CBO STAFF MEMORANDUM

CAFE INCENTIVES FOR THE SALE

OF ALTERNATIVE-FUEL VEHICLES

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This staff memorandum was prepared by the Congressional Budget Office (CBO) in response to a request from Senator J. Bennett Johnston, Chairman of the Committee on Energy and Natural Resources, to analyze the economic impact of changes in the nation's corporate average fuel economy (CAFE) standards for light-duty vehicles. This memorandum analyzes the effects of changing CAFE incentives for the sale of vehicles that use alternative fuels. An earlier CBO analysis focused on the relative fuel savings from different proposals for higher CAFE standards.

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INTRODUCTION AND SUMMARY

The Energy Policy and Conservation Act of 1975 first laid out the federal government's corporate average fuel economy (CAFE) standards for new automobiles and light trucks. Fourteen years later, the Alternative Motor Fuels Act (AMFA) established incentives, to begin in 1993, for automakers to produce vehicles capable of using alcohol (including methanol and ethanol) or natural gas. The effect of these requirements was to create a relationship between the demand for gasoline and automakers' incentives for the sale of alternative-fuel vehicles. By artificially raising the fuel economy ratings of alcohol- and natural gas-powered vehicles, the AMFA could provide strong CAFE incentives to car and truck manufacturers to make and sell those vehicles.

Depending on how many alternative-fuel vehicles automakers sell, what level of fuel economy they achieve, and, for those dual-fuel vehicles that may also run on gasoline, how often they are fueled on gasoline, different CAFE incentive policies may cause total gasoline consumption to rise or fall. This analysis of policy options for increasing CAFE incentives for alternative-fuel vehicles demonstrates general conditions that would lead not only to increased sales of dual-fuel vehicles, but also to greater total gasoline consumption.

How the Sale of Alternative-Fuel Vehicles May Benefit Automakers

The design and the mix of vehicles sold affect calculations of average fuel economy. Automakers can raise the overall fuel economy of the vehicles they sell by altering engine and body design, vehicle size, or performance. Such changes would generally increase the cost of vehicles, with the cost per vehicle of improving fuel economy rising with higher standards for fuel economy. Optionally, automakers may save themselves the cost of some these changes if they can stimulate sales of their more efficient models. Automakers may also save themselves some costs of fuel economy improvements if they take advantage of the CAFE incentives of the AMFA.

Automakers calculate the fuel economy of vehicles using fuels other than gasoline on the basis of the gasoline-equivalent of the energy content of those fuels. Generally, in terms of British thermal units (Btus) consumed per mile, alternative-fuel vehicles are not more fuel-efficient than conventional vehicles. But the AMFA allows automakers to apply "fuel economy multipliers" for vehicles powered by alcohol and natural gas, enabling them to factor those vehicles into their corporate average fuel economy at nearly seven times their actual ratings. The higher the statutory fuel economy of alternative-fuel vehicles sold, the lower the fuel economy of gasoline-powered vehicles needed to meet any corporate average fuel economy standard.

The efficiency ratings of dual-fuel vehicles, capable of switching between gasoline and alcohol or between gasoline and natural gas, are further inflated because automakers are allowed to assume that those vehicles are operated half time on alcohol or natural gas. This statutory share probably understates the actual use of

gasoline by these vehicles. (This analysis assumes dual-fuel vehicles on the road will use gasoline 75 percent of the time.) In part because of the resulting boost to their fuel economy multiplier, automakers are shown in this analysis to prefer dual-fuel vehicles to dedicated-fuel vehicles.

Taking into account this advantage in statutory fuel economy, the Alternative Motor Fuels Act limits the credit automakers can apply from the sale of dual-fuel vehicles towards the reduction of fuel economy of conventional, gasoline-powered cars. They cannot use dual-fuel vehicle sales to reduce the fuel economy of conventional vehicles by more than 1.2 miles per gallon (MPG) for model years 1993 to 2004 and 0.9 MPG for 2005 to 2008. (This analysis assumes the CAFE credits will continue after 2008.) Once these credit caps are reached, the preferential calculation of fuel economy for dual-fuel vehicles would presumably cease. Reductions in fuel economy from the sale of dedicated-fuel vehicles are not limited.

The Alternative Motor Fuels Act offers CAFE incentives only for the sale of vehicles powered by alcohol or natural gas. A separate Department of Energy rulemaking gives electric vehicles a boost in the calculation of fuel economy. For CAFE purposes, the fuel economy of electric vehicles can be based on the small amount of oil used in generating the electricity they consume. After accounting for losses of energy in electricity generation and transmission, the statutory fuel economy of electric vehicles is approximately double their actual fuel economy.

Vehicles propelled by other fuels (principally propane) receive no preferential treatment and so have a competitive handicap. Also, new companies that only manufacture alternative-fuel vehicles cannot realize these cost savings and may find it difficult to compete with multiproduct-line manufacturers.

Factors Affecting the Decision to Produce Alternative-Fuel Vehicles

The use of fuel economy multipliers may yield mileage figures on paper for individual vehicles that are much higher than the 1991 CAFE standard of 27.5 MPG for passenger cars and 20.5 MPG for light trucks. As long as the statutory fuel economy of alternative-fuel vehicles exceeds the standard for the corporate average, the more vehicles powered by alcohol and natural gas that automakers sell, the lower the required fuel economy of their conventional gasoline-powered fleet. And the lower the required fuel economy of gasoline vehicles, the less money automakers need spend on improvements for the sake of efficiency.

For automakers, the decision to produce alternative-fuel vehicles hinges on an economic trade-off. Is the cost of producing and marketing an additional alternative-fuel vehicle greater or less than the saving to be had from doing less to improve the fuel economy of conventional vehicles? The cost of alternative-fuel vehicles varies with fuel, engine technology, and class of vehicle. Precisely how much automakers may save will depend on the costs of redesigning conventional vehicles to improve fuel economy.

CAFE credits on their own may not provide sufficient incentives to automakers to produce alternative-fuel vehicles. Beginning in 1996, however, the Clean Air Act Amendments of 1990 will mandate sales of alternative-fuel vehicles in certain regions of the country. If automakers have to sell these vehicles to comply with the Clean Air Act, the incentives of the Alternative Motor Fuels Act may well influence their choices of alternative fuels and engine technologies and their selections of types of vehicles to convert.

How CAFE Incentives May Affect Gasoline Demand

The automakers' choice of alternative fuels and vehicle types will ultimately determine how CAFE credits affect the demand for gasoline. Because CAFE standards apply only to new vehicles sold each year, a change in the standards or in the use of credits by automakers could only affect the average fuel economy of the fleet slowly, as new vehicles come into service and older, less efficient ones go out.[1] An increase in the average fuel economy of gasoline-powered vehicles combined with an increase in the use of alternative fuels would save gasoline. However, if the increased demand for alternative fuels came at the price of lower fuel economy for gasoline-powered vehicles, gasoline demand could increase instead.

Analysis of CAFE Incentives and Key Findings

Changing any of three key elements of the CAFE incentive program could affect market penetration by alternative-fuel vehicles, the fuel economy required for gasoline-powered vehicles, and, as a consequence, the demand for gasoline. Those three key elements are:

- The maximum reduction in average fuel economy for conventional vehicles made possible by the sale of dual-fuel vehicles (or CAFE credit cap),
- The fuel economy multipliers for alternative-fuel vehicles, and
- The percentage of total fuel consumption by dual-fuel vehicles that automakers may assume to be gasoline in their CAFE calculation.

This analysis examines the impact on automakers' incentives to supply alternative-fuel vehicles and on the demand for gasoline of different policy options to change these elements. It does so under a range of assumptions about the costs of improvements in fuel economy and the costs of supplying alternative-fuel vehicles. In

1. The turnover rate for the fleet, and the improvement in fleet efficiency, could slow if consumers reacted to changes in the design or cost of vehicles by buying fewer new cars. However, vehicle efficiency is probably more important in deciding which car to buy than in the basic decision to buy a car. Unless corporate average fuel economy standards become very costly, the level of new car sales and the turnover rate should not change much.

a "base-case" set of assumptions, the average cost of raising the fuel economy of passenger cars from 27.5 MPG to 37 MPG would be about $100 for each MPG of improvement, and dual-fuel methanol vehicles (as an example) would cost $500 more than comparably equipped gasoline vehicles. Dual-fuel vehicles are assumed to dominate the market for alternative-fuel vehicles. Accordingly, the analysis also considers the impact on gasoline demand of different levels of gasoline use by dual-fuel vehicles, from 50 percent to 100 percent.

The analysis indicates that policies that create CAFE incentives, including the current incentives program, would have little impact on sales of alternative-fuel vehicles or on the demand for gasoline as long as CAFE standards remain at their current level (see Tables 1 and 2). Only the minimum numbers needed to meet the requirements of the Clean Air Act Amendments would be sold. Even with higher CAFE standards, CAFE incentives would have no impact if the cost of supplying alternative-fuel vehicles were significantly higher than assumed in the base case.

With higher corporate average fuel economy standards and with base-case costs, market penetration by dual-fuel vehicles could be very significant. Sales of these vehicles would be even higher if the costs of fuel economy improvements were greater than assumed in the base case. However, the resulting drop in fuel economy of gasoline-powered cars would offset the gasoline savings from increased sales of dual-fuel vehicles (see Table 3). Policies that increase CAFE incentives for the sale of dual-fuel vehicles could result in still higher gasoline demand, since the analysis assumes dual-fuel vehicles run 75 percent of the time on gasoline and have on-road fuel economies inferior to gasoline-powered cars.

In general, the different policy options do not yield greatly differing levels of gasoline demand. Increased gasoline demand as a result of the lower fuel economy of gasoline-powered vehicles narrowly offsets the reduced gasoline demand resulting from higher use of alternative fuels (see Table 4). If dual-fuel vehicles used gasoline only 50 percent of the time, policies that increased the CAFE credits from the sale of dual-fuel vehicles would be almost precisely in balance, with no net change in gasoline demand. If gasoline use by dual-fuel vehicles were greater than 75 percent, however, the effect of lower fuel economy of gasoline-powered vehicles would dominate to a greater extent, and increased CAFE incentives would result in even higher gasoline demand.

TABLE 1. DEMAND FOR MOTOR GASOLINE UNDER ALTERNATIVE SCENARIOS, 1990-2020
(In millions of barrels per day)

	1990	1996	2001	2006	2010	2015	2020
Scenario 1 (Current CAFE Standards, Base Costs)							
Option 1 (Current Incentives)	7.21	7.48	7.91	8.35	8.71	9.41	10.21
Option 2 (Higher Credit Cap)	<------------------ Same as Option 1 ------------------>						
Option 3 (No Credit Cap)	<------------------ Same as Option 1 ------------------>						
Option 4 (No Incentives)	7.21	7.48	7.91	8.35	8.71	9.35	10.03
Scenario 2 (Higher CAFE Standards, Base Costs)							
Option 1 (Current Incentives)	7.21	7.47	7.80	7.97	8.05	8.48	9.12
Option 2 (Higher Credit Cap)	7.21	7.47	7.80	7.97	8.07	8.53	9.17
Option 3 (No Credit Cap)	7.21	7.47	7.80	7.97	8.07	8.53	9.20
Option 4 (No Incentives)	7.21	7.47	7.77	7.90	7.94	8.34	8.95
Scenario 3 (Higher CAFE, Higher Cost of MPG Improvements)							
Option 1 (Current Incentives)	7.21	7.47	7.80	7.99	8.05	8.46	9.07
Option 2 (Higher Credit Cap)	7.21	7.47	7.81	8.02	8.08	8.47	9.07
Option 3 (No Credit Cap)	7.21	7.47	7.81	8.04	8.16	8.64	9.32
Option 4 (No Incentives)	7.21	7.47	7.77	7.90	7.94	8.34	8.95
Scenario 4 (Higher CAFE, Higher Alternative Vehicle Cost)							
Option 1 (Current Incentives)	7.21	7.47	7.80	7.97	8.04	8.47	9.09
Option 2 (Higher Credit Cap)	<------------------ Same as Option 1 ------------------>						
Option 3 (No Credit Cap)	<------------------ Same as Option 1 ------------------>						
Option 4 (No Incentives)	7.21	7.47	7.77	7.90	7.94	8.34	8.95

SOURCE: Congressional Budget Office.

NOTE: CAFE = corporate average fuel economy; MPG = miles per gallon.

TABLE 2. SHARE OF ALTERNATIVE-FUEL VEHICLES IN NEW SALES OF PASSENGER CARS UNDER ALTERNATIVE SCENARIOS, 1990-2020
(Percent of annual vehicle sales)

	1990	1996	2001	2006	2010	2015	2020
Scenario 1 (Current CAFE Standards, Base Costs)							
Option 1 (Current Incentives)	0.0	1.5	3.4	3.7	4.1	4.0	3.9
Option 2 (Higher Credit Cap)	0.0						
Option 3 (No Credit Cap)	0.0	<--------------- Same for All Options --------------->					
Option 4 (No Incentives)	0.0						
Scenario 2 (Higher CAFE Standards, Base Costs)							
Option 1 (Current Incentives)	0.0	1.5	3.4	9.2	8.9	8.5	8.0
Option 2 (Higher Credit Cap)	0.0	1.5	3.4	16.5	16.8	16.0	15.2
Option 3 (No Credit Cap)	0.0	1.5	3.4	15.7	17.0	19.4	21.3
Option 4 (No Incentives)	0.0	1.5	3.4	3.7	4.1	4.0	3.9
Scenario 3 (Higher CAFE, Higher Cost of MPG Improvements)							
Option 1 (Current Incentives)	0.0	1.5	11.1	9.2	8.9	8.5	8.0
Option 2 (Higher Credit Cap)	0.0	1.5	17.8	17.2	16.8	16.0	15.2
Option 3 (No Credit Cap)	0.0	1.5	19.1	34.7	35.0	35.4	35.7
Option 4 (No Incentives)	0.0	1.5	3.4	3.7	4.1	4.0	3.9
Scenario 4 (Higher CAFE, Higher Alternative Vehicle Cost)							
Option 1 (Current Incentives)	0.0	1.5	3.4	3.7	4.1	4.0	3.9
Option 2 (Higher Credit Cap)	0.0						
Option 3 (No Credit Cap)	0.0	<--------------- Same for All Options --------------->					
Option 4 (No Incentives)	0.0						

SOURCE: Congressional Budget Office.

NOTE: CAFE = corporate average fuel economy; MPG = miles per gallon.

TABLE 3. LOWERED CAFE REQUIREMENTS FOR GASOLINE-POWERED PASSENGER CARS UNDER ALTERNATIVE SCENARIOS, 1990-2020
(Miles per gallon)

	1990	1996	2001	2006	2010	2015	2020
Scenario 1 (Current CAFE Standards, Base Costs)							
Option 1 (Current Incentives)	27.5	27.3	27.1	27.0	27.0	27.0	27.0
Option 2 (Higher Credit Cap)	27.5	<------------- Same as Option 1 ------------>					
Option 3 (No Credit Cap)	27.5	<------------- Same as Option 1 ------------>					
Option 4 (No Incentives)	27.5	27.5	27.5	27.5	27.5	27.7	27.7
Scenario 2 (Higher CAFE Standards, Base Costs)							
Option 1 (Current Incentives)	27.5	30.0	33.7	36.1	36.1	36.1	36.1
Option 2 (Higher Credit Cap)	27.5	30.0	33.7	35.3	35.2	35.2	35.2
Option 3 (No Credit Cap)	27.5	30.0	33.7	35.4	35.2	34.7	34.4
Option 4 (No Incentives)	27.5	30.3	34.4	37.5	37.6	37.5	37.5
Scenario 3 (Higher CAFE, Higher Cost of MPG Improvements)							
Option 1 (Current Incentives)	27.5	30.0	32.8	36.1	36.1	36.1	36.1
Option 2 (Higher Credit Cap)	27.5	30.0	32.0	35.2	35.2	35.2	35.2
Option 3 (No Credit Cap)	27.5	30.0	31.8	32.7	32.6	32.2	31.9
Option 4 (No Incentives)	27.5	30.3	34.4	37.5	37.6	37.5	37.5
Scenario 4 (Higher CAFE, Higher Alternative Vehicle Cost)							
Option 1 (Current Incentives)	27.5	30.0	33.7	36.6	36.6	36.6	36.6
Option 2 (Higher Credit Cap)	27.5	<------------- Same as Option 1 ------------>					
Option 3 (No Credit Cap)	27.5	<------------- Same as Option 1 ------------>					
Option 4 (No Incentives)	27.5	30.3	34.4	37.5	37.6	37.5	37.5

SOURCE: Congressional Budget Office.

NOTE: CAFE = corporate average fuel economy; MPG = miles per gallon.

TABLE 4. DEMAND FOR MOTOR GASOLINE UNDER ALTERNATIVE SCENARIOS AND ASSUMPTIONS ABOUT GASOLINE USAGE BY DUAL-FUEL VEHICLES, 2020
(In millions of barrels per day)

	Gasoline Share of Total Fuel Use		
	50 Percent	75 Percent	100 Percent
Scenario 1 (Current CAFE Standards, Base Costs)			
Option 1 (Current Incentives)	10.15	10.21	10.27
Option 2 (Higher Credit Cap)	<------- Same as Option 1 ------>		
Option 3 (No Credit Cap)	<------- Same as Option 1 ------>		
Option 4 (No Incentives)	10.01	10.03	10.05
Scenario 2 (Higher CAFE Standards, Base Costs)			
Option 1 (Current Incentives)	9.03	9.12	9.21
Option 2 (Higher Credit Cap)	9.00	9.17	9.34
Option 3 (No Credit Cap)	9.00	9.20	9.40
Option 4 (No Incentives)	8.90	8.95	9.00
Scenario 3 (Higher CAFE, Higher Cost of MPG Improvements)			
Option 1 (Current Incentives)	8.94	9.07	9.20
Option 2 (Higher Credit Cap)	8.83	9.07	9.31
Option 3 (No Credit Cap)	8.88	9.32	9.76
Option 4 (No Incentives)	8.90	8.95	9.00
Scenario 4 (Higher CAFE, Higher Alternative Vehicle Cost)			
Option 1 (Current Incentives)	9.03	9.09	9.15
Option 2 (Higher Credit Cap)	<------- Same as Option 1 ------>		
Option 3 (No Credit Cap)	<------- Same as Option 1 ------>		
Option 4 (No Incentives)	8.90	8.95	9.00

SOURCE: Congressional Budget Office.

NOTE: CAFE = corporate average fuel economy; MPG = miles per gallon.

POLICY OPTIONS: CAFE INCENTIVES FOR ALTERNATIVE-FUEL VEHICLES

Four different policy options for changing CAFE incentives are considered in this memorandum (see Table 5):

- o First, continue the current program of CAFE incentives;
- o Second, double the CAFE credit cap for sales of dual-fuel vehicles;
- o Third, eliminate the credit cap, so there would no limits on how much the fuel economy of gasoline vehicles may be lowered by sales of dual-fuel vehicles; and
- o Fourth, discontinue all CAFE incentives for the sale of alternative-fuel vehicles, including fuel economy multipliers and the artificially low gasoline use that automakers assume for dual-fuel vehicles.

Regardless of the underlying assumptions about the costs of fuel economy improvements or the costs of supplying alternative-fuel vehicles, neither of the two options for increasing the CAFE incentives (Options 2 and 3) would affect the demand for alternative-fuel vehicles as long as CAFE standards remain at their current level (27.5 MPG).

If fuel economy standards were raised to 37 MPG in 2006, the current CAFE incentives would assume greater value. The share of new car sales accounted for by dual-fuel vehicles would double, from about 4 percent (the minimum needed to meet requirements of the Clean Air Act Amendments) with current CAFE standards to 8 percent with higher standards (see Table 2). However, as market penetration by dual-fuel vehicles increases, gasoline demand rises. Gasoline savings from greater alternative fuel use are more than offset by the effects of lowered fuel economy of gasoline-powered vehicles.

CAFE incentive options that increase market penetration result in even higher gasoline demand. Assuming higher CAFE standards and base-case costs, a doubling of the CAFE credit cap (Option 2) could raise dual-fuel vehicles' share of new car sales in 2020 to over 15 percent. Eliminating the CAFE credit cap altogether (Option 3) could increase their share of new car sales to over 21 percent.

With both current CAFE standards and higher standards, the only policy option that lowers gasoline demand is the one that would eliminate all CAFE incentives for the sale of alternative-fuel vehicles (Option 4). Savings result because gasoline-powered vehicles would need to have greater fuel economy to compensate for the assumed poorer on-road fuel economy of alternative-fuel vehicles. This does not mean, however, that CAFE incentives for the sale of alternative-fuel vehicles represent poor energy policy.

TABLE 5. CAFE INCENTIVE OPTIONS FOR ALTERNATIVE-FUEL VEHICLES

			Fuel Economy Multipliers	
	CAFE Credit Cap	Statutory Gasoline Use by Dual-Fuel Vehicles	Alcohol and Natural Gas	Electric Vehicles
Option 1 (Current Incentives)	Base Case (1.2 MPG[a])	Base Case (50 Percent)	Base Case (6.7[b])	Base Case (2.2[c])
Option 2 (Higher Credit Cap)	100 Percent Higher	Base Case	Base Case	Base Case
Option 3 (No Credit Cap)	No Limit	Base Case	Base Case	Base Case
Option 4 (No Incentives)	No Limit	75 Percent	1.0	1.0

SOURCE: Congressional Budget Office.

NOTE: CAFE = corporate average fuel economy; MPG = miles per gallon.

a. The CAFE incentives provided by the Alternative Motor Fuels Act, which terminate after 2008, are assumed to be extended indefinitely here to aid in comparing options.
b. Actually, the Alternative Motor Fuels Act states that the fuel economy of alcohol and natural gas vehicles should be divided by 0.15. One divided by 0.15 equals 6.7.
c. The Code of Federal Regulations (10 CFR Chapter 11, Part 474) specifies a range of multipliers (or petroleum equivalency factors) from 1.8 to 2.2, depending on the number of petroleum-powered accessories.

Despite some increase in gasoline demand, alternative-fuel vehicles would instill some flexibility in fuel choice that is currently missing in the transportation sector. Added flexibility would help mitigate the adverse economic effects of future oil price increases as drivers switch to nonpetroleum fuels. Prices and supplies of alternative fuels would be more responsive to changes in the price of oil, too.

CBO selected the four options for incentives to cover a range of potential policy options that the Congress may consider. The Congress is not currently considering any of these options, and this analysis assigns no rankings to them (for example, along the lines of net social benefits). The assumption of higher CAFE standards evaluated in the study reflects a proposed amendment by Senator J. Bennett Johnston to the National Energy Security Act, a bill currently pending in the Congress.[2]

COST SCENARIOS: IDENTIFYING THE RANGE OF UNCERTAINTY

The ultimate effect of CAFE incentives for alternative-fuel vehicles on gasoline demand will depend on the response of automakers to those incentives and, for dual-fuel vehicles, on what fraction gasoline accounts for in their total fuel use. Regardless of the precise nature of any CAFE incentive program, automakers' incentives for selling those vehicles will be affected by three factors:

- o The future level of CAFE standards (presently being debated in the Congress);
- o The cost of making improvements in fuel economy in conventional vehicles; and
- o The incremental cost of producing and marketing alternative-fuel vehicles (that is, beyond the cost of comparably equipped conventional vehicles).

To address the range of uncertainty underlying these factors, this analysis evaluates the gasoline savings for each of the four options for CAFE incentives under four scenarios, or alternative sets of assumptions. The analysis also

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2. These same CAFE standards are addressed separately in the Congressional Budget Office Staff Memorandum "Fuel Savings from Alternative Proposed Standards for Corporate Average Fuel Economy" (June 1991).

looks at gasoline demand resulting from these scenarios under a range of assumptions about gasoline use by dual-fuel vehicles: from 50 percent to 100 percent of total fuel use (see Table 4).

Scenario 1 assumes the current CAFE standards for 1991 will continue, along with a set of base-case assumptions about the costs of improving fuel economy and of supplying alternative-fuel vehicles. Scenario 2 assumes higher CAFE standards, along with the same base-case cost assumptions used in Scenario 1 (see Table 6).

The other two scenarios assume the same higher CAFE standards along with varying assumptions related to the economics of converting part of the vehicle fleet to alternative fuels. Scenario 3 assumes more favorable conversion costs (relative to Scenario 2) by assuming a higher cost of raising the fuel economy of conventional vehicles. Scenario 4 assumes less favorable conversion costs by assuming higher incremental costs of supplying alternative-fuel vehicles. Analytical scenarios are described in Table 7.

TABLE 6. CURRENT AND PROPOSED CAFE STANDARDS (Miles per gallon)

	1990	1996	2001	2006	2010
Current Standards					
Passenger cars	27.5	27.5	27.5	27.5	27.5
Light trucks	20.0	20.5	20.5	20.5	20.5
Proposed Standards					
Passenger cars	27.5	30.2	34.0	37.0	37.0
Light trucks	20.0	22.0	24.0	26.6	26.6

SOURCE: Congressional Budget Office.

Gasoline savings for each CAFE incentive option represent the difference between the forecast for gasoline demand with a continuation of the current incentives program (Option 1) and the forecast with each respective option (see Table 8). On the basis of expected turnover in the vehicle fleet, the ultimate savings from the higher efficiency standards of all three options would be achieved by 2020.

TABLE 7. SCENARIO DEFINITIONS

	CAFE Standards[a]	Cost of MPG Improvements[b]	Incremental Cost of Alternative-Fuel Vehicles[c]
Scenario 1	Current 1991 Standards	Base Case	Base Case
Scenario 2	Proposed Standards	Base Case	Base Case
Scenario 3	Proposed Standards	50% Higher	Base Case
Scenario 4	Proposed Standards	Base Case	50% Higher

SOURCE: Congressional Budget Office.

NOTE: MPG = miles per gallon.

a. See Table 3.
b. See Appendix, Figure A-1.
c. See Appendix, Table A-2.

TABLE 8. GASOLINE SAVINGS UNDER ALTERNATIVE SCENARIOS, 1990-2020
(In millions of barrels per day)

	1990	1996	2001	2006	2010	2015	2020
Scenario 1 (Current CAFE Standards, Base Costs)							
Total Gasoline Demand							
Option 1 (Current Incentives)	7.21	7.48	7.91	8.35	8.71	9.41	10.21
Savings over Option 1							
Option 2 (Higher Credit Cap)	n.a.	<------------------		No Savings			------------------>
Option 3 (No Credit Cap)	n.a.	<------------------		No Savings			------------------>
Option 4 (No Incentives)	n.a.	0.00	0.00	0.00	0.00	0.06	0.18
Scenario 2 (Higher CAFE Standards, Base Costs)							
Total Gasoline Demand							
Option 1 (Current Incentives)	7.21	7.47	7.80	7.97	8.05	8.48	9.12
Savings over Option 1							
Option 2 (Higher Credit Cap)	n.a.	0.00	0.00	0.00	-0.02	-0.05	-0.05
Option 3 (No Credit Cap)	n.a.	0.00	0.00	0.00	-0.02	-0.05	-0.08
Option 4 (No Incentives)	n.a.	0.00	0.03	0.07	0.11	0.14	0.17
Scenario 3 (Higher CAFE, Higher Cost of MPG Improvements)							
Total Gasoline Demand							
Option 1 (Current Incentives)	7.21	7.47	7.80	7.99	8.05	8.46	9.07
Savings over Option 1							
Option 2 (Higher Credit Cap)	n.a.	0.00	-0.01	-0.03	-0.03	-0.01	0.00
Option 3 (No Credit Cap)	n.a.	0.00	-0.01	-0.05	-0.11	-0.18	-0.25
Option 4 (No Incentives)	n.a.	0.00	0.03	0.09	0.09	0.12	0.12
Scenario 4 (Higher CAFE, Higher Alternative Vehicle Cost)							
Total Gasoline Demand							
Option 1 (Current Incentives)	7.21	7.47	7.80	7.97	8.04	8.47	9.09
Savings over Option 1							
Option 2 (Higher Credit Cap)	n.a.	<------------------		No Savings			------------------>
Option 3 (No Credit Cap)	n.a.	<------------------		No Savings			------------------>
Option 4 (No Incentives)	n.a.	0.00	0.03	0.07	0.10	0.13	0.14

SOURCE: Congressional Budget Office.

NOTE: Negative values indicate increased demand. CAFE = corporate average fuel economy; MPG = miles per gallon; n.a. = not applicable.

The major findings of the quantitative analysis of CAFE incentives are as follows:

- o Estimates of gasoline demand in 2020 with current CAFE incentives range between 9.07 million barrels per day (bbl/day) (with higher CAFE standards and higher costs of supplying alternative-fuel vehicles) and 10.21 million bbl/day (with current CAFE standards and base-case costs).

- o If CAFE standards remained at their current level and costs remained near their base-case level (Scenario 1), neither of the two options for increasing CAFE incentives would affect gasoline demand. Automakers would supply only the minimum number of alternative-fuel vehicles required by the Clean Air Act Amendments of 1990.

- o With higher CAFE standards and base-case costs (Scenario 2), the impact on gasoline demand of changing the current incentives policy would range from a decrease of 170,000 bbl/day (with no incentives) to an increase of 80,000 bbl/day (with no credit cap). Little difference exists between doubling the credit cap and lifting it altogether.

- o With higher CAFE standards and higher costs of improvements in fuel economy (Scenario 3), the impact on gasoline demand of changing CAFE incentives ranges between a decrease of 120,000 bbl/day (with no incentives) and an increase of 250,000 bbl/day (with no credit cap).

- o With higher CAFE standards and higher incremental costs of supplying alternative-fuel vehicles (Scenario 4), neither of the options for increasing CAFE incentives would affect gasoline demand. Alternative-fuel vehicles would be too costly, regardless of the incentive package. Automakers would supply only the minimum number of alternative-fuel vehicles required by the Clean Air Act Amendments of 1990.

Both the current CAFE credit cap (Option 1) and a credit cap twice as high (Option 2) may constrain incentives for automakers to supply more alternative-fuel vehicles if CAFE standards were higher and the costs of improvements in fuel economy were at the base-case level or higher (Scenarios 2 or 3). (The extent of market penetration by alternative-fuel vehicles is shown in Table 2.) In that situation, raising the credit cap further would result in higher sales of dual-fuel vehicles. If the cost of fuel economy improvements were greater (Scenario 3), lifting the credit cap could more than double the market penetration of those vehicles (Scenario 3). The penetration by dual-fuel vehicles in Scenarios 2 and 3 with no credit cap (Option 3) reflects an

economic balance between savings from fuel economy improvements and costs of supplying dual-fuel vehicles.

A further finding of the study is that automakers may have significantly different levels of incentives for supplying alternative-fuel vehicles as light trucks or passenger cars. With higher CAFE standards and base-case costs (Scenario 2), sales of alternative-fuel vehicles as passenger cars would be above the minimum needed to meet the requirements of the Clean Air Act Amendments; sales as light trucks would be at the minimum. However, with higher costs of improving fuel economy (Scenario 3), sales of alternative-fuel vehicles as light trucks grow in relation to sales of these vehicles as passenger cars.

Several factors account for differences in the relative economics of supplying dual-fuel passenger cars and light trucks. The credit cap is currently the same for both passenger cars and light trucks, even though the CAFE standard for passenger cars is higher. As a result, the maximum market penetration by dual-fuel light trucks is greater than that for dual-fuel passenger cars for any given cap on CAFE credits. Moreover, this analysis assumes the costs of improving fuel economy are higher for light trucks than for passenger cars. This means that for any given percentage of increase in the costs of fuel economy improvements (as in Scenario 3), the costs of those improvements, when compared with the incremental costs of supplying alternative-fuel vehicles, rises more for light trucks than for passenger cars.

IMPORTANT CAVEATS TO STUDY FINDINGS

The range of results presented here does not encompass the full economic response that would result from the CAFE incentives or take account of all the uncertainties underlying the estimates. Potential gasoline savings depend on a number of further assumptions that have not been investigated here. First, what are consumer preferences for different types of conventional and alternative-fuel vehicles? Second, what would happen to the average fuel economy of the conventional gasoline-powered fleet in the absence of any changes in CAFE standards or in CAFE incentives for alternative-fuel vehicles? Third, what are the relative sales of different types of alternative-fuel vehicles? And fourth, what would happen to the demand for alternative-fuel vehicles in the absence of CAFE incentives?

Limited Demand for Alternative-Fuel Vehicles

Because this analysis focuses on the automakers' response to the CAFE incentives program, it takes only partial account of the consumer response. It is unlikely that automakers could save enough from avoided improvements in fuel economy to compensate consumers fully for the cost of owning alternative-fuel vehicles. In addition to the higher purchase price for alternative-fuel vehicles, the full cost of ownership would reflect the price and availability of the fuels and maintenance and differences in vehicle performance. CBO has not analyzed these additional costs.

If the full added cost of owning alternative-fuel vehicles were significantly greater than the direct cost of producing and marketing them, consumers would not buy as many of these vehicles as automakers would want to sell. In that case, the sales of alternative-fuel vehicles indicated in this study would be overstated.

The analysis did take partial account of the likely higher costs of owning dedicated-fuel vehicles in deciding only to consider sales of dual-fuel vehicles. On the basis of assumed fuel economies and direct costs of production and marketing alone, the model used for the study indicated that dedicated-fuel vehicles would be preferred over dual-fuel vehicles by automakers under the no-CAFE incentives option. If dedicated-fuel vehicles were indeed sold under that option, gasoline demand would be significantly lower by 2020 (8.68 million bbl/day instead of 8.95 million bbl/day in Scenarios 2, 3, and 4).

Independent Changes in Average Fuel Economy

Some improvement in vehicle efficiency may result from technological improvements unrelated to CAFE standards or from increases in gasoline prices that encourage consumers to buy more efficient vehicles. Such improvements would diminish the incentives for automakers to supply alternative-fuel vehicles for the purpose of avoiding improvements in fuel economy in the gasoline-powered fleet. At the same time, any continuation of the recent trend in demand toward larger, more powerful cars would increase the incentives for automakers.

This analysis includes a baseline improvement in the average fuel economy of conventional and alternative-fuel vehicles in all options and scenarios (without more stringent fuel economy standards) as a result of a long-term rise in gasoline prices. The average fuel economy of passenger cars would reach 30.1 MPG by 2010 in response to gasoline prices at $1.50 per

gallon by that year (in 1991 dollars). The analysis does not address additional changes in fleet efficiency that might occur as consumers responded to the higher costs of vehicles (for example, by buying more light trucks to avoid paying for higher levels of unwanted improvements in the fuel economy of passenger cars).

The analysis assumes that growth in the fuel economy of alternative-fuel vehicles over time is commensurate only with the growth in gasoline prices. It is reasonable to assume, however, that some of the technological improvements that find their way into conventional gasoline vehicles (for example, piston redesign or lower vehicle weight) may also be applied to some alternative-fuel vehicles. If so, the demand for future gasoline would be lower than shown here. Conceptually, CBO found it difficult to determine how many fuel economy improvements would find their way into alternative-fuel vehicles, since the sale of alternative-fuel vehicles was largely premised on the value of avoiding those improvements.

Relative Sales of Different Alternative-Fuel Vehicles

CBO's analysis assumes that the relative importance of different technologies will not change (see Table A-2). As a result, the study findings are probably biased against certain types of dedicated-fuel vehicles. The methodology groups all alternative-fuel vehicles into dual- and dedicated-fuel classes. To the extent that the dual-fuel vehicle group is found to be more profitable for automakers to supply (as indicated in the study), this approach is biased against the more fuel-efficient vehicles within the dedicated-vehicle group.

If dedicated-fuel vehicles replaced dual-fuel vehicles (which are assumed to operate 75 percent of the time on gasoline) in some scenarios, gasoline savings would be higher than shown here. Increased sales of dedicated-fuel vehicles would lead unambiguously to lower gasoline demand.

Independent Changes in the Demand for Alternative-Fuel Vehicles

As noted in the first section, the Clean Air Act Amendments will create a regional demand for alternative-fuel vehicles quite independent of any cost or policy incentives for automakers. The analysis assumes a base level of sales of alternative-fuel vehicles resulting from the amendments (see Table A-1). This sales level does not change for options or scenarios.

APPENDIX A: METHODS AND ASSUMPTIONS

The findings of this study are based on runs of the Energy Information Administration's PC-Transportation Model, as used to produce EIA's *Annual Energy Outlook 1991* base-case forecast.[3] The EIA model simulates the effects of new-vehicle fuel economy on the changing composition of the fleets of passenger cars and light trucks.[4] Gasoline prices, vehicle fuel economy, and income jointly determine the demand for travel. Average fleet fuel economy determines the fuel requirements of that travel demand.

Assumptions of the Model

The objective of this analysis was to investigate the relationship between the demand for motor gasoline and CAFE incentives for the sale of alternative-fuel vehicles. Accordingly, there was no need to alter basic assumptions of the EIA model that would not be significantly affected by changes in the CAFE incentives program. Specifically, CBO did not alter the important assumptions of the *Annual Energy Outlook 1991* base case concerning the total stock of vehicles (see Table A-1).

CBO also retained the model's assumptions concerning growth in the real price of gasoline (1.7 percent annually), growth in real disposable income (1.7 percent annually), and the relationship between income and vehicle-miles traveled (an increase of 1 percent in real income causes an increase of 0.8 percent in miles driven). These price and income forecasts differ from CBO's baseline forecast.

Changes Made by CBO

CBO made several changes in the EIA model:

- o Forecasts were extended from 2010 to 2020.

- o An explicit variable was created to reflect the effect of higher vehicle efficiency on miles driven. This rebound effect, measured as the

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3. Energy Information Administration, *Annual Energy Outlook 1991*, DOE/EIA-0383(91), (March 1991).

4. A description of the EIA model is presented in Energy Information Administration, *Assumptions for the Annual Energy Outlook 1990*, DOE/EIA-0527(90), (February 1990).

TABLE A-1. ALTERNATIVE-FUEL VEHICLES REQUIRED BY THE AMENDMENTS TO THE CLEAN AIR ACT (In millions of dollars)

	1990	1996	2001	2006	2010
Total Light-Duty Vehicles (Passenger Cars and Light Trucks)	9.50	10.10	11.00	11.20	11.40
New Clean-Fuel Vehicles Required by Clean Air Act	0.00	0.15	0.38	0.42	0.47
Percent of Total Vehicle Sales	0.0	1.5	3.4	3.7	4.1

SOURCES: Total vehicle sales, Energy Information Administration; new vehicles required by the Clean Air Act Amendments of 1990, Environmental Protection Agency.

percentage change in miles traveled that results from a change of 1 percent in MPG, was set at 0.1.[5]

- The highest MPG attainable each year under the incentives of market forces alone was calibrated to a range of potential fuel economy levels estimated by the Office of Technology Assessment.[6] This range represents the maximum that would be technologically feasible by the year 2001--33.4 MPG at $1.55 per gallon (in 1991 dollars) and 37 MPG at $2.85-$3.50 per gallon--assuming a four-year payback for consumers and no change in the overall fleet composition of different vehicle classes after 1990. On the basis of this relationship, average fuel economy would grow to 30.1 MPG by 2010 in response to gasoline prices at $1.50 per gallon.

5. This estimate was based on work by David L. Greene, "Vehicle Use and Fuel Economy: How Big is the Rebound Effect?" (unpublished manuscript, Center for Transportation Analysis, Oak Ridge National Laboratory, Oak Ridge, Tennessee, March 1991).

6. From values presented in 1987 dollars in "Estimating Feasible Levels of Corporate Average Fuel Economy," Testimony of Steven Plotkin, Office of Technology Assessment, before the Senate Committee on Energy and Natural Resources, March 20,1991. These values replaced a higher Energy Information Administration estimate (40 miles per gallon after 1990), for which there was no empirical basis.

- o Estimates of the total numbers of alternative-fuel vehicles required by the Clean Air Act Amendments were added (see Table A-1).

- o A representation of the economics of substituting alternative-fuel vehicles for conventional gasoline-powered vehicles was added, along with a revision of the formula for calculating corporate average fuel economy. These last changes are described in the remainder of this section.

Estimates of the costs of improving fuel economy and of supplying alternative vehicles are based on earlier studies by CBO (1980), the General Accounting Office (1991), the Department of Energy (1990), Difiglio *et al* (1990), and the Office of Technology Assessment (1990) (see References section). The relationship between cost and level of improvements in fuel economy assumed in this study is compared with point estimates of improvement costs from these earlier studies in Figure A-1. Estimates of the numbers of alternative-fuel vehicles that will be required by the Clean Air Act Amendments come from the Environmental Protection Agency (see Table A-1).[7] CBO made no effort to assess the reasonableness of these base-case assumptions.

Alternative-Fuel Vehicles and Gasoline Demand

The analysis calculates the effect of different CAFE incentive programs on gasoline demand in eight steps. Separate calculations were performed for passenger cars and light trucks.

1. The starting point is the formula for calculating corporate average fuel economy. The CAFE reflects a harmonic average of the fuel economies of different vehicles. Compared with the more familiar arithmetic average, the harmonic average provides a less biased estimate of total fleet efficiency. If we consider three classes of vehicles (gasoline, dual-fuel, and dedicated), with market shares for each class "*d*Q" (recall that total vehicle sales are not varied in the analysis) and with fuel economies "MPG," the corporate new-vehicle fuel economy (CAFE) would be

$$(1) \qquad CAFE = \frac{dQ_{mogas} + dQ_{dual} + dQ_{ded}}{\frac{dQ_{mogas}}{MPG_{mogas}} + \frac{dQ_{dual}}{MPG_{dual}} + \frac{dQ_{ded}}{MPG_{ded}}}$$

7. Environmental Protection Agency, Standards Development and Support Branch, "Estimated Number of Fleet Vehicles Affected by the Clean Fuel Fleet Program," staff memorandum from Sheri Dunatchik (Docket A-91-25), June 11, 1991.

where $dQ_{mogas}+dQ_{dual}+dQ_{ded} = 1$

As a modeling convenience, the analysis groups the individual types of dual- and dedicated-fuel vehicles together into two groups, calculating an average incremental vehicle cost and an average fuel economy for each group (see Table A-2 and Table A-3).

2. The second step uses the CAFE formula (equation 1) along with assumptions for the market shares for different alternative fuel technologies, estimates of the actual fuel economy of different technologies, and the CAFE fuel economy multipliers, to calculate separately the average CAFE rating for

TABLE A-2. COST, FUEL ECONOMY, AND MARKET SHARE ASSUMPTIONS FOR ALTERNATIVE-FUEL VEHICLES (In dollars)

Alternative-Fuel Vehicle	Estimated Incremental Production Cost	Base-Case Incremental Production & Marketing Cost	Real Fuel Economy Relative to 1990 Gasoline Vehicles	Share of Dual-Fuel or Dedicated-Fuel Vehicle Market (In percent)
Dual-Fuel Methanol/ Gasoline	$350	$500	.84[a]	50
Dedicated Methanol	$350	$500	.57	25
Dual-Fuel Compressed Natural Gas/Gasoline	$1,600	$2,000	.97[a]	50
Dedicated Compressed Natural Gas	$800	$1,000	.91	25
Electric	$8,000	$10,000	1.00	25
Liquified Petroleum Gas (Propane)	$800	$1,000	.73	25

SOURCE: Congressional Budget Office.

a. Assumes gasoline accounts for 75 percent of vehicle fuel.

TABLE A-3. ESTIMATES OF INCREMENTAL COSTS FOR ALTERNATIVE-FUEL VEHICLES (In dollars)

Alternative-Fuel Vehicle	Base-Case Incremental Production & Marketing Cost	DOE (1990)[a]	OTA (1990)[a]	GAO (1991)[b]
Dual-Fuel Methanol/ Gasoline	500	210-340	n.a.	n.a.
Dedicated Methanol	500	n.a	n.a.	n.a.
Dual-Fuel Compressed Natural Gas/Gasoline	2,000	600-800	750-1,600	4,150
Dedicated Compressed Natural Gas	1,000	n.a.	700-800	n.a.
Electric	10,000	5,600-7,500	6,000+	n.a.
Liquefied Petroleum Gas (Propane)	1,000	n.a.	n.a.	n.a.

SOURCES: Department of Energy, *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*, DOE/PE-0095P (August 1990); Office of Technology Assessment, "Replacing Gasoline--Alternative Fuels for Light-Duty Vehicles," September 1990; General Accounting Office, "Alternative Fuels--Increasing Federal Procurement of Alternative-Fueled Vehicles," GAO/RCED-91-169 (May 1991).

NOTE: DOE = Department of Energy; OTA = Office of Technology Assessment; GAO = General Accounting Office; n.a. = not available.

a. Reflects only incremental costs of vehicle components.

b. Reflects incremental costs of vehicle components and operation and maintenance.

all dual-fuel vehicles and all dedicated alternative-fuel vehicles. If alcohol and natural gas vehicles each accounted for half of dual-fuel vehicle sales, the statutory rating for dual-fuel vehicles would be

$$(2) \qquad MPG_{dual} = \frac{1}{\dfrac{0.5}{MPG_{dual,\ alcohol}} + \dfrac{0.5}{MPG_{dual,\ natural\ gas}}}$$

The assumed statutory CAFE ratings for 2010 are described in Table A-4. The ratings are calculated using the assumptions summarized in Table A-2. The analysis assumes no further increase in the fuel economy of alternative-fuel vehicles relative to the average fuel economy of gasoline vehicles in 1991.

3. The third step determines whether dual-fuel vehicles or dedicated alternative-fuel vehicles would represent a more economical option for automakers who want to reduce the required fuel economy of their gasoline-powered fleet. The basic calculation makes use of: the CAFE formula (equation 1) as a basis for defining the change in fuel economy of conventional vehicles made possible by a change in the alternative vehicle market share;

TABLE A-4. ASSUMED STATUTORY FUEL ECONOMIES FOR ALTERNATIVE-FUEL VEHICLES WITH HIGHER CAFE STANDARDS, 2010
(In miles per gallon, gasoline equivalent)

	50 Percent Gasoline Use (Options 1-3)	75 Percent Gasoline Use (Option 4)
Dual-Fuel Vehicles		
Passenger Cars	49.6	37.6
Light Trucks	35.2	26.5
Dedicated Alternative-Fuel Vehicles		
Passenger Cars	55.3	55.5
Light Trucks	39.6	39.7

SOURCE: Congressional Budget Office.

estimates of the statutory fuel economy of alternative-fuel vehicles (from step two); and incremental vehicle costs (see Table A-2). The relative cost of changing the fuel economy of the conventional fleet by altering the market shares of dual- or dedicated-fuel vehicles is represented by

$$(3) \qquad \frac{COST_{dual}}{dMPG_{mogas}/\, dQ_{dual}} - \frac{COST_{dedicated}}{dMPG_{mogas}/\, dQ_{ded}}$$

Negative values from (3) would indicate that dual-fuel vehicles represent a more cost-effective choice for automakers.

Note that averaging individual vehicle properties into two alternative vehicle categories implicitly discriminates against the more efficient vehicle types within each category. In particular, based on automakers' production costs alone, dedicated natural gas and methanol vehicles would probably appear more economic than dual-fuel vehicles, while dedicated electric and propane vehicles would be less economic.

However, there may be significant additional costs that come with the ownership and operation of dedicated-fuel vehicles that are accounted for here (primarily related to fuel availability and performance). For that reason, wherever the methodology (equation 3) would indicate that dedicated-fuel vehicles are more economical for automakers to supply, this analysis caps the potential market share for dedicated-fuel vehicles at the level required to meet the minimum requirements of the Clean Air Act Amendments. In that case, the methodology skips directly to step seven.

4. If the economic choice in equation 3 is for dual-fuel vehicles, the fourth step calculates the maximum number of dual-fuel vehicles (or the maximum share of total new-vehicle demand) that automakers could profitably supply.

The focus here is entirely on whether the savings from avoided fuel economy improvements outweigh the incremental costs of selling alternative-fuel vehicles, regardless of any caps on CAFE reductions. This interim calculation also ignores the CAFE effects of any alternative-fuel vehicles that automakers might find profitable to supply on their own, not in response to CAFE incentives. (Recall that the purpose of this analysis is only to evaluate the effects of various CAFE incentives options.)

The calculation of the optimal market share for dual-fuel vehicles proceeds from three preliminary relationships. The first is an identity, taken from the CAFE formula, and shows the basic trade-off between any reduction in the fuel economy of conventional vehicles below the statutory CAFE and the

share of alternative-fuel vehicles (dQ). With no sales of alternative-fuel vehicles, the fuel economy of conventional vehicles must match the CAFE standard. With these sales, however, the fuel economy of conventional vehicles can be lower (so long as the rated fuel economy of alternative-fuel vehicles is higher). With no change in the CAFE standard

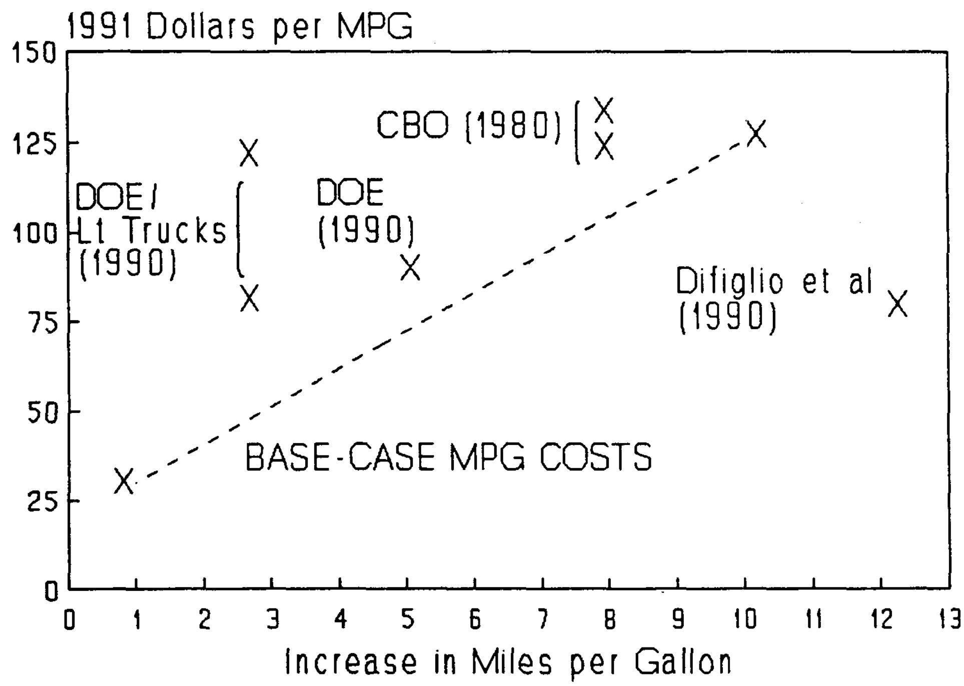
$$(4.1) \qquad MPG_{mogas,\ new} = \frac{1 - dQ_{dual}}{\dfrac{1}{CAFE} - \dfrac{dQ_{dual}}{MPG_{dual}}}$$

The second relationship is the marginal economic requirement that equates the cost of fuel economy improvements in conventional vehicles with the incremental cost of alternative-fuel vehicles (COST), or

$$(4.2) \qquad COST_{dual} * dQ_{dual} = COST_{MPG} * (CAFE - MPG_{mogas,\ new}) * (1 - dQ_{dual})$$

The third relationship shows the marginal cost of higher fuel economy as a function of the increase in fuel economy for conventional vehicles. This relationship is an assumption of the analysis, calibrated to be consistent with independent estimates of these costs, but defined so that successive improvements in fuel economy become more costly. Coefficients for the cost formula were selected that yield an average cost of $100 for each MPG for increasing fuel economy from 27.5 to 37 miles per gallon. This yields a marginal cost of $175 for increasing fuel economy from 37 to 38 miles per gallon. Fuel economy improvements for light trucks are assumed to be 50 percent more costly than those for passenger cars. Results from the base-case relationship between average costs and increased fuel economy for passenger cars are compared with estimates from other studies in Figure A-1.

FIGURE A-1. AVERAGE COSTS OF IMPROVING VEHICLE FUEL ECONOMY: BASE-CASE ASSUMPTIONS VERSUS POINT ESTIMATES FROM DIFFERENT STUDIES



SOURCES: Congressional Budget Office, *Fuel Economy Standards for New Passenger Cars after 1985* (December 1980); Department of Energy, *Assessment of Costs and Benefits of Flexible and Alternative Fuel Use on the U.S. Transportation Sector* (August 1990); Carmen Difiglio, K.G. Duleep, David L. Greene, "Cost Effectiveness of Future Fuel Economy Improvements," *The Energy Journal* 11/1 (1990), pp. 65-83.

NOTE: MPG = miles per gallon; CBO = Congressional Budget Office; DOE = Department of Energy; Lt Trucks = light trucks.

5. The fifth step then determines whether the optimal share calculated for dual-fuel vehicles would cause automakers to exceed the CAFE reduction allowed by the cap on CAFE credits. (There is no cap for dedicated alternative-fuel vehicles.) At that point, automakers presumably would lose further special CAFE treatment, and the profit incentive for selling additional dual-fuel vehicles would go away. Again using the CAFE formula (1) and defining the minimum fuel economy of conventional vehicles to be the CAFE standard minus the credit cap (for example, 1.2 miles per gallon), the highest allowable market share for dual-fuel vehicles without exceeding the credit cap would be

$$(5.1) \qquad CAPPED\ dQ_{dual} = \frac{\dfrac{1}{CAFE} - \dfrac{1}{(CAFE-1.2)}}{\dfrac{1}{MPG_{dual}} - \dfrac{1}{(CAFE-1.2)}}$$

The actual market share for alternative-fuel vehicles is then identified as the lower of the economic optimum and the credit-capped levels, or

$$(5.2) \qquad dQ_{dual} = MINIMUM\left[OPTIMAL\ dQ_{dual}\ ,\ CAPPED\ dQ_{dual}\right]$$

6. In the sixth step, any additional numbers of clean-fuel vehicles needed to meet the requirements of the Clean Air Act Amendments (see Table A-1) are added to any positive share of dual-fuel or dedicated vehicles calculated in the preceding steps. If the cap on CAFE credits is reached before meeting the Clean Air Act requirements, any additional clean-fuel vehicles are assumed to be dual-fuel vehicles.

From steps five and six, the market shares for conventional, dual-fuel, and dedicated alternative-fuel vehicles are all defined.

7. Thus, in step seven it is possible, going back to the basic CAFE formula (equation 1), to calculate a new required minimum fuel economy for conventional gasoline-powered vehicles. If that new minimum exceeds the level automakers would independently supply in response to market forces, it will serve as the basis for all subsequent gasoline demand calculations in the model.

8. In the final step, the actual average fuel economy of all vehicle classes is calculated. The actual fuel economy is the basis for forecasting fuel demand. In estimating fuel use, the analysis further assumes that dual-fuel vehicles will operate 25 percent of the time on the appropriate alternative fuel (or 75 percent on gasoline). Note that the statutory average fuel economy for all vehicles will match the CAFE standard in every year. However, because of the

role of the fuel economy multipliers for alcohol, natural gas, and electric vehicles, the actual on-road average fuel economy may be lower than the CAFE standard.

Not all the key costs and technical parameters needed for these calculations are available or even exist. However, this analysis presents a methodological framework for assessing the impact of different assumptions concerning those values. The section on caveats lists some important considerations to keep in mind when interpreting the model results.

APPENDIX B: REFERENCES

Congressional Budget Office, *Fuel Economy Standards for New Passenger Cars after 1985* (December 1980).

Department of Energy, *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*, DOE/PE-0095P (August 1990).

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