4. Understanding the Potential Impact of Alternative-Fuel Use

4.1 Introduction

This chapter presents a conceptual discussion of the Alternative Fuels Trade Model (AFTM), which can be used to analyze the energy market interrelationships that result from alternative-fuel use. The Department of Energy (DOE) is presently using this framework to examine implications of alternative-fuel use, based on the multifuel scenario presented in Chapter 3. A more detailed analysis will be provided in 1992.

4.2 The AFTM as a Tool for Analyzing Market Behavior

Petroleum is an internationally traded commodity, so changes in U.S. consumption patterns can have an impact on prices, consumption, and production throughout the world. Natural gas is currently traded on a more limited basis than petroleum, but our analysis is conducted on the premise that a world natural gas market is likely to emerge over the next two decades through new pipelines and expanded trade. Furthermore, in each region, natural gas and petroleum products substitute for one another. Substitution between gas and residual fuel in boiler-fuel markets and substitution between methanol and gasoline in motor-fuel markets will strengthen the links between oil and gas price movements. These market relationships are characterized in a formal way by the AFTM, which was developed for DOE by Alan Manne of Stanford University (Manne 1990) and is being enhanced by Paul Leiby of Oak Ridge National Laboratory.

The AFTM focuses on the production and consumption of alternative transportation fuels as substitutes for motor gasoline and diesel fuel. The AFTM determines prices and quantities that balance the interrelated world oil and gas markets. A critical modeling issue relates to the extent of market power held by the major oil-exporting nations and the manner in which such market power may be exercised. The AFTM model is sufficiently flexible to allow for the calculation of market balances under a variety of alternative characterizations of the world oil market. It characterizes market balances, or equilibria, in a selected year, for multiple fuels that derive from oil or gas (see Table 17). The model is being used to examine the alternative fuels in the multifuel scenario that was discussed in Chapter 3. Supply and demand are evaluated at the same level of regional detail used in DOE's International Energy Outlook (U.S. DOE 1991b). Further regional detail is added for promising new sources of remote natural gas. The supplies of the two principal raw materials (crude oil and natural gas) are represented by upward-sloping price-responsive curves. The model provides for fuel transportation between regions and includes processes that convert crude oil or natural gas to industrial and consumer fuels. The AFTM models the final demand for each fuel by downward-sloping constant-elasticity demand curves. It provides opportunities for long-run fuel substitution in flexible-fuel vehicles and industrial and utility boilers.[1] The degree of fuel switching by flexible-fuel vehicles influences the market penetration and success of alternative transportation fuels, such as methanol or compressed natural gas (CNG). Substitution between oil and gas in the industrial-utility boiler market establishes an important connection between the prices of petroleum products and gas-based products.

The AFTM model provides insights into the market effects of introducing alternative transportation fuels. It estimates changes in the prices, supplies, and demands of conventional fuels. It reports the levels of alternative-fuel use and tracks the geographic sources of U.S. energy supplies. The economic costs and benefits of introducing these substitute fuels are also measured, based on a standard social surplus analysis. Net benefit is estimated as the benefits that consumers gain from their levels of final demand, minus all the costs of fuel production, transportation, and conversion.

It is important to recognize that a comparison of the world "with" and "without" alternative fuels

Table 17. Fuels Included in AFTM

Fuel Name	Description
NTGAS	Natural gas (a primary resource)
CRUDEL	Light crude oil (a primary resource, composite blend of light/sweet crudes)
CRUDEH	Heavy crude oil (a primary resource, composite blend of heavy/sour crudes)
LTPRD	Light petroleum products (an aggregate refinery output, defined as 50% motor gasoline, 20% kerosene and jet fuel, and 30% distillate oil)
DISTIL	Distillate fuel
RESID	Residual fuel oil (a refinery output)
LPG	Liquefied petroleum gas
BOILR	Boiler fuel (substitutable between residual fuel oil and natural gas)
LNG	Liquified natural gas (for ocean transport of remote natural gas)
GASO	Conventional gasoline (single type)
RGASO	Reformulated gasoline (single type)
ETHNL	Ethanol, wholesale (for subsequent processing into transport fuels) from corn or cellulosic biomass
E-85	85% Ethanol-15% gasoline
GASOHOL	Gasoline (91%) mixed with ethanol (9% by volume)
MTHNL	Methanol, wholesale (for subsequent processing into transport fuels)
M-100	100% methanol (motor fuel, for dedicated methanol-vehicle use)
MTHG	Methanol and gasoline (motor fuel for flexible-fuel methanol vehicles, substitutable between M-85 (85% methanol-15% gasoline) and gasoline)
CNG	Compressed Natural Gas
CNGG	CNG and gasoline (motor fuel for flexible-fuel CNG vehicles, substitutable between CNG and gasoline)

does not, in general, provide insight into the costs and benefits of a particular alternative fuels policy or program. Rather, the costs and benefits of a particular program or policy depend directly on its expected impacts, and how those impacts would vary under alternative sets of possible future conditions. Different program designs (for example, incentives or mandates) generally have differing sensitivities to variation in projected future conditions.

For example, a program of incentives to promote the introduction of alternative-fuel vehicles might advance the date or rapidity of the market introduction of alternative fuels that would, under some future scenario, be economically viable in any case. The impact of such a program is measured by the difference between outcomes with and without the program outcomes. Assuming no barriers to the production, distribution, and use of alternative fuels, both outcomes would presumably include some alternative-fuels use. Under a different scenario (slower-than-expected technology advance or lower-than-projected world oil prices), the same incentive program would yield a lower "return" measured in terms of actual use of alternative fuels (if the vehicles are flexibly fueled) or in terms of fueling costs impacts (if the vehicles are dedicated). For this reason, policy analysis must explicitly assess the impact of proposed policies under a plausible range of possible future conditions. A simple comparison of the world with and without alternative fuels should not be construed as an analysis of any particular program.

For each run, the AFTM provides a long-run comparative statics analysis for a particular year. The model is currently benchmarked for the year 2010, using DOE base-case projections.[2] There are no explicit dynamics governing the time lags in consumers' responses, producers' exploration, and industrial investments. In the absence of these dynamics, the AFTM market outcomes are best viewed as long-run balances, balances which would occur if market conditions persist long enough (or have been changing slowly enough) for all adjustments to be completed. For the gradual introduction of alternative fuels as specified by the multifuel scenario, the use of AFTM long-run equilibria to approximate the outcomes in 2010 seems reasonable.

There are six main supply-demand regions in the AFTM: the United States, Canada, Japan, Western Europe, the Organization of Oil Exporting Countries (OPEC), and the rest of the world. Recognizing that OPEC-member countries differ in terms of their oil resource bases and supply behavior, OPEC is divided into two subregions: OPEC-Core and OPEC-NonCore.[3] Alternative motor fuels based on natural gas may utilize new foreign natural gas resources that are currently undeveloped in part because of limited world demand and high transportation costs. To investigate this possibility, the AFTM includes natural gas supply from remote locations with significant undeveloped nonassociated natural gas reserves and with low domestic demand for the gas.

Notes

1. For each substitutable fuel market, a logistic function describes the competition between two fuels. It relates the market share of one fuel to its price advantage over another. The logistic function follows the commonly used "S-shaped" curve for market penetration, in which small changes in the price advantage lead to only small changes in market shares (Boyd, Phillips and Regulinski 1982, McFadden 1974).

2. To the extent possible, the AFTM supply and demand curves are based upon EIA's 1991 *Annual Energy Outlook* and 1991 *International Energy Outlook* base case (U.S. DOE 1991a,b).

3. The OPEC-Core countries are assumed to coordinate and restrict output more rigorously to influence oil prices. OPEC-NonCore countries produce at or near capacity with smaller resource bases.

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5. Interactions Between AMFA Goals, the Clean Air Act Amendments of 1990, and California's Low-Emission Vehicles and Clean-Fuels Program

The primary goal of the Alternative Motor Fuels Act (AMFA) is to encourage the development and use of alternative transportation fuels in order to address national energy security and air quality concerns. The Clean Air Act Amendments of 1990 (CAAA) contain provisions that will lead to greater use of oxygenates in gasoline. The CAAA may also lead to the use of alternative-fuel vehicles to meet more stringent vehicle emission standards. The State of California has recently adopted a low-emission vehicles (LEV) and clean-fuels program. The requirements of this program may similarly lead to the use of alternative-fuel vehicles (AFVs). In fact, the program's zero-emission vehicle (ZEV) standards can only be met by electric vehicles. This chapter assesses the implications of the CAAA and the California requirements for the achievement of the AMFA's primary goal.

The chapter will (1) review the specific provisions of the CAAA and California LEV program that may encourage the use of alternative fuels (Sections 5.1 and 5.2); (2) briefly discuss the technologies potentially available to meet the new, more stringent vehicle-emission standards set in these two actions (Section 5.3); and (3) provide estimates of the level of alternative-fuel use and subsequent oil displacement that can be anticipated as a result of these two actions (Section 5.4).

5.1 The 1990 CAAA Requirements

The provisions of the CAAA that may encourage the use of nonpetroleum fuels and fuel additives include the reformulated and oxygenated gasoline requirements, the clean-fuel-fleet program, the California pilot test program, the low-polluting fuel requirement for urban buses, and Phase II of the emission standards for conventional vehicles. Each of these provisions is described briefly below.

5.1.1 Reformulated Gasoline and Oxygenated Gasoline (Sec. 219)

The oxygen content requirements of the reformulated gasoline and oxygenated gasoline provisions of the CAAA will lead to substantial use of oxygenates in gasoline. Such use of oxygenates will displace petroleum, thereby advancing the goals of the AMFA. Methyl tertiary-butyl ether (MTBE), produced from methanol and isobutylene, and ethanol will be among the oxygenates used.

The CAAA require that all gasoline sold throughout the year in the nine worst ozone nonattainment areas with a 1980 population in excess of 250,000 must be reformulated beginning in 1995. Several content- or performance-based standards, or both standards, must be met, including an oxygen content of 2.0 percent. The nine areas are Los Angeles, Houston, New York, Baltimore, Chicago, San Diego, Philadelphia, Milwaukee, and Hartford. Approximately 22 percent of the U.S. population lives in these areas.

All other ozone nonattainment areas (approximately 90) may opt in to the program, effective in 1995 or later. Insufficient domestic capacity to produce reformulated gasoline may lead to delays of up to 3 years in the use of this fuel in these opt-in areas. Another one-third of the U.S. population lives in these areas.

Beginning in November 1992, all carbon monoxide (CO) nonattainment areas (41) are also required to use oxygenated fuels during that portion of the year (winter) when their areas are prone to high ambient concentrations of CO. These fuels must be used for a minimum of 4 months, but the time period can be longer. The fuel must contain no less than 2.7 percent oxygen by weight. The oxygen level may be raised to 3.1 percent in CO areas classified as "serious" in 2001. There are three cities in that classification now.

5.1.2 Clean-Fuel Centrally Fueled Fleets (Sec. 229)

The CAAA require that in certain nonattainment areas, an increasing percentage of new vehicles purchased for fleets of 10 or more that are centrally refueled or capable of being centrally refueled must be clean fuel vehicles. Some vehicles are exempt—namely, rental fleet vehicles and law enforcement and other emergency vehicles. The program applies in ozone nonattainment areas with ozone design values of 0.16 parts per million (ppm) or higher, and in CO nonattainment areas with CO design values of 16 ppm or higher and that have a population of 250,000 or more. Twenty-one nonattainment areas are included in the program.

The standards for passenger cars (PC's) and light-duty trucks (LDT's) are presented in Table 18. As indicated there, the Federal clean-fuel vehicle standards are equivalent to California's transitional low-emission vehicle (TLEV) and LEV exhaust standards. (See 5.2 below for a discussion of the California program.) Non-methane organic gas (NMOG) emissions include traditionally measured hydrocarbons, as well as oxygenated hydrocarbons. Regulation of NMOG emissions is designed to limit the ozone-forming potential of vehicular emissions. Vehicles able to meet the standards using reformulated gasoline are considered clean-fuel vehicles. In the case of vehicles using a fuel other than gasoline, the level of the NMOG emissions will be adjusted based upon the ozone reactivity of their emissions relative to vehicles using gasoline.

Federal standards are also set for heavier LDT's and heavy-duty vehicles (HDV's) up to 26,000 pounds. Those for the heavier LDT's are equal to California's TLEV or LEV standards, or both, for these vehicle types. The program begins in 1998; by model year (MY) 2000, 70 percent of all new vehicles in the fleets covered by the program must be clean fuel. The program can be delayed to 2001 if vehicles meeting these standards are not being sold in California in 1998.

5.1.3 California Pilot Test Program (Sec. 229)

The CAAA California pilot test program is distinct from the California LEV and Clean-fuels Program. The pilot test program requires the production and sale of clean-fuel vehicles in California beginning with the 1996 MY. In the first 3 years of the program, 150,000 new clean-fuel LDV's and LDT's must be sold annually;

Table 18. Clean-Fuel Vehicle Exhaust Emission Standards for PC's and LDT's at 50,000 Miles
(grams per mile)

CAAA	California	NMOG[a]	CO	NO_x	Formaldehyde
Phase I[b]	TLEV	0.125[c]	3.4	0.4	0.015
Phase II[b]	LEV	0.075[c]	3.4	0.2	0.015
	ULEV	0.040[c]	1.7	0.2	0.008
	ZEV	—	—	—	—

Note: LDT's less than 3,750-pounds LVW and up to 6,000-pounds GVW

[a] Adjusted for clean fuels

[b] Phase I emission standards applicable to California Pilot Program in 1996. Phase II emission standards applicable to the CAAA fleets program in 1998 and to the California Pilot Program in 2001.

[c] FFV's operating on alternative fuel must meet these standards. When operating on gasoline, they may meet the next less stringent standard.

beginning in 1999, annual sales must reach 300,000. The clean-fuel vehicle standards are to be phased in and by 2001, these vehicles must meet California LEV standards. As in the national fleet program, vehicles able to meet the LEV standards with reformulated gasoline are considered to be clean-fuel vehicles. AFV's may also be used. Other States may opt in to the program. However, these States are not allowed to mandate any clean-fuel vehicle or clean-fuel sales.

5.1.4 Low-Polluting Fuel Requirement for Urban Buses (Sec. 227)

Beginning in MY 1994, all new urban buses are required to meet a 0.05-gram-per-brake-horsepower-hour (g/bhph) particulate matter (PM) standard. This standard may be raised to 0.07 g/bhph if the lower standard is not technically feasible. The Environmental Protection Agency (EPA) is required to conduct a testing program to determine whether or not buses comply with this more stringent standard. If buses cannot meet this standard over their full useful life, then EPA must implement a program requiring the use of low-polluting fuels in urban buses in Metropolitan Statistical Areas or Consolidated Metropolitan Statistical Areas of 750,000 population or more. The buses will be required to operate exclusively on methanol, compressed natural gas (CNG), ethanol, LP Gas, or other low-polluting fuels. EPA may also extend this program to smaller urban areas for health benefits.

5.1.5 Phase II Standards (Sec. 203)

Phase I of the conventional vehicle standards will be implemented beginning with MY 1994 (see Table 19). EPA and the Office of Technology Assessment are required to conduct a study to determine if Phase II standards should be required beginning in MY 2004. These standards would cut the Phase I 50,000-mile nonmethane hydrocarbon, CO, and nitrogen oxide (NO_x) standards in half and extend the useful life for which they must apply. The study will examine the availability of technology to meet the standards and the need for and cost-effectiveness of obtaining further emission reductions. Other standards may also be considered.

Table 19. Conventional Passenger-Car and LDT Standards: Federal and 1993 California
(grams per mile)[a]

CAAA	NMHC	CO	NO_x	PM	Miles
Current[b]	0.41[c]	3.4	1.0	0.20	50,000
1994+ (Phase I)	0.25	3.4	0.4[d]	0.08	50,000
	0.32	4.4	0.7[d]	0.10	100,000
2004+ (Phase II)	0.125	1.7	0.2		100,000
California	**NMHC**	**CO**	**NO_x**	**PM**	**Miles**
Current	0.39	7.0	0.4	0.08	50,000
1993+	0.25	3.4	0.4	0.08	50,000

[a] LDT's less than 3,750-pounds LVW

[b] PC only

[c] THC

[d] Higher for diesel

5.2 California's Low-Emission Vehicles and Clean-Fuels Program

In August 1991, California adopted its LEV's and clean-fuels program. The emission standards are for LDV's and LDT's less than 3,750 pounds. Light-vehicle weights are presented in Table 18 and the fleet average NMOG standards in Table 20. Vehicle manufacturers will be allowed to sell any mix of conventional vehicles or TLEV's, LEV's, ZEV's, and ultra-low-emission vehicles (ULEV's) to meet these standards, with one exception. To foster the development of the cleanest vehicle technologies, California is requiring sales of ZEV's beginning in 1998. Two percent of each manufacturer's sales must be ZEV's in that year; the ZEV sales share would rise to 10 percent by 2003. California has also established LEV and ULEV emission standards for medium-duty vehicles less than 14,000 pounds gross vehicle weight (GVW). The total number of clean-fuel vehicles sold under this program will be significantly greater than would be sold under the California pilot test program.

Table 20. California Fleet Average Standards for Passenger Cars and ZEV Sales Requirements

Model Year	ZEV[b] (%)	Fleet Average Standard: NMOG (grams per mile)
1994	—	0.250
1995	—	0.231
1996	—	0.225
1997	—	0.202
1998	2	0.157
1999	2	0.113
2000	2	0.073
2001	5	0.070
2002	5	0.068
2003	10	0.062

Note: Includes LDT's less than 3,750-pounds LVW

[b] The percentage requirements for ZEV's are mandatory.

California also adopted regulations to ensure that any clean fuels needed for LEV operation would be available at convenient locations. The fuel availability requirement would be triggered when more than 20,000 alternate-fuel LEV's are sold statewide. Fuel-availability requirements could start in southern California in 1994 and would go statewide by 1997.

Under Section 177 of the Clean Air Act, other States may adopt California's vehicle-emission standards. Using this approach, other States would be able to mandate production of vehicles meeting these standards.

5.3 Technologies Available To Meet Stringent Vehicle-Emission Standards

5.3.1 Light-Duty Vehicles

In preparing for its LEV program rulemaking, the California Air Resources Board (CARB) prepared an evaluation of the various technologies that may be available to achieve the TLEV, LEV, ULEV, and ZEV standards (CARB 1990). A summary of that assessment for LDV's is presented in Table 21. The discussion below draws on the CARB assessment and related material. The discussion focuses upon the technologies that can be used in gasoline-fueled vehicles to reach these emission levels, in particular the NMOG levels. (Diesel-fueled vehicles are not expected to be able to achieve the LEV NO_x standards and therefore are not discussed.) If gasoline-fueled vehicles can achieve these standards, then the standards themselves will not necessarily result in the production of AFV's, except the required ZEV sales share in California.

CARB expects that the conventional gasoline-fueled vehicles meeting California's 1993 exhaust standards will utilize close-coupled catalysts and advanced fuel-injection systems. These technologies will also be used in TLEV's. Additionally, to meet the TLEV standards, CARB expects manufacturers to first modify the vehicles that have small- or medium-displacement engines that are already near TLEV levels in certification testing. More precise air and fuel control may be em-

Table 21. Projected Low-Emission Vehicle Technologies: PC's and LDT's

	50,000-Mile Standards			Projected Fuel and Vehicle Systems[a]	
	NMOG	CO	NO_x		
Transitional Low-Emission Vehicles	0.125	3.4	0.4	Gasoline	– Small and medium displacement engines – Heated fuel-preparation system – Close-coupled catalyst
				Alcohol	– Improved close-coupled catalyst
				CNG	– Underfloor catalyst
				LPG	– Close-coupled catalyst
Low-Emission Vehicles	0.075	3.4	0.2	Gasoline	– Electrically heated catalyst – Phase II gasoline
				Alcohol	– Heated fuel-preparation system – Close-coupled catalyst
				CNG	– Electronic fuel-injection – Close-coupled catalyst
				LPG	– Electronic fuel-injection – Close-coupled catalyst
Ultra-Low-Emission Vehicles	0.040	1.7	0.2	Gasoline	– Heated preparation system – Electrically heated catalyst – Phase II gasoline
				Alcohol	– Heated fuel-preparation system – Electrically heated catalyst
				CNG	– Electronic fuel-injection – Close-coupled catalyst
				LPG	– Electronic fuel-injection – Electrically heated catalyst
				Electric	– Range-extended hybrid vehicles – Battery-powered vehicles with auxilliary combustion heaters
Zero-Emission Vehicles				Electric	– Battery-powered vehicles

[a] Improved NO_x control also needed for all LEV's and ULEV's.

ployed. Heated fuel-preparation systems may also be used to reduce cold-start emissions. These systems atomize the gasoline, which results in more complete combustion and thus a lowering of cold-start emissions.

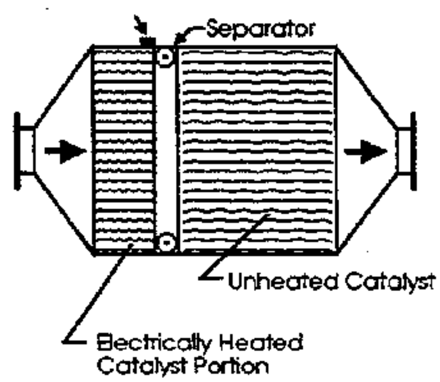
While these technologies may be used, some development effort is still required to optimize their use. Simply close-coupling the catalyst to the exhaust manifold poses a problem with gasoline. The severe operating temperature of gasoline (that is, the extremes of heating and cooling with the high temperature of gasoline exhaust) can significantly compromise the long-term performance and durability of catalysts. Also, further testing is required to ensure that the heated fuel-preparation systems do not overheat and result in engine fires.

For the LEV standard, cold-start emissions will have to be reduced even further. Cold-start emissions are estimated to comprise 70 to 85 percent of the total emissions measured during certification testing of vehicles at the TLEV emission level (CARB, 1990). CARB believes that electrically preheated catalysts could be used to attain the needed reduction in NMOG emissions. Because catalyst efficiency in reducing exhaust emissions is strongly dependent on operating temperature, preheating the catalyst enables emissions to be further reduced during the cold-start period. The use of a cleaner gasoline could be used to provide an additional margin for compliance. Gasoline-fueled vehicles may achieve the ULEV standards by further improving upon the design and durability of these electrically heated catalysts and utilizing clean-burning gasoline. Additionally, the use of a heated fuel-preparation system, as may be employed in TLEV's, could provide additional compliance margin for gasoline-fueled ULEV's.

The use of a preheated catalyst and reformulated gasoline is critical to the achievement of the LEV and ULEV standards by conventionally fueled vehicles. The characteristics and emission reduction potential of reformulated gasoline are discussed in Appendix A, "Reformulated Gasoline." As indicated there, the Federal standards require that reformulated gasoline achieve a 15-percent reduction in volatile organic compounds (VOC) and toxics beginning in 1995 and 25 percent by the year 2000. California has already implemented its Phase I reformulated gasoline requirements and is still developing its Phase II requirements. California expects that the Phase II requirements will be more stringent than the Federal standards.

Current catalytic converters do not work effectively until they are heated to about 300 degrees Celsius or what is called the "light-off" point (Schatz, 1991, Heimrich, 1991, and Methanol-Powered Cars, 1991). Hot exhaust gases from the engine provide this heat and light-off is achieved a few minutes after the engine is started. Preheated catalysts are being designed that achieve this operating temperature within 10 to 15 seconds. These catalysts are generally electrically preheated. Their design requires the use of metallic substrate (for example, stainless steel foil) rather than ceramic substrate. They may also require a second battery to provide the heat and air pumps to provide additional oxygen during cold start. One possible design of a preheated three-way catalyst is shown in Figure 7. It is sectioned into two parts: one preheated and one unheated. This type of segregation may enhance the durability of the total catalytic system.

Figure 7. Schematic of Electrically Heated Catalyst



Source: Heimrich, 1991

Instead of attempting to achieve the TLEV-LEV-ULEV standards with gasoline, manufacturers could choose to produce vehicles powered by alternative-fuels which have lower ozone reactivities than gasoline. Less complex emission-control systems may be required. The systems that CARB believes may be required in AFV's are indicated in Table 21. Only battery-powered electric vehicles would be able to meet the ZEV standards.

The Phase II conventional vehicle standards, which may be required nationally in MY 2004, are less stringent with respect to HC-based emissions than the LEV and ULEV 100,000-mile standards (0.090- and 0.055-gallon-per-mile NMOG, respectively). The Tier II CO and NO_x standards are slightly more stringent than the ULEV 100,000-mile standards for these pollutants, which are 2.1-gallon-per-mile CO and 0.3-gallon-per-mile NO_x. We are not aware of any assessment to date of the technologies specifically required to meet the Tier II standards. It would appear, however, that technologies similar to those discussed above for meeting the LEV and ULEV standards with gasoline could be employed.

At this time, we do not know which technologies will be used to meet the TLEV-LEV-ULEV-ZEV and Tier II standards. As discussed above, CARB has prepared a comprehensive assessment of what it believes is possible. The Department of Energy is initiating its own study of the range of fuels and vehicle-emission-control technologies that can comply with the CAAA and California LEV program requirements. Manufacturers and consumers together, however, will ultimately make the tradeoffs and choices among technologies and fuels.

5.3.2 Other Vehicle Types

CARB believes that similar technologies to those discussed above could be used for the heavier LDT's and medium-duty vehicles that are included in its LEV program. Because the Federal standards under the clean-fuel-fleet program for heavier LDT's are virtually the same as the California TLEV and LEV standards for these trucks, these technologies may also be used to meet the Federal requirements. In other words, gasoline-fueled vehicles are expected to be able to meet these standards. The emission standards for HDV's covered under the CAAA clean-fuel fleet program are required to be set so that clean diesel-fueled vehicles can meet them. No further discussion of the additional technologies that might be used in these HDV's is provided here.

Urban buses are expected to be able to meet the 0.05-g/bhph particulate standard with diesel fuel by using a combination of particulate trap, oxidation catalyst, and/or clean diesel fuel (for example, the low-sulfur/low-aromatic diesel fuel required in California). Alternative fuels could also be used to meet this standard. As with LDV's, we do not know yet which technologies will ultimately be chosen.

5.4 Alternative-Fuel Use and Oil-Displacement Potential

It appears that the various CAAA emission standards and the California LEV program vehicle-emission standards can generally be met by gasoline- (or diesel-) fueled vehicle technologies. Therefore, except for California's requirement that a certain percentage of vehicle sales be ZEV's, there *need not be any AFV's* in operation as a result of these standards. Table 22 presents an estimate of the minimum number of ZEV's operating in California in 2010 as a result of the production mandate and their electricity use and oil-displacement potential. Approximately 1.6 million electric vehicles may be in operation, displacing approximately 50,000 barrels per day of oil.

This number can be expanded, of course, if manufacturers choose to produce AFV's instead of gasoline-fueled vehicles to meet the CAAA centrally fueled fleet program and California's LEV and ULEV requirements, or instead of diesel-fueled urban buses. It may also be increased if other States opt into the California LEV program standards and require the production of ZEV's. For example, various States belonging to the Northeast States for Coordinated Air Use Management are drafting or considering regulations and policies requiring vehicles sold in their States to meet the California standards and

Table 22. Minimum Effect of CAAA and California LEV Programs on Alternative-Fuel Use and Oil Displacement: 2010

Item	Number of Vehicles in Operation	Oil Displacement	Alternative-Fuel Use
Vehicles			
California ZEV Only	1.6 million	48,000 b/d	30.3 GWh/day
Reformulated and Oxygenated Gasoline			
9 Cities/Oxyfuels in CO Areas	—	200,000 b/d	3.5 bil gal MTBE (1.2 bil gal Methanol) 0.9 bil gal Ethanol

mandating the same percentage of ZEV sales as in California (Marin, 1991). If all States belonging to the Northeast States for Coordinated Air Use Management were to adopt ZEV requirements and mandate sales according to California's schedule, there could be approximately 4 million electric vehicles in operation in California and the Northeast in 2010.

Reformulated gasoline with oxygenates is actually required in only nine nonattainment areas, and oxygenated gasoline in only approximately 40 nonattainment areas for part of the year. Table 4 presents an estimate of the displacement and alternative-fuel use associated with these requirements. Approximately 200,000 barrels per day of oil may be displaced (Singh, 1991). MTBE is assumed to be used in areas requiring reformulated gasoline. Ethanol is assumed to be used in areas that are CO nonattainment only. Approximately 1 billion gallons of ethanol and methanol (in MTBE) each would be used.

Many nonattainment areas may choose to opt into the required use of reformulated gasoline as an ozone-control method. If all eligible ozone nonattainment areas opt into the use of reformulated gasoline, then 55 percent of the gasoline in the country would be reformulated. Given the logistics of gasoline distribution, spillover of sales and use of reformulated gasoline may occur. Reformulated gasoline will probably be marketed in areas not mandated to use it, but adjacent to those areas and part of the distribution system to them. If all ozone nonattainment areas opt into the use of reformulated gasoline and spillover occurs, it is possible that the oil industry would find it simplest to reformulate all gasoline in the United States. In the latter case, a displacement of approximately 700,000 barrels per day of oil could be achieved. (This estimate assumes no use of AFV's other than ZEV's in California.)

The above estimates are just that, estimates. They do indicate, however, that the *minimum* effect of the CAAA and the California LEV programs are not substantial. The total oil displacement that may be achieved as a result of the programs would be 250,000 barrels per day of oil or approximately 2.5 percent of highway petroleum consumption.

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