollars) per thousand cubic feet (MCF) and annual heating costs per household for the 50 million households using natural gas as their main fuel increase by $5-$6; 2) the price of home heating oil declines by just over $2 per barrel, lowering annual costs per household to the 12 million households depending on heating oil by $35. In scenario II, 100% of alternative fuel dual energy vehicles use CNG and the price impacts are much larger, $0.50-$0.60/MCF or $50-$60 per year per household. The reduction in heating oil price is a bit larger, $2.70 per gallon or $45/year for households heating with oil. Still larger impacts can be generated by assuming dedicated CNG vehicles that cannot use gasoline are sold. If as much as 5% of all light duty vehicles sold after 1997 were dedicated CNG vehicles, the estimated natural gas price increase would be over $0.80/MCF, and the heating oil price decrease would exceed $4/bbl.

I. BACKGROUND

This report was prepared in compliance with section 9 of the Alternative Motor Fuels Act of 1988 (Public Law 100-494) (the Act). The Act provides incentives in the form of fuel economy credits to manufacturers who produce vehicles capable of using natural gas or alcohol fuels. Section 9 of the Act requires a report, to be transmitted to Congress by December 1, 1989, examining whether these incentives for producing alternative fuel vehicles will result in a significant increase in the average price of home heating to residential consumers.

This report uses data on projected prices of natural gas and heating oil from the 1989 Annual Energy Outlook (AEO). The 1989 AEO projected these prices only through year 2000. As a result, certain assumptions have been made to derive price projections past 2000. In January 1990, the Energy Information Administration will publish the 1990 AEO, which will contain projections of natural gas and heating oil prices through year 2010. It is our intention to update the analysis when the new data are available.

Section 6 of the Act provides incentives for manufacturers choosing to produce dedicated and dual-fueled alcohol or natural gas vehicles, by counting a gallon of alcohol fuel or a gallon equivalent of natural gas as only 0.15 gallon of "fuel" when calculating the manufacturers' Corporate Average Fuel Economy (CAFE) number. A manufacturer's CAFE number is used to determine compliance with the automotive fuel economy standards specified by the Energy Policy and Conservation Act of 1975 (EPCA), and subsequent rulemakings by the Department of Transportation. For dual fuel alcohol and natural gas vehicles produced in model years (MY) 1993 to 2004, a manufacturer may increase his CAFE number by up to 1.2 MPG and for MYs 2005 - 2008 by up to 0.9 MPG. There is no limit on the increase that can be claimed for dedicated alcohol or natural gas vehicles.

No specific provision is made for alternative fuels other than alcohols and natural gas; however, section 7 of the Act directs the Secretary of Transportation, in consultation with the Secretary of Energy, to study the need for additional regulations to stimulate the production and use of electric and solar powered vehicles. Only the impacts of manufacturing incentives for alcohol powered, dual energy, natural gas powered, and natural gas dual energy automobiles, as described in section 6 of the Act, are considered in this study.

Greater use of alcohols and compressed natural gas (CNG) as motor fuels will increase demand for natural gas, although it is unlikely that methanol will be produced from domestic natural gas feedstock. Increased demand for natural gas can be expected to raise the wellhead price of natural gas and, thus, the prices paid by residential consumers. Reducing demand for gasoline, on the other hand, will affect the price of home heating oil by shifting the slate of petroleum products made by refineries away from gasoline toward greater production of distillate fuel, reducing the cost of home heating oil to residential customers.

II. OBJECTIVE

This study's objective is to determine whether calculating the average fuel economy of vehicles as provided in the Act is likely to result in a significant increase in the average price of home heating to residential consumers. This study will evaluate and quantify the possible effects of the CAFE provisions in terms of numbers of alternative and dual-fuel vehicles that might be built as a result of this provision, consumption of alcohol and natural gas by these vehicles, whether the alcohol or CNG is likely to be derived from domestic resources, the effects on domestic natural gas and home heating oil prices, and the resulting impact on home heating costs.

III. ALTERNATIVE FUEL VEHICLE SALES AND FUEL USE

The impact of the Act's CAFE incentives on home heating costs depends on four key factors:

1. the numbers of dual and dedicated methanol and natural gas vehicles produced as a result of the CAFE incentives permitted by the Act;
2. the usage rates and efficiencies of the alternative fuel vehicles;
3. the sources of energy supply (domestic or imported, natural gas, coal, or biomass) for the vehicles;
4. the sensitivity of domestic natural gas price to increased demand for natural gas and of distillate oil prices to decreased demand for motor gasoline.

It is not possible to predict the precise numbers and types of dual energy vehicles manufacturers will choose to produce and consumers will choose to buy as a result of the Alternative Motor Fuels Act of 1988. The approach we take in this study is to attempt to define the maximum impact possible and, for comparison, a more likely but still ambitious alternative. This approach provides a plausible single estimate of the potential impact of AMFA and places it within the context of an upper bound on the range of possible impacts.

Readers may then make their own judgments about where within this range the actual effect is most likely to lie. Some may agree that our more likely estimate is still quite high, and thus conclude that the true impact will be even less. Others may use the scenarios to interpolate results that seem more likely to them. Our goal in carrying out this analysis has been to provide sufficient information for individuals who wish to make their own judgments about what the future sales of alternative fuel vehicles are likely to be to infer the size of the impacts on home heating costs that would result.

The following subsections describe more fully the procedures we used and the assumptions we made. The 1.2 MPG and 0.9 MPG caps on AMFA CAFE credits provide a basis for calculating how many dual energy vehicles would be produced if manufacturers took full advantage of the credits. The next step is to determine how many of those vehicles would use alcohol and how many would be fueled by natural gas.

III.1 Estimating the Number of Dual Energy Automobiles and Light Trucks

Estimating the number of vehicles the Act's incentives will cause to be produced is a critical element of the analysis. However, the most important factors are all difficult to predict:

1. the importance of the CAFE credits to manufacturers;
2. the desirability of the dual and dedicated fuel vehicles from the consumer's perspective;
3. the availability and cost of methanol and CNG.

The importance of CAFE credits to manufacturers depends on the level of MPG required by the CAFE law, market interest in fuel efficiency which is primarily influenced by petroleum prices, and the manufacturers' product line. The greater a manufacturer's shortfall and the less market demand for MPG, the more valuable the credits will be. Rather than try to predict these factors, we assume that all manufacturers will take full advantage of the AMFA fuel economy credits. We do this by calculating the number of vehicles (passenger cars and light trucks) it would take to achieve 1.2 MPG and 0.9 MPG gains for each manufacturer, using the AMFA incentive formula for MPG. The mathematics of the formula are such that as the MPG of all cars increases, the number (or fraction) of cars which must be dual energy to achieve a fixed MPG credit decreases. Again, to obtain the maximum impact we use data on sales and fuel economy for the year 1988 to estimate the numbers of cars and sales fractions. If vehicle efficiencies increase in the future, the actual numbers of cars or sales fraction would be lower than our assumption.

Since the incremental cost of a dual energy automobile is likely to be insensitive to car size, it makes sense for the manufacturers to convert their least efficient vehicles to dual energy capability. Table 1 shows sales and efficiencies by car size class for GM, Ford, and Chrysler. Credits of 1.2 MPG can be obtained by GM by converting 450,000 of its large cars, by Ford by producing 200,000 dual energy cars, while 120,000 cars will achieve the same result for Chrysler. The corresponding numbers for an 0.9 MPG credit are 350,000, 150,000, and 90,000. For the 1.2 credit, these numbers represent 10.3% of the sales of these domestic car manufacturers, and for 0.9 MPG the sales fraction is 7.9%. Since the average fuel economy of large domestic automobiles was 24.4 MPG in 1988, we use this as the gasoline equivalent efficiency of dual energy passenger cars in that year. Although other manufacturers generally have higher MPG fleets and would, thus, require fewer vehicles to reach the maximum credit limits, we assume that all manufacturers will produce the same sales fraction of dual energy vehicles.

For light trucks, the computations are based on the average fuel efficiency for all light truck types. In 1988, average light truck fuel economy was 21.2 MPG. Calculations for the 1.2 and 0.9 incentives are shown in table 2. It would take approximately 14.7% of sales to reach the 1.2 MPG maximum, and 11% to hit the 0.9 limit. These market shares were considered somewhat high relative to those for automobiles, so penetrations halfway between the calculated light truck market shares and the automobile market shares were used.

Table 1. Sales and Fuel Economies of Domestic Manufacturers, 1988

	1988 MY		Scenarios (Sales in 1,000s)	
Chrysler				
	Sales	MPG	Conventional	Dual Energy
Subcompact	353.4	29.6	353.4	0.0
Compact	273.6	30.8	273.6	0.0
Intermediate	513.0	29.2	393.0	120.0
	1140.0	29.7	New MPG=30.9	
Ford				
	Sales	MPG	Conventional	Dual Energy
Subcompact	360.0	36.8	360.0	0.0
Compact	450.0	28.3	450.0	0.0
Intermediate	790.0	25.2	790.0	0.0
Large	400.0	22.7	200.0	200.0
	2000.0	26.8	New MPG=28.0	
General Motors				
	Sales	MPG	Conventional	Dual Energy
Subcompact	783.0	31.3	783.0	0.0
Compact	870.0	28.6	870.0	0.0
Intermediate	1435.5	28.5	1435.5	0.0
Large	1261.5	27.1	811.5	450.0
	4350.0	27.1	New MPG=28.3	

Table 2. Computation of Maximum CAFE Incentive
Market Shares for Light Trucks

Light truck MPG = 21.2
Let x = market share of dual energy light trucks that achieves a CAFE of 21.2+1.2 = 22.4. Solve for x,

$$\left[\frac{(1-x)}{21.2} + \frac{x}{\left\{ \frac{.5}{21.2} + \frac{.135}{21.2} \right\}^{-1}} \right]^{-1} = 22.4$$

(1/21.2) - (x/21.2) + (x/33.39) = (1/22.4)

0.04464 - 0.04717 = x (-0.04717 + 0.02995)

x = 0.147 .

Similarly, for the 0.9 MPG credit,

(1/22.1) - (1/21.2) = -(x/21.2) + (x/33.39)

x = 0.11 .

We assume that from 1993 to 2004 manufacturers will produce 10.3% of automobiles and 12.5% of light trucks as dual energy "automobiles." After 2004, we assume that 7.9% of automobiles and 9.5% of light trucks will be dual energy.

We assume that these vehicles will be sold regardless of cost and consumer acceptance issues. Based on studies done for the Department of Energy, a flexible fuel methanol vehicle is likely to cost $200-400 more than a conventional vehicle. The mark-up for a dual fuel CNG vehicle is expected to be considerably higher (about $800) because of the cost of storage tanks and the fact that two fuel systems are required. The storage tanks will take up a considerable amount of room, probably in the vehicle's trunk. Because compressed natural gas vehicles are not likely to offer the consumer other advantages over alcohol powered vehicles, it seems likely that the large majority of vehicles sold as a result of the manufacturing incentives of the Act will be alcohol, rather than natural gas, powered.

III.2 Vehicle Usage Rates and Efficiencies

Dual energy passenger car efficiency is set at 24.4 MPG and light truck efficiency is taken to be 21.2 MPG in 1988. Both are assumed to increase over time in proportion to increases in efficiencies for all new passenger cars and light trucks, respectively. MPG for new, gasoline-powered passenger cars is assumed to increase to 31.3 by 2000 and remain constant thereafter. Similarly, new, gasoline-powered light trucks reach 23 MPG by 2000 and remain constant thereafter. The increases are based on projections made for the Department of Energy (EEA, Inc., 1989). In actual use, vehicles are assumed to achieve 85% of their combined city-highway fuel economy rating according to the Environmental Protection Agency testing procedures.

Vehicle usage characteristics are assumed to be the same as conventional cars and trucks. Usage varies according to fuel costs per mile. Since CNG is generally cheaper per Btu than gasoline and we have assumed equal energy efficiency, CNG vehicles will be driven a small amount more under the above assumptions.

III.3 Fuel Costs and Frequency of Alternative Fuel Use

Fuel price projections were taken from the Base Case projection of the 1989 Annual Energy Outlook (EIA, 1989, table A3). The price of natural gas to transportation users was set at the price to commercial users plus a highway user tax of $0.18 per gallon of gasoline equivalent energy.

It was assumed that dual energy passenger cars and light trucks would refuel with the nonpetroleum fuel about 75% of the time. This number is consistent with assumptions of other DOE analyses and with survey data for compressed natural gas dual energy vehicles in Canada (Greene, 1989).

III.4 Sources of Methanol and Compressed Natural Gas Supply

Methanol production capacity in the United States totalled 1.9 billion gallons in 1986, of which approximately 30% was shut down (DOE/PE-0080, 1988, pp. B4-B6). U.S. plants produce chemical grade methanol, which is purer and more expensive than fuel grade methanol. Given increasing demand for MTBE, an oxygenate for blending with gasoline, it is unlikely that any significant domestic excess capacity will be available for producing fuel grade methanol by 1993. Furthermore, DOE analyses of worldwide methanol production costs indicate that many countries could produce methanol at costs far below the United States because they possess large natural gas reserves with low production costs that are presently unmarketable (DOE/PE, November 1989). Therefore, it is highly unlikely that future expansions to methanol production capacity will be made in the United States. Since future supplies of fuel grade methanol will be imported, methanol use by dual energy vehicles would have no impact on domestic natural gas prices and, thus, no impact on residential gas consumers.

Domestic natural gas, on the other hand, is likely to be much less expensive than imported natural gas in the form of liquified natural gas (LNG) for some time to come. Therefore, we assume that all natural gas for dual energy CNG vehicles will come from domestic gas supplies. It follows that the maximum impact of the AMF Act of 1989 on home heating costs would occur if all dual energy vehicles were gasoline/CNG vehicles.

III.5 Dual Energy Vehicle Scenarios

The four scenarios described below were chosen to portray one reasonable but ambitious scenario for CNG vehicles and three high impact scenarios intended to describe the largest impacts on natural gas prices imaginable. The first scenario, in which dual energy alcohol vehicles predominate, provides a reference point which we believe is far closer to what is likely to happen than the maximum case, yet is still ambitious for CNG vehicles in view of the lower cost of flexible fuel alcohol-gasoline vehicles. Each scenario is described briefly below.

Scenario I: 10% Natural Gas Dual Energy Automobiles

This scenario assumes that manufacturers will take maximum advantage of the 1.2 MPG incentive from 1993 to 2004 and the optional 0.9 credit through 2008. It is further assumed that they will continue to produce dual energy CNG vehicles at the 0.9 MPG credit level through 2013. Because of the lower cost of alcohol dual energy vehicles, 90% of dual energy vehicles produced run on alcohol, and only 10% are equipped to use CNG. No significant numbers of dedicated vehicles of any alternative fuel type are produced. Because we know of no plans of any major manufacturer to produce original equipment manufactured CNG vehicles, we consider this scenario to be the most likely of the four.

Scenario II: Maximum Natural Gas Dual Energy Automobiles

This scenario is the same as Scenario I, except that all dual energy vehicles produced are equipped to use CNG. None use alcohol fuels. No significant numbers of dedicated CNG vehicles are ever produced.

Scenario III: 1% Dedicated CNG Vehicles

In addition to the assumptions of scenario II, it is assumed that when natural gas demand reaches 5% of light duty vehicle energy use, 1% of all vehicles produced will be dedicated CNG vehicles.

Scenario IV: 5% Dedicated CNG Vehicles

In addition to the assumptions of scenario II, it is assumed that when natural gas demand reaches 5% of light duty vehicle energy use, 5% of all vehicles produced will be dedicated CNG vehicles.

III.6 Stock Evolution and Fuel Use

As new dual energy vehicles are added to the stock the total alternative fuel use will grow over time. Because the process of stock turnover is a gradual one, the full effect of a lasting change in new automobiles is not felt until at least ten years after it occurs. We used the Alternative Motor Fuel Use Model, developed for the Department of Energy by Oak Ridge National Laboratory (Greene and Rathi, 1989) to predict the evolution of alternative fuel use over time, given the assumptions outlined above. We continue the forecast beyond 2004 to 2013 to more completely capture the change in the total vehicle stock resulting from the sales of new dual energy automobiles.

Table 3 summarizes the four scenario projections. Fuel use is reported in volumetric gallons for gasoline and methanol and in energy equivalent gallons of gasoline for compressed natural gas (CNG). In each, total automobile and light truck fuel use rises through 1989, then declines slightly as new vehicle efficiency increases and vehicle sales decline slightly. Motor fuel demand begins increasing after 1994 and reaches 130 billion gallons (gasoline equivalent) by 2013. In scenario I, methanol use grows from 950 million gallons (514 gasoline equivalent gallons) in 1993, the first year of the AMFA CAFE credits, to 12.7 billion gallons (6.9 bg gasoline eq.) in 2013 (Figure 1). Natural gas use by motor vehicles rises from 62 million gallons gasoline equivalent (0.0075 TCF) in 1993 to 1.0 billion (0.1245 TCF) in 2013. The fact that fuel use by natural gas vehicles is greater than one-ninth of that by methanol vehicles reflects the fact that methanol is assumed to be M85, a blend of 85% methanol and 15% gasoline, and the gasoline in M85 shows up as gasoline in table 3. Also the model makes minor adjustments for the lower cost of natural gas on an energy equivalent basis and, to a very small degree, the fact that since CNG vehicles cost more, they will not be scrapped as quickly.

Methanol in the form of M85 is assumed to cost $0.70 per gallon or about $1.25 per gallon of gasoline equivalent in all years. Gasoline initially costs less, $0.98 in 1993, but increases to $1.32/gal. by 2000. Natural gas costs only $0.83/gallon-of-gasoline-equivalent in 1993, but its cost also escalates to $1.01/gal.-eq. in 2000 and continues to increase thereafter. In the other three scenarios all alternative energy vehicles are assumed to use CNG so there is no alcohol use. Natural gas use begins at 0.08 TCF in the first year and rises to 1.16 TCF in 2013 in scenario II with no dedicated CNG vehicles and 1.89 TCF in scenario IV, in which 5% of all new vehicles are dedicated CNG beginning in 1998 (dedicated and dual energy natural gas vehicles are combined in Table 3). Roughly speaking, there is nine times as much natural gas use by motor vehicles in 2013 in scenario II as in scenario I, and fifteen times as much in scenario IV.

Table 3. Projections of Vehicle Stock and Fuel Use

		1990	1995	2000	2005	2010
Scenario I						
Vehicles (millions)						
	Methanol	0	3.9	11.5	17.6	19.9
	CNG	0	0.4	1.2	1.9	2.3
	Other	171.9	181.8	190.4	198.3	212.3
Miles (billions)						
	Methanol	0	59	150	206	216
	CNG	0	6	16	22	26
	Other	1990	2099	2201	2314	2519
Fuel (billion gallons)						
	Methanol	0	3.6	8.9	12.0	12.5
	CNG	0	0.2	0.6	0.8	1.0
	Other	102.8	97.7	99.3	103.2	111.2
Scenario II						
Vehicles (millions)						
	CNG	0	4.4	13.1	20.3	23.0
	Other	171.9	181.8	190.4	198.3	212.3
Miles (billions)						
	CNG	0	67	174	240	253
	Other	1990	2099	2201	2314	2519
Fuel (billion gallons)						
	CNG	0	2.6	6.6	8.9	9.4
	Other	102.8	97.1	97.8	101.1	109.1
Scenario III						
Vehicles (millions)						
	CNG	0	4.4	13.6	21.6	25.1
	Other	171.9	181.8	190.0	197.0	210.3
Miles (billions)						
	CNG	0	67	180	256	277
	Other	1990	2099	2194	2296	2494
Fuel (billion gallons)						
	CNG	0	2.6	6.9	9.7	10.5
	Other	102.8	97.1	97.4	100.3	108.0
Scenario IV						
Vehicles (millions)						
	CNG	0	4.4	15.4	26.7	33.1
	Other	171.9	181.8	188.2	191.9	202.4
Miles (billions)						
	CNG	0	67	207	323	371
	Other	1990	2099	2165	2224	2393
Fuel (billion gallons)						
	CNG	0	2.6	8.1	12.7	14.8
	Other	102.8	97.1	96.2	97.3	103.8

IV. DOMESTIC NATURAL GAS AND HOME HEATING OIL PRICE ANALYSIS.

Increased demand for domestic natural gas to fuel motor vehicles will raise domestic natural gas prices, encouraging additional development of domestic natural gas supplies and reducing the demand for natural gas by other users. The approach we have taken begins with a baseline energy market forecast and treats the automotive alternative fuel demand as a perturbation of that forecast that increases the demand for natural gas and decreases the demand for motor gasoline. To quantify these impacts, we require a baseline forecast of natural gas, home heating oil, and motor gasoline demand, production, and prices, and a method of calculating the market response to the additional demand for motor vehicle use. The Energy Information Administration carried out the natural gas market analysis and has described their method in detail in another report (EIA, 1989). The essential elements of that method are presented below.

The 1989 Annual Energy Outlook (DOE/EIA-0383 (89)) forecast of natural gas production, consumption, and wellhead price provides the baseline forecast through the year 2000. Since the 1989 AEO does not extend beyond 2000, production consumption and price were extrapolated to 2013 using the following assumed growth rates for natural gas: 1) production, 0.75%/yr., 2) consumption, 0.75%/yr., 3) wellhead natural gas price, 3.5%/yr. This results in levels of domestic production, consumption, and price of 18.5 TCF, 20.3 TCF, and $3.91/MCF at the wellhead in 2000 and 20.4 TCF, 22.4 TCF, and $6.12/MCF, respectively, in 2013. Home heating oil and motor gasoline prices and quantities are similarly taken from the 1989 AEO through 2000 and extrapolated to 2013. The assumed rates are: 0.75%/yr. for home heating oil use, 1.5%/yr. for home heating oil price, 1%/yr. for motor gasoline demand, and 3.5%/yr. for motor gasoline price.

The market supply and demand responses are represented by simple price elasticities derived from EIA's PC-AEO model (EIA, DOE/EIA-MO29, 1988). The elasticity parameters describe the percent change in market price that each percent change in quantity demanded will produce. Thus, they summarize the sensitivity of price to changes in quantity, and quantity to changes in price. In the PC-AEO model elasticities are not constant as we assume them to be in this analysis. Natural gas supply, for example, is very insensitive to price over a period of time as short as one year, since there is little gas suppliers can do in a few months to increase supplies. Given more time, firms will invest more in exploration, development, and production leading to a much greater increase in gas supply. In this analysis, we use elasticities derived from the simulated response of PC-AEO models over a ten-year period to a one-time change in price. Since demand for natural gas by motor vehicles builds up gradually and can be anticipated several years in advance, given knowledge of automobile manufacturers' product plans, the ten-year elasticity should be a reasonable compromise between short-run and full long-run response. The ten-year elasticities used here (Table 4) were taken from an Energy Information Administration study (EIA, Office of Energy Markets and End Use, 1989).

Table 4. Ten-Year Supply and Demand Elasticities

Elasticity of:	With respect to:	Value
Natural Gas Demand	Own Price	-0.28
Natural Gas Supply	Own Price	0.37
Heating Oil Demand	Own Price	-0.26
Heating Oil Price	Heating Oil Supply	0.82*
Heating Oil Price	Gasoline Supply	1.01*

* These values are ratios, not elasticities

Estimation of new market equilibrium prices and quantities for natural gas begins by adding motor vehicle demand for natural gas for the scenario in question to the baseline demand forecast. The supply elasticity, n, is used to compute an initial estimate of the price increase using the definition of the price elasticity of supply:

$$(dQ/Q)/(dp/p) = n \ ,$$

$$dp = (p/Q)\ dQ\ (1/n),$$

where dQ reflects the changed demand attributable to the AMFA incentives, plus any further price induced demand changes. The change in price, dp, will cause a change in the quantity demanded. A first approximation of the change in demand can be estimated using the demand elasticity and its mathematical definition in a similar manner.

$$(dQ/Q)/(dp/p) = e \ ,$$

$$dQ = e\ Q\ (dp/p)$$

The estimated change in demand implies another change in the supply price which, in turn, will imply a change in demand. Provided the elasticities satisfy certain conditions, this process can be repeated until price and quantity converge toward a new equilibrium solution.

A similar process was used to compute the impact of the change in demand for motor gasoline on the price of home heating oil (details can be found in EIA, Energy Markets and End Use, 1989). The heating oil price impact comes via the cross elasticity of the price of distillate oil with respect to the quantity of motor gasoline demanded. When demand for gasoline declines, refineries are able to produce more distillate at a lower price.

This lowers the price of home heating oil, increasing demand and thereby tending to increase price. By iteratively solving for supply price and quantity demanded, a market equilibrium can be found.

The above approach predicts the change in prices and quantities from the baseline forecast caused by the increased demand for natural gas and decreased demand for gasoline. We tested the sensitivity of these results to the values we assumed for natural gas supply and demand elasticities by recomputing the results with 20% lower elasticities and then again with 20% higher elasticities. The change in elasticity values had an impact on the size of the price changes produced but did not change the general tenor of the results.

V. NATURAL GAS AND HEATING OIL PRICE IMPACTS

The Alternative Motor Fuels Act of 1988 scenarios add from 0.12 to 1.89 trillion cubic feet of natural gas demand to the baseline forecast in 2013. In scenario I, in which 10% of automobiles and light trucks produced to obtain CAFE credits under AMFA are natural gas dual energy automobiles, motor vehicle CNG demand starts at 7.5 billion cubic feet in 1993 and increases gradually to 72 billion cubic feet in 2000, 100 billion in 2005, 117 in 2010, and finally 125 billion in 2013. This is on top of a forecasted consumption of 18.3 TCF in 1993 (motor vehicle use is 0.04%), rising to 20.3 TCF in 2000 (motor vehicle use is 0.4%), 21.9 in 2010, and 22.4 TCF in 2013, by which time motor vehicles account for one-half percent of total natural gas demand. Because supply and demand are inelastic, the price impact is somewhat larger (all prices are in 1988$). The initial impact on price at the wellhead in 1993 is 0.16 cents (16 mills per MCF). This increases to 2.2 cents per

MCF by 2000 (a one-half percent increase), 4.8 cents by 2010 and 5.5 cents per MCF in 2013 (an 0.9% increase). Because of the price increases, total natural gas demand increases less than the incremental amount of motor vehicle demand. For example, in 2013, the motor vehicle demand increment is 0.1245 TCF but because price goes up 0.9% at the wellhead on all natural gas, demand falls by 0.0565 TCF, resulting in a net increase of only 0.0680 TCF.

In the three scenarios in which all vehicles produced under the AMFA CAFE credit provisions are CNG vehicles, the price impacts are much greater (Figure 2). In scenario II, in which no dedicated natural gas powered automobiles are produced, the incremental natural gas use by motor vehicles increases from 0.08 TCF in 1993 to 0.80 TCF by 2000, 1.14 TCF in 2010, and 1.16 TCF in 2013. This produces an initial price increase of 1.75 cents per MCF in 1993, which grows to 25 cents per MCF by 2000, 47 cents by 2010, and 52 cents in 2013 (an 8.4% increase). This represents our estimate of the maximum impact possible due to the AMFA credits, assuming that no dedicated CNG vehicles are ever introduced.

In our judgment, it is highly unlikely that a large number of dedicated CNG vehicles would be sold during the forecast period. Nonetheless, unlimited CAFE credits are available for natural gas powered vehicles and so, to define an extreme upper limit, we have included dedicated CNG vehicles in scenarios III and IV. In both of these scenarios it is assumed that after CNG demand for natural gas dual energy automobiles reaches 5% of automobile energy use, dedicated CNG vehicles will be introduced (this occurs in 1998). In scenario III, dedicated vehicles are limited to specialized applications and comprise only 1% of new vehicle sales. In scenario IV, we assume more widespread use and allow 5% of new automobile and light truck sales to be dedicated CNG vehicles. We consider these scenarios even less likely than scenario II.

In scenario III (1% of sales are dedicated CNG) the price impact grows from 0.7% in 1993 to 6.6% in 2000 and 9.5% in 2013. This is a mere 1% more than scenario II which has no dedicated CNG vehicles. Introducing 5% dedicated CNG vehicles in 1993 generates a 7.8% price increase in 2000, which grows to 13.7%, or $0.84/MCF by 2013. These price increases are substantial but represent an upper bound on the range of plausible levels of additional natural gas demand.

The effect of alternative motor fuel demand on home heating oil costs is similar across scenarios (Figure 3). Decreased demand for motor gasoline, no matter what fuel takes its place, drives home heating oil costs down. The differences between scenarios flow from: 1) the greater number of alternative fuel vehicles in scenarios III and IV, and 2) the fact that 15% of methanol is assumed to be gasoline in scenario I versus scenario II. Because of this we assume that a CNG vehicle will displace a slightly greater amount of gasoline than an alcohol-powered vehicle and will, therefore, have a greater impact on distillate fuel prices.

The initial impact of gasoline displacement on residential heating oil prices is 0.5% in 1993 (heating oil prices are prices per barrel to residential consumers, in contrast to the natural gas prices discussed above which are wellhead prices). In scenario I the price decline as a percent of market price peaks around 3.7% in the period 2005 to 2009. Scenario IV generates the greatest impact, a 7% price reduction in 2013 (Table 5). Note that for home heating oil the price impacts are presented in units of 1988 dollars per barrel rather than dollars per thousand cubic feet (approximately 1 million Btu). There are approximately 5.8 million Btu per barrel of distillate fuel oil, so that a $4.40/bbl price reduction is about $0.76 per million Btu. On a Btu basis, about four times more natural gas than distillate fuel oil is consumed in the U.S. each year.

Table 5. Impact of Alternative Motor Fuel Use on Prices of Natural Gas (Wellhead) and Home Heating Oil (to Residential Customers).

Scenario	1993	2000	2005	2010	2013
			Natural Gas (1988$/MCF)		
I	$0.018 (0.73%)	$0.25 (6.4%)	$0.39 (8.3%)	$0.47 (8.4%)	$0.52 (8.4%)
II	$0.018 (0.73%)	$0.26 (6.6%)	$0.42 (9.0%)	$0.52 (9.4%)	$0.58 (9.5%)
III	$0.018 (0.73%)	$0.31 (7.8%)	$0.55 (11.9%)	$0.73 (13.3%)	$0.84 (13.7%)
IV	$0.0016 (0.07%)	$0.022 (0.57%)	$0.037 (0.77%)	$0.048 (0.87%)	$0.055 (0.90%)
			Home Heating Oil (1988$/BBL)		
I	$-0.19 (-0.5%)	$-1.84 (-3.6%)	$-2.52 (-4.5%)	$-2.66 (-4.4%)	$-2.69 (-4.3%)
II	$-0.19 (-0.5%)	$-1.93 (-3.7%)	$-2.73 (-4.9%)	$-2.97 (-5.0%)	$-3.03 (-4.9%)
III	$-0.19 (-0.5%)	$-2.26 (-4.4%)	$-3.58 (-6.4%)	$-4.18 (-7.0%)	$-4.38 (-7.1%)
IV	$-0.16 (-0.4%)	$-1.51 (-2.9%)	$-2.05 (-3.7%)	$-2.19 (-3.6%)	$-2.25 (-3.6%)

The use of elasticities, rather than the full PC-AEO model, greatly simplified this analysis but also raises the possibility that different elasticity values might give very different results. To explore the sensitivity of our results to the key natural gas supply and demand elasticities, we redid the estimation by first lowering the elasticities by 20% and then raising them by 20%. Thus, in the low elasticity test the demand elasticity was reduced from -0.28 to -0.224, and the supply elasticity from 0.37 to 0.296. In the high elasticity test the supply elasticity was raised to 0.444 and the demand elasticity to -0.336. Table 6 shows the sensitivity of natural gas prices to these elasticity values in each of the four scenarios. Reducing the elasticities of supply and demand leads to somewhat greater price increase. In scenario I, gas prices go up 6.9 cents per MCF (1.13%) in 2013 as opposed to 5.5 cents/MCF (0.90%) using the PC-AEO ten-year elasticity estimates. In scenario II gas prices increase $0.64/MCF (10.5%) versus $0.52 (8.4%) with the original elasticity estimates. Assuming greater elasticity of supply and demand produces correspondingly lower price increases. Prices in scenario I increase only 4.6 cents per MCF (0.75%) over the baseline forecast. In scenario II prices are up $0.43/MCF (7.0%). All in all, the general pattern and magnitude of the results are not strongly affected by moderately different assumptions about natural gas supply and demand elasticities. Additional caveats on these results are listed in the EIA study (Office of Energy Markets and End Use, 1989).

Table 6. Sensitivity of Natural Gas Price Changes
to Market Elasticity Assumptions

Scenario	Year 2013 Price Change by Elasticity		
	LOW	PC-AEO 10-YR	HIGH
I	+ 1.1%	+ 0.9%	+ 0.8%
II	+10.5%	+ 8.4%	+ 7.0%
III	+11.8%	+ 9.5%	+ 7.9%
IV	+17.1%	+13.7%	+11.4%

V. EFFECTS OF PRICE IMPACTS ON RESIDENTIAL HEATING EXPENDITURES

The difference in annual expenditures more meaningfully measures the financial impact of fuel price changes on households than the simple per unit prices given above. The Energy Information Administration's Residential Energy Consumption Survey provides information on natural gas and home heating oil consumption and expenditures in the U.S., broken down by a variety of household characteristics. At present, data for 1984-85 are the most recent available. In this section we use these data to assess the impact of fuel price changes on annual household home heating costs.

Rather than attempt a sophisticated modeling of household energy demand, we will simply assume that consumption patterns seen in the 1984-85 REC Survey remain the same through the period of this analysis. In fact, as energy prices rise and technology improves, it is likely that the quantity of energy required for home heating will decrease on a per household basis (DOE/EIA, AEO, 1989, pp. 17 & 21). Thus, our approach should conservatively overestimate the likely cost impact by a small amount. The natural gas cost increases represent wellhead prices, which must be adjusted to represent residential natural gas prices. Two approaches have been used. The first, method I, assumes that residential gas prices equal wellhead prices plus a fixed markup of about $3.80/MCF. In this case residential prices would rise by an amount exactly equal to the wellhead price increase. The second, method II, is based on a regression of national residential prices against wellhead prices for the period 1973-88. The results indicated that residential prices equal wellhead prices times 1.14 plus a constant markup of $3.66.

Impacts of the estimated price changes range from negligible to moderate. Annual heating expenditures by income group and fuel type range from $547 to $901 (1988 $). Only households using either natural gas or heating oil as their main heating fuel are shown in Table 7. In scenario I, the impacts range from +$4.62 to +$6.22 for natural gas (method I), and from -$41 to -$31 for home heating oil. The national average annual home heating cost increase is $5.34 under method I and $6.08 using method II for those using natural gas. The average savings for heating oil users were estimated to be $36.70. Once again, the heating oil savings include the effect of reduced gasoline demand due to both alcohol and CNG vehicles.

When all dual energy vehicles are assumed to be natural gas powered (scenario II), the impacts on households heating with natural gas become noticeable. At the national level the cost is $50 per year over 48 million households for natural gas ($2.4 billion). The savings amount to $44 per year over 12 million households ($528 million, in total). The cost impacts vary only slightly by income group.

Table 7. Natural Gas Consumption and Expenditures for Households Using Natural Gas as Main Heating Fuel

NATURAL GAS

Family Income	No. HH's (millions)	Amount (MCF)	Expenditures (1988$)	Method I Cost Increase 1988$/MCF Scenario I $0.055	Method I Cost Increase 1988$/MCF Scenario II $0.515	Method II Cost Increase 1988$/MCF Scenario I $0.063	Method II Cost Increase 1988$/MCF Scenario II $0.587
< $5,000	4.4	92	$591	$5.06	$47.38	$5.77	$54.01
$5,000-$9,999	7.0	94	$617	$5.17	$48.41	$5.89	$55.19
$10,000-14,999	7.3	84	$547	$4.62	$43.26	$5.27	$49.32
$15,000-19,999	4.8	94	$622	$5.17	$48.41	$5.89	$55.19
$20,000-24,999	4.8	88	$590	$4.84	$45.32	$5.52	$51.66
$25,000-34,999	8.4	98	$662	$5.39	$50.47	$6.14	$57.54
> $34,999	11.3	113	$777	$6.22	$58.20	$7.09	$66.34
TOTAL	47.8	97	$647	$5.34	$49.96	$6.08	$56.95

HOME HEATING OIL

Family Income	No. HH's (millions)	Amount (BBLS)	Expenditures (1988$)	Cost Increase 1988$/MCF Scenario I ($2.25)	Cost Increase 1988$/MCF Scenario II ($2.725)
< $5,000	1.0	13.7	$667	($30.86)	($37.30)
$5,000-$9,999	2.4	15.5	$752	($34.82)	($42.10)
$10,000-14,999	1.9	15.4	$747	($34.55)	($41.77)
$15,000-19,999	1.5	15.0	$713	($33.75)	($40.80)
$20,000-24,999	1.1	16.9	$829	($37.98)	($45.92)
$25,000-34,999	2.0	17.7	$868	($39.75)	($48.05)
> $34,999	2.4	18.4	$901	($41.46)	($50.13)
TOTAL	12.2	16.3	$794	($36.70)	($44.36)

Source: DOE/EIA-0321/1(84), 1987.

VI. CONCLUSIONS

Use of compressed natural gas and methanol by alternative fueled vehicles built in response to the manufacturing incentives of the Alternative Motor Fuels Act of 1988, will tend to increase natural gas prices and reduce the cost of home heating oil. Because of the likely higher cost of compressed natural gas vehicles and other characteristics relative to dual energy alcohol vehicles, it does not seem likely that even ten percent of dual energy vehicles will be powered by CNG. Nonetheless, if manufacturers took full advantage of the AMFA CAFE credits and if ten percent of the dual energy vehicles produced used natural gas, the 0.12 TCF required by these vehicles would raise residential natural gas prices by about 5-6 cents (1988 $) per MCF by the year 2013. This would raise the cost of home heating to an average U.S. household using natural gas as its main heating fuel by $5-$6 per year. We assume that all the gas for CNG vehicles comes from domestic sources and that all of the methanol used by alcohol-powered vehicles is imported.

The maximum conceivable impact on natural gas prices would occur if all dual energy vehicles were built to run on natural gas and, further, if manufacturers began producing dedicated CNG vehicles in significant numbers before the turn of the century. These vehicles would require about fifteen times as much natural gas, 1.9 TCF by 2013. This could push wellhead natural gas prices up as much as $1/MCF in 2013, a 17% increase. The impact of this on residential consumers heating with natural gas would approach $100 per year. If only dual energy vehicles were produced, yet still all were natural gas powered, annual heating costs for gas users would rise by about $50.

The reduction in demand for gasoline caused by substituting alcohol and CNG vehicles would benefit households heating with fuel oil because refiners would be able to produce more distillate at a lower price. Annual heating cost savings would range from $35 to $70 per year, depending on the number and type of alternative fuel vehicles produced. The benefits would accrue to a smaller number of households, however. According to estimates by the Energy Information Administration, only 12 million U.S. households used home heating oil as their main fuel in 1985, while 48 million used natural gas.

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