GUIDEBOOK

ABCs of AFVs

A Guide to Alternative Fuel Vehicles

Fifth Edition
November 1999

Gray Davis, Governor

CALIFORNIA ENERGY COMMISSION

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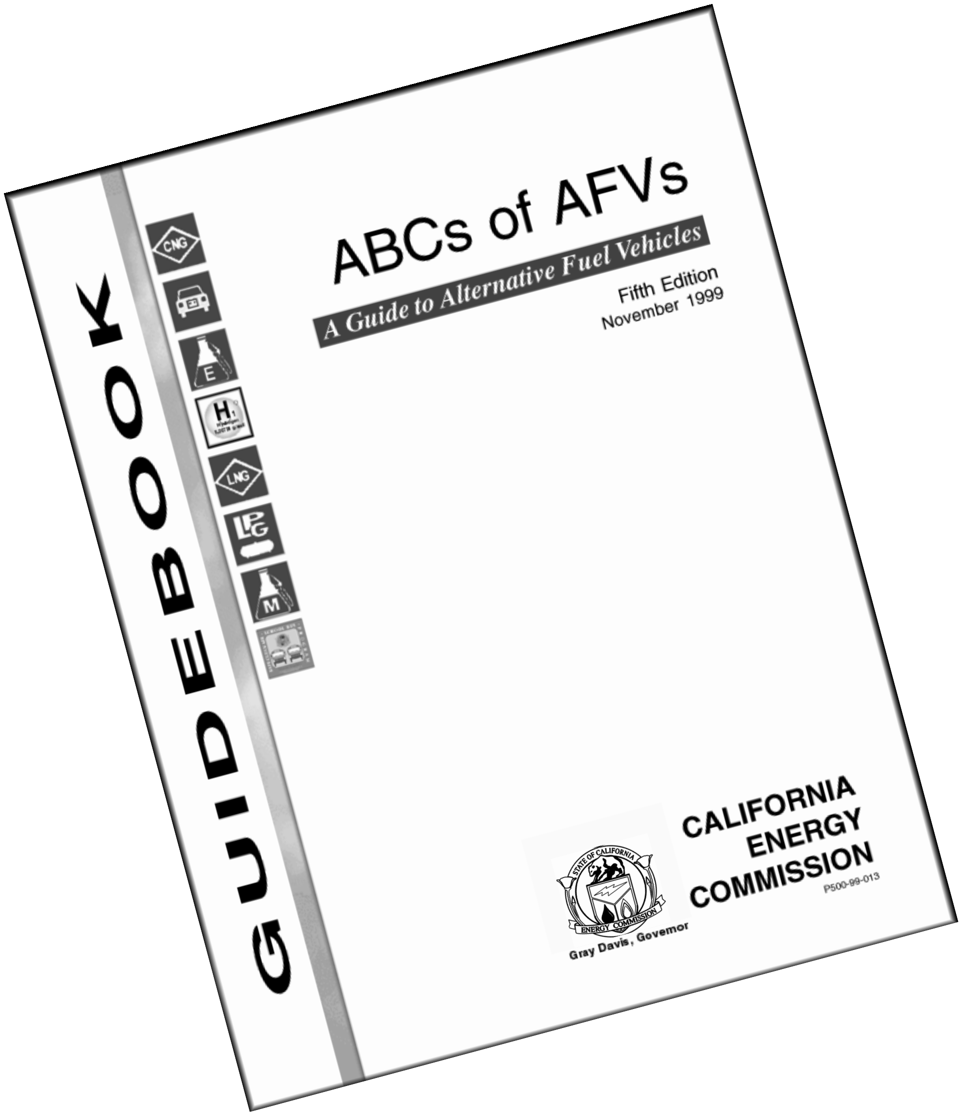

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Introduction

The California Energy Commission (Energy Commission) is the State's primary energy policy and planning agency and has been involved in testing and demonstrating alternative fuels and alternative fuel vehicles since 1978. As part of the State's energy policy, the Energy Commission supports the use of clean, alternative transportation fuels to reduce the State's dependence on petroleum and to improve air quality. The Energy Commission has been involved in all areas of transportation fuel research, development, demonstration and commercialization.

This report was prepared by staff of the Energy Commission with input from industry to serve as an informational source for a variety of alternative transportation vehicle and fuel types. Topics include the following:

- Fuel type
- Fuel characteristics
- History
- Transportation applications
- Infrastructure
- Supply
- Pricing
- Environmental, health and safety issues
- Future potential for each fuel type

This is the fifth edition of this report. Updates of this report will be made on the internet site at:
< http://www.energy.ca.gov/afvs>.

Chapter 1

An Overview of Alternative Fuel Vehicles

Introduction

This chapter discusses the history of alternative fuels, alternative fuel vehicles and their importance. Also included are reasons alternative fuels are cleaner burning and alternative fuel vehicle development in California.

History of Alternative Fuels and Alternative Fuel Vehicles

Alternative Fuel Vehicles (AFVs) that run on fuels other than petroleum products have been used in one form or another for more than one hundred years. Only recently, however, have they become more commonplace.

The Federal Energy Policy Act of 1992 (EPAct) defines an alternative fuel as any fuel that is substantially non-petroleum and yields energy security and environmental benefits. EPAct recognizes the following as alternative fuels:

- Alcohol fuels such as methanol (methyl alcohol), denatured ethanol (ethyl alcohol) and other alcohols, in pure form (called "neat" alcohols) or in mixtures that contain no less than 70 percent alcohol fuel
- Compressed Natural Gas (CNG)
- Electricity
- Hydrogen
- Liquefied Natural Gas (LNG)
- Liquefied Petroleum Gas (LPG)
- Coal-derived Liquid Fuels
- Fuels other than alcohols derived from biological materials: like soybean, rapeseed or other vegetable oil-based fuels

Vehicles using these fuels can be either original equipment manufactured (OEM) vehicles or aftermarket conversions and are discussed more completely in the chapters that follow.

Before the introduction of gasoline as a motor fuel in the late 1800s, vehicles were often powered by what are now considered alternative fuels. For example, coal gas, which is a form of methane or natural gas, was used in early prototype internal combustion engines in the 1860s. Electricity, stored in lead acid batteries, was a popular energy source for vehicles from as early as the 1830s until the 1920s. In the 1880s, Henry Ford fueled one of his first automobiles on ethanol, often called "farm alcohol" because it was made from corn. His early Model Ts were designed with an adjustable carburetor to allow them to run on alcohol fuel. Liquefied petroleum gas (commonly called propane) has been used as a transportation fuel since the 1930s.

In those early years of the automobile, naturally occurring gasoline was expensive and often sold by the pint in pharmacies. Gasoline began to be produced inexpensively with the advent of petroleum refining technologies such as thermal cracking and eventually catalytic cracking. As a result, gasoline became the fuel of choice for internal combustion engines because of its high energy content.

Many alternatives to gasoline are returning to the transportation fuel market. Alternative fuels are important for energy security and air quality.

Table I-1
California Vehicle Statistics

	1989	1990	1991	1992	1993	1994	1995	1996	1997
Total Registered Vehicles (thousands)	22,368	22,679	22,957	22,794	22,982	22,843	23,248	23,725	22,522
Vehicle Miles of Travel (millions of miles)	134,371	139,209	139,680	141,686	142,343	144,141	146,164	149,572	153,146
Taxable Gasoline Sales (millions of gallons, excluding aviation fuel)	13,206	13,377	13,161	13,064	13,202	13,262	13,406	13,672	13,759

Sources: Department of Motor Vehicles, Transportation and Board of Equalization

The Importance of AFVs

California's transportation system is vital to the State's economy, but the transportation sector is our greatest source of air pollution. The increased use of petroleum products, the number of vehicles on the road and California's geography and climate make the perfect recipe for air pollution (See Table I-1). California's cities and countryside are frequently subjected to unhealthy levels of air pollution. To attack this problem and in response to the oil crises of the 1970s, California assumed a national leadership role and worked to encourage fuel diversity with cleaner, alternative transportation fuels and vehicles.

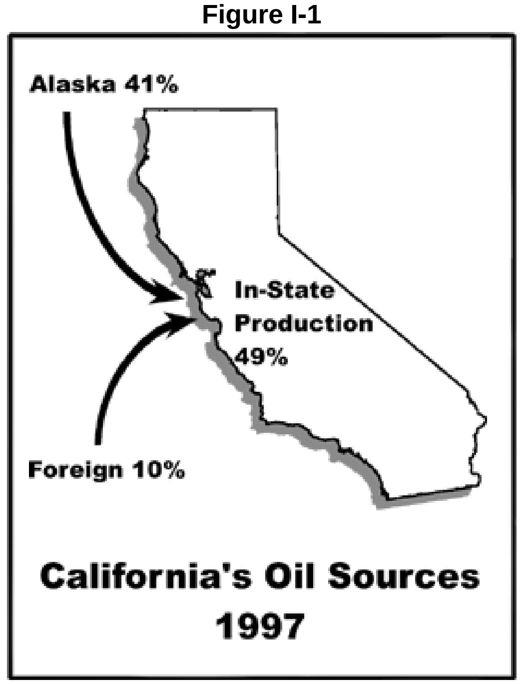
Working with automakers, fuel producers, utility companies, and air quality districts, California is making progress toward achieving a diverse transportation landscape. This effort will provide the consumer competitive choices in transportation technology, fuels and fueling options to meet California's increasingly stringent clean air goals. These choices will include cleaner-burning gasoline, clean diesel, electricity, ethanol, hydrogen, methanol, natural gas and LPG.

California produces 49 percent of the oil it consumes. About 41 percent of its oil originates from Alaskan oil fields; the remaining 10 percent is from foreign sources. (See Figure I-1). This will change as California's and Alaska's oil production decreases. The Energy Commission's *1999 Fuels Report* estimates that Alaska and California oil production is expected to decline five percent per year from 2000 to 2015. Foreign sources of crude oil will be relied upon more heavily in the future unless alternatives are found to replace this loss of domestically produced fuel.

Alternative Fuels are Cleaner

Alternative fuels are inherently cleaner than gasoline because they are chemically less complex and burn cleaner. When used with advanced engine and emission control technologies, alternative fuels burn more efficiently because they are chemically less complex, and thus release fewer emissions from incomplete combustion. In addition, because alternative fuels evaporate less readily than gasoline, there are fewer evaporative emissions from the vehicle's tank, limiting smog-forming emissions. It is important, however, to recognize that to meet health-based air quality standards, clean fuels must be combined with advanced emission control technologies.

Figure I-1



Electric vehicles, which have no internal combustion engine, potentially offer greater emission reductions. Their primary source of air pollution comes from the power plants that create electricity to charge batteries.

From 1992 to 1994, Battelle Memorial Institute conducted one of the most comprehensive studies of alternative fueled vehicles in Southern California. The Clean Fleet Project, or the South Coast Alternative Fuels Demonstration Project, tested six fuels (five alternative fuels and regular gasoline) in 111 Federal Express delivery vans over more than three million miles during the two-year study. The study used Chevrolet, Dodge, and Ford vans that were similar in characteristics and in usage.

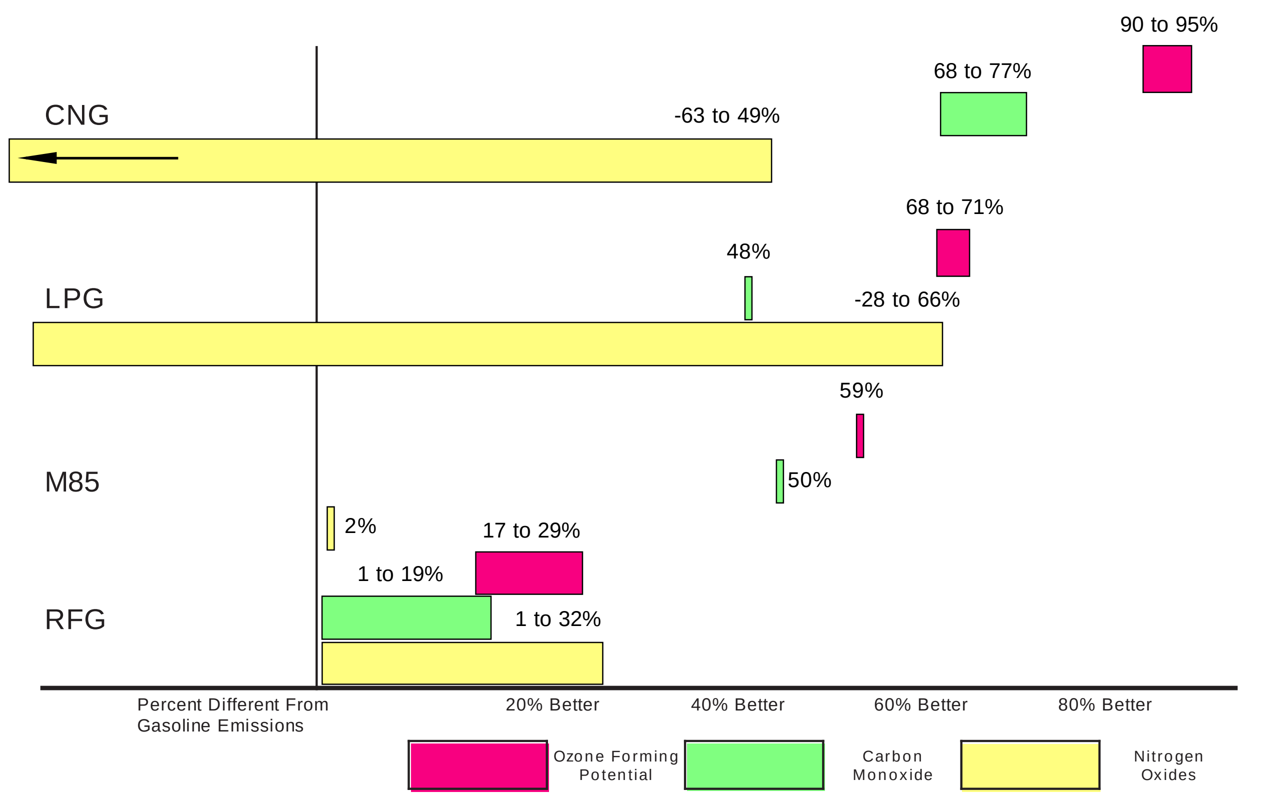
In nearly all emissions categories, the study demonstrated that all alternative fuels were better than the control fuel. The alternative fuels tested included compressed natural gas, electricity, methanol, LPG, and reformulated (Phase 2) gasoline. (Ethanol was not used in this test because of its limited availability in California).

The alternative fuels had fewer emissions than regular unleaded gasoline and reformulated gasoline (See Figure I-2) . For compressed natural gas, carbon monoxide (CO) levels were 68 to 77 percent less than with regular gasoline. The ozone forming potential (OFP) for CNG was 90 to 95 percent less than with regular unleaded gasoline. M85 vehicles had 50 percent less CO emissions than gasoline and up to 59 percent less OFP. Propane-powered vehicles had 48 percent less CO and 68 to 71 percent less OFP. Reformulated Phase 2 gasoline was also cleaner with 1 to 19 percent less CO and Reformulated gasoline's OFP was 17 to 29 percent less than regular unleaded gasoline. The study also included two electric vehicles.

Energy Content of Alternative Fuels

Alternative fuels have less energy density than petroleum-based fuels (See Table I-2). Hence, alternative fueled vehicles go fewer miles per gallon than gasoline fueled vehicles.

Figure I-2
1992 - 1994 Clean Fleet Emissions Study (Percent Cleaner Than Regular Unleaded Gasoline)



Note: Range of percentage is because of different types of vehicle being used in the test - Chevrolet, Dodge, and Ford.

Source: Battelle Memorial Institute, 1995

Table I-2
Comparison of Fuel Energy Content

Fuel	Pressure	Btu per Gallon	Volumetric Energy Content Ratio (Compared to Gasoline)
Diesel		129,000	0.86 to 1
Gasoline		111,400	1.00
E85		80,460	1.38 to 1
Propane		84,000	1.33 to 1
Ethanol		75,000	1.49 to 1
CNG	@3000 psi	29,000	3.84 to 1
LNG		73,500	1.52 to 1
M85		64,735	1.72 to 1
Methanol		56,500	1.97 to 1
Liquid Hydrogen		34,000	3.28 to 1
Hydrogen	@3000 psi	9,667	11.52 to 1

Note: These ratios do not reflect actual energy based volumetric substitution ratios in a vehicle. For example, some early model FFVs used 1.64 gallons of M85 to drive the same distance as one gallon of gasoline, thus indicating an efficiency gain when operating on M85. The above ratios may change when considering engine efficiency .

Alternative Fuel Vehicle Development in California

Since 1978, the Energy Commission has worked with automobile manufacturers, fuel providers, utility companies, universities, and research and development organizations to advance alternative fuel vehicles. The Energy Commission has undertaken the following programs:

1978 The Energy Commission began its first alternative fuel vehicle demonstration program. Honda CVCCs used a gasoline blended with ethanol and methanol in a side-by-side test program. Early national emphasis was on domestic coal-derived synthetic fuels: shale oil, gasoline, methanol and hydrogen. The goals were for alternative fuels to displace oil and meet California emissions standards.

1980 Continued testing of ethanol and methanol blends with gasoline on Ford Pintos.

1981 The Energy Commission in cooperation with Ford Motor Company created a methanol demonstration fleet, placing methanol-powered Ford Escorts in the County of Los Angeles fleet in 1981 and 1982. Volkswagen Rabbits, factory-built to run on ethanol and methanol, were delivered in late 1981 and added to the program.

1983 The Energy Commission funded the first two methanol-fueled transit buses in the country. The buses operated in commuter service between Marin County and San Francisco.

Five hundred "dedicated" methanol-fueled Ford Escorts were put into state and local government fleets. Vehicles traveled 20 million miles and showed a 50 to 80 percent emission reduction potential.

1986 The Energy Commission's Energy Technologies Advancement Program (ETAP) funded the retrofit of three diesel engines to methanol fuel in a $1.8 million project with Riverside Transit Agency.

The Energy Commission began a $700,000 Heavy Duty Truck Demonstration Program. This project was done jointly with South Coast Air Quality Management District and five engine manufacturers: Caterpillar, Cummins, Detroit Diesel, Ford and Navistar. Vehicles placed at eight host sites included a water delivery truck, refuse haulers, dump trucks, a sludge hauler, tractor/trailers and a line truck.

1987 The Energy Commission conducted an evaluation on the cost and availability of low-emission fuels and vehicles.

Ford introduced the Flexible Fuel Vehicle (FFV) technology fueled on methanol or gasoline or any combination of the two fuels from a single tank. Between 1987 and 1989, Ford produced 217 Crown Victoria FFVs for a demonstration fleet.

The Gas Research Institute funded the development of first natural gas heavy-duty engine, Cummins L-10.

The Energy Commission's ETAP project funded the development of a hybrid electric vehicle. This $404,000 project was undertaken by the Electric Auto Association and Stanford University. A Chevrolet Corsica was converted to a hybrid EV with a gasoline-powered generator.

1988 Safe School Bus Program provided $100 million in four phases to replace buses built prior to 1977 Federal Motor Vehicle Safety Standards. A minimum of 35 percent of the vehicles must be powered by nonpetroleum-based fuels.

Phase 1 **-** Fourteen school districts and consortia received 163 buses (103 advanced diesel, 50 methanol, 10 compressed natural gas). The buses were delivered in 1990.

Phase 2 **-** Forty-seven school districts and consortia received 400 buses (200 advanced diesel, 100 methanol, 100 compressed natural gas). The buses were delivered in 1992-93.

Phase 3 **-** Forty-eight school districts and consortia received 214 buses (107 advanced diesel and 107 CNG). The buses were delivered in early 1997.

Phase 4 **-** Eighteen school districts and consortia received 49 CNG buses. The buses were delivered in 1999.

GM announced the Variable Fuel Vehicle (VFV) technology fueled on methanol or gasoline or any combination of the two fuels from a single tank. Chevrolet produced 20 Corsica VFVs for use in the State of California and air district fleets in demonstration programs.

The 1988 Alternative Motor Fuels Act was enacted by the federal government. It established Corporate Average Fuel Economy credits for AFVs produced by auto companies.

The Energy Commission established the California Fuel Methanol Reserve.

ARCO, Chevron, Exxon, Mobil, Shell,Texaco and Ultramar, as well as independent fleet operators signed agreements with the Energy Commission to establish M85 fueling stations in California for a ten-year demonstration program. The Energy Commission signs contracts for 83 M85 facilities.

The Energy Commission funded an ETAP project to develop a medium-duty natural gas engine for United Parcel Service step-van in a $1.5 million project.

1989 ARCO announced Reformulated Gasolines - EC1, EC Premium and eventually ECX.

Chevrolet delivered the first Lumina VFVs to the Energy Commission. In 1990, 265 of the Lumina VFVs were delivered to fleets.

1990 Ford agrees to deliver 250, 1991 Taurus Flexible Fuel Vehicles for demonstration in government/private fleets and 183 Econoline Van FFVs for 1992.

The federal Clean Air Act Amendment (CAAA) was enacted which establishes the California Pilot Program requiring 150,000 clean fuel vehicles a year for California by 1996, increasing to 300,000 a year by 1999.

The California Air Resources Board Low Emission Vehicle and Clean Fuel Regulations were adopted September 1990. Required zero emission vehicles (ZEV) to be offered for sale in 1998.

1991 Chrysler announced production of 2,500 1992 Plymouth Acclaim and Dodge Spirit methanol FFVs.

The Energy Commission's Electric Vehicle Demonstration Program began in partnership with Pacific Gas and Electric Company. The three-year project demonstrated three Conceptor G-Van EVs used by the cities of Oakland and Santa Rosa for mail delivery and in Yosemite National Park. The Energy Commission contributed $60,000 and PG&E matched that amount.

The Energy Commission announced the Advanced Technology EV Demo Program . The Energy Commission contributed $692,000 to these projects:

Four Chrysler TEVans with Nickel-Cadmium or Nickel-Iron batteries.

Seven Ford Ecostar vans with Sodium Sulfur batteries.

Four Solectria Force vehicles with Advanced Lead-Acid batteries.

1992 The Energy Commission co-funded CALSTART to establish an advanced transportation technologies industry in California. The consortium has more than 80 member companies. A total of $2 million was committed by the Energy Commission to match $4 million in federal support and more than $20 million in private capital.

The Energy Commission began its Light-Duty Natural Gas Vehicle Demonstration Program with 100 GMC and Chevrolet 1992 3/4-ton dedicated natural gas pickup trucks. They were placed into service in 10 fleets around the State.

The Energy Commission project with Vons Companies Inc., Ford, National Renewable Energy Laboratory, SoCal Gas, and SCAQMD demonstrated a heavy-duty natural gas-powered truck equipped with a Ford LTLA-9000 "Aeromax" tractor with Caterpillar G3406 engine. It was the country's first long-haul CNG-fueled truck with an OEM engine.

1993 The Energy Commission Natural Gas Vehicle (NGV) Demonstration Program was cost-shared with utility companies to purchase 40 vehicles. Vehicles were placed with the City of Ontario—five B-350 Dodge RAM Vans for a rideshare program, County of Sacramento— five GMC Sierra pickup trucks for County Department of Public Works, and VPSI Commuter Vanpools — 30 Dodge B-350 RAM Vans for use in Orange County.

The Energy Commission created the Transportation Energy Technologies Advancement Program (TETAP) which funded research by California companies in the following projects:

$66,666 for medium-duty CNG engines in delivery vehicles.

CALSTART Electric School Bus: $1 million project to retrofit two diesel buses to electricity and build one "ground-up" bus.

GM Impact PreView Program: $500,000 from the Energy Commission for a program that loaned GM Impacts to 1,000 drivers around U.S. for two to four weeks.

Cummins Engine: $977,000 project to develop an advanced turbocharger for a diesel engine.

The Energy Commission Diesel Emission Reduction Fund Program funded the following projects through fines collected from polluting heavy-duty vehicles:

Cal State Fresno: $19,672 to use water injection to reduce diesel exhaust.

Cummins Engine: $480,000 to develope a low-cost diesel particulate trap.

University of California, Riverside, College of Engineering -Center for Environmental Research and Technology (CE-CERT) Advanced Transportation Research & Testing: Energy Commission contributed $1,400,000 toward the $125 million research center. The Center focuses primarily on atmospheric processes, vehicle emissions, environmental modeling, transportation systems, advanced vehicle engineering, renewable fuels, manufacturing processes and stationary source emissions.

1994 Alternative Fuel Vehicle Demonstration Program in Yosemite National Park. The Energy Commission awarded $640,000 for the Yosemite Electric Bus Program in cooperation with the National Park Service, Caltrans, local transit companies, and Pacific Gas and Electric Company. This funding was used to replace two diesel buses with electric buses in a three-year demonstration program. Total Cost: $1.47 million ($500,000 from The Energy Commission).

The Energy Commission TETAP funded the following:

Amerigon - Advanced Heating/Cooling System for EVs - $675,000 project.

APS Systems – Advanced EV Shuttle & Paratransit Buses - $440,000 project.

CALSTART - Hybrid EV/Natural Gas, 40-foot Transit Bus - $1.1 million project.

Pinnacle Research Institute - Ultra-Capacitor for EVs and Hybrids - $690,000 project.

U.S. Electricar - Conversion to electricity of Grumman "Long Life" U.S. Postal Service (USPS) Delivery Trucks - $855,000 project with six Post Office EVs split between Torrance, California, and USPS Headquarters in Merrifield, Virginia.

The Energy Commission funded a $600,000 Medium-Duty NGV Program for 54 natural gas vehicles in a diverse range of uses: package delivery trucks, dump trucks, shuttle buses, "trolley" buses, tow truck and utility crew trucks. Ten public and private fleets participated.

The Energy Commission funded a demonstration project with several parties for a heavy-duty natural gas truck. These parties included the Los Angeles Times/Times Mirror Company, the South Coast Air Quality Management District (SCAQMD), SoCal Gas, National Renewable Energy Laboratory (NREL) and American Trucking Association Foundation (ATAF). The project used a Ford LTLA-9000 "Aeromax" tractor using Detroit Diesel Corporation Series 60-G, 370 horsepower engine.

The Energy Commision funded a demonstration project with Los Angeles County Sanitation District, SCAQMD, SoCal Gas, NREL and ATAF for a heavy-duty natural gas truck. The truck is a Freightliner tractor using Detroit Diesel Corporation Series 60-G 370 horsepower engine. The vehicle will be powered by Cleaned Landfill Gas (CLG).

The Energy Commision funded the following Diesel Emission Reduction Fund projects:

CeraMem Corp., $300,000 project - Exhaust Gas Recirculation and particulate filter.

Southwest Research Institute, $1 million project - Direct and indirect injection systems.

1995 During 1995, the Energy Commission projects listed in 1994 were either implemented and/or completed.

1996 The ARB modified its Zero-Emission Vehicle mandate to allow auto companies to voluntarily introduce ZEVs from 1998 to 2002. However, the ARB maintained the requirement that in model year 2003, 10 percent of all vehicles offered for sale by the major auto companies must be ZEVs.

1997 The TETAP funded the following projects:

$174,937 to Catalytica Advanced Technologies to develop a gasoline desulfurizer for fuel cell powered vehicles.

The Medium and Heavy Duty Alternative Fuel Vehicle Demonstration Program

$246,750 for a 400 hp DDC LNG engine in a class 8 truck.

$90,000 to San Francisco to install Cummins 5.9L CNG engines in 6 street sweepers.

The Electric Vehicle Infrastructure Demonstration Program

$270,00 in funding for electric vehicle charging equipment and related installation. The SCAQMD also allocated $250,000 to this program.

The Electric Vehicles Incentive Program

$800,000 was provided for electric vehicle acquisition. The following agencies matched the per vehicle funding:

- San Luis Obispo County Air Pollution Control District
- Sacramento Metropolitan Air Quality Management District
- Santa Barbara County Air Pollution Control District
- Ventura County Air Pollution Control District
- San Diego County Air Pollution Control District
- Bay Area Air Quality Management District

Medium and Heavy Duty Alternative Fuel Vehicle Incentives

$49,500 for Elk Grove Unified School District to install 225 horsepower CNG John Deere Model HFN 6.8 engines in 1992 Bluebird TC2000 school buses.

$157,500 to United Parcel Service of America, Inc. to repower up to 104 package delivery vehicles to operate on CNG using GM 4.3 L engines operating with the Baytech CNG link system.

$200,000 to United Parcel Service to assist in funding the conversion of 104 vehicles from diesel to CNG.

$49,425 to Matheson LNG to convert three heavy-duty class 8 trucks to low-emission LNG diesel dual fuel.

Alternative Fuel Infrastructure Incentives

$100,000 to Ventura County Air Pollution Control District for a CNG fueling facility in Camarillo.

$100,000 for a CNG fueling facility at Napa Unified School District.

$56,000 to assist Tehachapi Unified School District in the development of a CNG fueling facility.

$50,000 to assist San Joaquin Valley Unified Air Pollution Control District in the development of a CNG fueling facility in Fresno.

$40,000 to Tahoe Transportation District for ground support equipment to support a portable CNG fueling site.

$10,700 to Paradise Unified School District to develop a CNG fueling facility.

1998 The Electric Vehicle Incentive Program provided the following for EV acquisition:

$125,000 to Sacramento Metropolitan Air Quality Management District.

$400,000 to Bay Area Air Quality Management District.

$50,000 to Ventura County Air Pollution Control District.

$25,000 to San Luis Obispo County Air Pollution Control District.

$145,000 to Ovonics for Nickel Metal Hydride School Bus Demonstration.

The Energy Commission supported the 1998-99 Ethanol Vehicle Challenge.

The Energy Commission contributed $89,000 to the Interstate Clean Transportation Corridor project.

1999 Work In Progress

$400,000 to fund development of small-scale natural gas liquefaction facilities in California.

$40,000 to develop a CNG fueling facility at the state Department of General Services garage in Sacramento.

$400,000 to demonstrate Neighborhood Electric Vehicle concepts in planned communities.

$500,000 to support Alternative Fuel Infrastructure Program.

$500,000 to support contract with Gas Research Institute to develop C8.3G CM566 Natural Gas Engine in association with Cummins Engine Company, Inc.

Fleet Options

When determining the type(s) of fuels to use, private vehicle owners and fleet managers should weigh all the factors: economics, available models, rebates, incentives, refueling, fueling facilities, dedicated vehicle or a bi-fuel vehicle, operating range, trade-in value, and maintenance.

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Chapter 2

Laws, Regulations and Incentives Applicable to Alternate Fueled Vehicles

Introduction

This chapter discusses current federal, State and local air district laws, regulations and incentives. Also included is a description of the U.S. Department of Energy (DOE) Clean Cities Program regarding alternative fueled vehicles.

Federal and State Regulations

Federal and State regulations exist to encourage industry to develop and deploy alternative fuel vehicles in California and/or require the purchase of alternative fuel vehicles. The most pertinent federal laws became effective in the late 1980s and early 1990s. These include the Alternative Motor Fuels Act (AMFA) of 1988, the Clean Air Act Amendments (CAAA) of 1990 and the National Energy Policy Act (EPAct) of 1992. In addition, President Clinton issued an Executive Order in 1993 requiring federal agencies to enhance alternative fuel vehicle purchases beyond the requirements of EPAct.

Federal legislation such as the Transportation Equity Act for the 21st century (TEA 21) makes funding available for alternative fuel vehicles through the Congestion Mitigation and Air Quality Improvement (CMAQ) Program and Clean Fuel Formula Grant Program. These programs can provide funding to help pay for the incremental costs of alternative fuel vehicles. The DOE's Clean Cities Program provides a mechanism to expand the use of alternative fuels at the local level. This is accomplished through the voluntary actions of stakeholders with local decision making under coordinating efforts provided by DOE.

The California Air Resources Board (ARB) adopted the Low-Emission Vehicle and Clean Fuels (LEV/CF) regulations in 1990 (See Table II-1). In 1998 the ARB adopted LEV II , which provides partial credit for hybrid-electric, fuel cell, and other near zero emission vehicles (See Table II-2).

Table II-1
ARB Low Emission Vehicle (LEV 1) Standards for Passenger Cars and Light-Duty Trucks

ALLOWABLE CERTIFICATION EMISSION FOR 50,000 MILES AND 100,000 MILES IN GRAMS PER MILE

	NMOG		CO		NOx	
	50,000	100,000	50,000	100,000	50,000	100,000
1993 Standards	.25	.31	3.4	4.2	0.4	0.6
TLEV	0.125	.31	3.4	4.2	0.4	0.6
LEV	0.075	0.90	3.4	4.2	0.2	0.3
ULEV	0.040	0.055	1.7	2.1	0.2	0.3
ZEV	--	--	--	--	--	--

Note: NMOG = Non-Methane Organic Gases, CO = Carbon Monoxide, NOx = Nitrogen Oxides; TLEV = Transitional Low Emission Vehicle, LEV = Low Emission Vehicle, ULEV = Ultra-Low Emission Vehicle, ZEV = Zero (tailpipe) Emission Vehicle. Emissions in grams per mile are allowed to increase as the car ages from 50,000-100,000 miles.

These regulations encourage industry to develop clean alternative fuels and vehicles. By design, these regulations are fuel neutral but do require oil companies to install retail facilities and make alternative fuels available under certain circumstances. In addition, automobile manufacturers are required to offer 10 percent of all new cars for sale as zero emission vehicles in the 2003 model year.

The ARB also administers incentive programs such as the Carl Moyer Clean Engine Incentive Program. This program encourages deployment of alternative fuel engines/vehicles based on their low emissions potential. Substantial funding is available through local air pollution control districts and air quality management districts to pay for the incremental cost of low-emission alternative fuel engines, trucks or buses. Local air quality district programs encourage the development and deployment of alternative fuel vehicles and fuel infrastructure for air quality purposes.

Federal Laws

The Alternative Motor Fuels Act of 1988 (Act)

The Alternative Motor Fuels Act of 1988 (Act), Public Law 100-494, encourages the development, production and demonstration of alternative motor fuels and alternative fuel vehicles. This law allows Corporate Average Fuel Economy (CAFE) credits for new vehicles designed to use alternative fuels exclusively or those capable of operating on conventional and alternative fuel. For dedicated alternative fuel vehicles, fuel economy is based on the amount of gasoline consumed. Thus, a M85 vehicle achieving fuel economy of 15 miles per gallon (mpg) would recalculate the fuel economy by dividing this number by the fraction of gasoline (0.15) to yield a fuel economy of 100 mpg for CAFE purposes. For bi-fuel or flexible fuel vehicles, the mpg is calculated as an average of the mpg's for the alternative and conventional fuel. For this calculation, we assume that the vehicle operates on both fuels for an equal time. However, to avoid abuse of this provision of the law when no alternative fuel may be available, the Act places a 1.2-mpg cap on the total CAFE credit available to manufacturers in any given year. The CAFE credit has encouraged automobile manufacturers to develop and sell AFVs such as bi-fuel vehicles that operate on CNG or LPG, FFVs that operate on ethanol and methanol, and dedicated natural gas cars, light trucks and electric vehicles.

Clean Air Act Amendments (CAAA) of 1990

The CAAA of 1990, Public Law 101-549, amended the original Clean Air Act passed in 1970. The amendments include provisions requiring the use of clean fuels in several metropolitan areas nationwide that are in severe or extreme non-attainment of the national ambient air quality standards for ozone or carbon monoxide. In contrast to the EPAct definition of clean fuels as non-petroleum fuels that can displace petroleum based fuels, the CAAA defines clean fuels to include reformulated gasoline and diesel fuel, recognizing that these fuels provide air quality benefits. Alternative fuels identified as "clean fuels" in the CAAA include methanol (M85), ethanol (E85), other alcohols, natural gas and liquefied petroleum gas (LPG). The differences in provisions of EPAct and CAAA, geographic areas covered, and vehicle purchase requirements are summarized in Tables II-3 through II-6.

Table II-2
ARB Low Emission Vehicle (LEV 2) Standards for Passenger Cars and Light Trucks Less Than 8,500 lbs. Gross Vehicle Weight.

ALLOWABLE CERTIFICATION EMISSION FOR 50,000 MILES AND 120,000 MILES IN GRAMS PER MILE								
2004 and Subsequent Years	NMOG		CO		NOx		Particulates	
	50,000	120,000	50,000	120,000	50,000	120,000	50,000	120,000
TLEV	0.125	0.156	3.4	4.2	0.4	0.6	--	0.04
LEV	0.075	0.090	3.4	4.2	0.05	0.07	--	0.01
ULEV	0.040	0.055	1.7	2.1	0.05	0.07	--	0.01
SULEV	--	0.010	--	1.0	--	0.02	--	0.01

Notes are same as LEV 1 table except add "SULEV = Super Ultra-Low Emission Vehicle." "ZEV standards not shown."

Table II-3
Comparison of the Amended Clean Air Act of 1990 and National Energy Policy Act of 1992

PROVISION	CLEAN AIR ACT AMENDMENTS OF 1990	NATIONAL ENERGY POLICY ACT OF 1992
Persons Affected	Public or private fleet owners or operators with 10 or more vehicles capable of being centrally fueled. Note: California fleets are exempt.	"Persons" who own, operate, lease or control at least 50 vehicles in the U.S. (centrally fueled or capable of being centrally fueled), primarily operated in a Consolidated Metropolitan Statiscal Area (CMSA) with a 1980 population of 250,000 or more.
Areas Affected	22 metropolitan areas with a 1980 population of 250,000 or more and designated by the U.S. EPA as in severe,or extreme non-attainment of either ambient ozone or carbon monoxide standards (See Table II-4 page16). Other areas may "opt-in" to the program per state air quality attainment strategy (no other areas have done so through mid-1994).	More than 120 cities with a 1980 population of 250,000 or more (See Table II-5 page 16 for California Cities).
Fleet Definition	Ten or more light-duty or heavy-duty vehicles located in the affected area.	Fleets of 20 or more light-duty vehicles, less than 8,500 pounds gross vehicle weight capable of being centrally fueled that are owned, operated, leased, or controlled by a govenment entity or by any person who controls 50 or more such vehicles.
Effective Dates	Begins in 1998 (See Table II-6 page 17).	1993 (federal fleets). 1997 (State fleets). 1997("fuel providers"). 1999 (municipal/private). 2002 (municipal/private by U.S.DOE rule). (See Table II-6 page 17).
Purchase Requirements	Clean Fuel Vehicle (CFV) Fleet Program (See Table II-6 page 17).	There are requirements for federal, State, fuel providers, municipal, and private fleets. (See Table II-6 page 17).
Fuel Definition	Clean Fuels including: - Methanol (M85). - Ethanol (E85). - Other alcohols. - Reformulated Gasoline. - Clean Diesel. - Natural Gas. - Liquefied Petroleum Gas.	Alternative Fuels including: - Methanol. - Ethanol. - Other alcohols, separately or in mixtures of 85% by volume or more (but not less than 70% volume by rule) with gasoline or other fuels. - Compressed Natural Gas (CNG). - LPG. - Hydrogen. - "Coal-derived liquid fuels." - Fuels derived from "biological materials."

Table II-3 (continued)
Comparison of the Amended Clean Air Act of 1990 and National Energy Policy Act of 1992

PROVISION	CLEAN AIR ACT AMENDMENTS OF 1990	NATIONAL ENERGY POLICY ACT OF 1992
Fuel Definition (continued)	Electricity "Any other power source" able to meet California vehicle emissions standards.	Electricity Any other fuel "substantially not petroleum" yielding "substantial energy security benefits and substantial environmental benefits." Reformulated gasoline may not be used to meet EPAct requirements.
Credits	Provides credits for CFV fleets. (California fleets are not covered.) Emissions reduction credits available for CFVs that are exempt from requirements, purchased in advance or requirement, or purchased in excess of minimum requirement. Credits can be transferred, "banked," or used to offset new sources within the same non-attainment area.	Credits earned if AFVs are acquired in excess of minimum required or in advance of date of requirement at the rate of one credit per vehicle. Credits earned are transferable from one area to another.
Buses	Bus Requirements: Initially, all buses in cities with populations of 750,000 or more would be operated on "clean fuels" (phased-in starting in 1994). Urban bus retrofit regulations are effective beginning in 1995. They require buses to be retrofitted according to a schedule and meet stricter emissions standards, including a minimum reduction in particulates of 25% either on a per-vehicle or fleet average basis. Bus Retrofit Requirements: Effective in 1995, new emissions requirements for rebuilt, heavy-duty diesel-engine urban buses will be applicable to model year 1993 or earlier. There is a 0.10 gram/bhp-hr (maximum) particulate matter (PM) emissions limit in cities with a population of 750,000 or more.	Bus Demonstrations Urban Buses:The Department of Transportation (DOT) and DOE shall initiate cooperative ventures with local governments with populations of 100,000 or more to demonstrate the feasibility of commercializing the use of alternative fuels. School Buses: The DOT may provide financial assistance to local units of government (in urban areas with populations of 100,000 or more) to cover the incremental costs of operating and purchasing buses using alternative fuels, including vehicle conversions.
Off-Road Engines	The EPA is preparing to propose regulations to control emissions NO_x and PM from heavy-duty (and other) engines used in off-road applications, including farm equipment, marine engines and locomotives.	The DOE is required to conduct a study to determine the effectiveness of using alternative fuels in off-road vehicles in "surface transportation" such as rail, airport vehicles, marine engines and others.

Table II-3 (continued)
Comparison of the Amended Clean Air Act of 1990 and National Energy Policy Act of 1992

PROVISION	CLEAN AIR ACT AMENDMENTS OF 1990	NATIONAL ENERGY POLICY ACT OF 1992
Tax Incentives	No provisions.	Maximum tax deductions are provided as follows for the incremental costs of AFVs (including retrofits) and refueling facilities placed in service after June 30, 1993: AFVs up to 10,000 lb. GVW: up to $2,000 AFVs 10,0001 - 26,000 lb. GVW: up to $5,000 Trucks/Vans over 26,000 lb. GVW: $50,000 Buses with seating capacity of 20 or more adults: $50,000 Electric Vehicles: 10% tax credit up to $4,000/vehicle AFV Refueling Facility: $100,000
Biodiesel Study	Study on "alcohol esters of rapeseed oil" concerning its "feasibility, engine performance, emissions and production capability."	No provisions.
Replacement Fuels	No provisions.	The portion of a motor fuel that is methanol, ethanol, or other alcohol, CNG, LPG, hydrogen, coal-derived liquid fuel, fuel "other than alcohol" derived from "biological materials," electricity, and ethers. The DOE may determine by rule that any other fuel that is "substantially not petroleum" and yielding "substantial energy security benefits and substantial environmental benefits" will qualify as a replacement fuel. National Petroleum Reduction Targets: By 2000: 10 percent replacement By 2010: 30 percent replacement

Table II-4
Areas Covered in Clean Air Amendments of 1990

(Clean-Fuel Vehicle Fleet Program)
California Cities/Regions in Bold

Los Angeles-Anaheim-Riverside, CA
Sacramento, CA
San Diego, CA
San Joaquin Valley, CA
Southeast Desert, CA
Ventura County, CA

Atlanta, GA
Baltimore, MD
Baton Rouge, LA
Beaumont-Port Arthur, TX
Chicago-Gary-Lake County, IL-IN-WI
Denver-Boulder, CO
El Paso, TX
Greater Connecticut, CT
Houston-Galveston-Brazoria, TX
Milwaukee-Racine, WI
New York-Long Island-Northern Jersey, Ny-NJ
Philadelphia-Wilmington-Trenton, PA-DE-MD-NJ
Providence-Pawtuckett-Fall River, RI-MA
Springfield, MA
Washington, DC Area, MD-VA-DC

Table II-5
EPAct-Affected Areas in California

Bakersfield	Fresno
Los Angeles-Anaheim-Riverside	Modesto
Sacramento	Salinas-Seaside-Monterey
San Diego	San Francisco-Oakland-San José
Santa Barbara-Santa Maria-Lompoc	Stockton

Metropolitan Areas of California with a 1980 Population of 250,000 or More

Table II-6
Comparison of New AFV Purchase Requirements For Affected Vehicle Fleets

	Clean Air Act	National Energy Policy Act of 1992 [1]				
Year	(% of CFVs) **Percentages Do Not Apply to California Fleets**	Federal (% or # of AFVs)	State (% of AFVs)	Fuel Provider (% of AFVs)	Municipal & Private [1] **Early Rule** (% of AFVs)	Municipal & Private [1] **Late Rule** (% of AFVs)
1993		5,000/7,500[2]				
1994		7,500/11,250[2]				
1995		10,000/15,000[2]				
1996		25%/17,500[2]	10%/25%[3,4]	30%[4]		
1997		33%/20,000[2]	15%/33%[3,4]	50%[4]		
1998	30%	50%/30,000[2]	25%/50%[3,4]	70%[4]		
1999	50%	75%/40,000[2]	50%/75%[3,4]	90[4]	20%	
2000	70%	75%	75%[3,4]	90%	20%	
2001	100%	75%	75%	90%	20%	
2002	100%	75%	75%	90%	30%	20%
2003	100%	75%	75%	90%	40%	40%
2004	100%	75%	75%	90%	50%	60%
2005	100%	75%	75%	90%	60%	70%
2006	100%	75%	75%	90%	70%	70%

1) Under the National Energy Policy Act, the U.S. Secretary of Energy has two opportunities to rule on AFV purchases for private fleets. If a rulemaking is issued by December 16, 1996, then the percentages in the "early rule" column apply. If a rulemaking is not issued until later (January 1, 2000, deadline), then the percentages in the "late rule" column apply.

2) Federal fleet purchases were changed by Executive Order 12844 signed by President Clinton in February 1993. This increases federal purchases (if vehicles are available from auto companies) to 7,500 in 1993; 11,250 in 1994; 15,000 in 1995; 17,500 in 1996; 20,000 in 1997; 30,000 in 1998; and 40,000 in 1999. Purchase percentages are based on about 50,000 vehicle acquisitions per year and vehicle turn-over/replacement after five years.

3) The percentage of AFVs required by the State of California were increased by Executive Order No. W-100-94, signed by Governor Wilson on August 15, 1994. The Executive Order requires: 25 percent of vehicles purchased in 1996; 33 percent in 1997; 50 percent in 1998; and 75 percent in 1999 be AFVs (if vehicles are available from manufacturer and at a reasonable cost). The order also requires that 10 percent, inclusive, must be Ultra-Low Emission Vehicles or Zero-Emission Vehicles in 1996 and beyond.

(Note: Both the Presidential and Governor's Executive Orders are not fully binding in that vehicle acquisitions may be based on cost and availability of AFVs, availability of funds, etc.)

4) In March 1996, the U.S. Department of Energy ruled that states and fuel providers will have an additional year to begin purchasing AFVs, thus delaying implementation for these two groups until 1997.

The National Energy Policy Act of 1992 (EPAct)

The EPAct, Public Law 102-486, was signed into law on October 24, 1992. Several titles are directed at alternative transportation fuels to determine the feasibility of achieving 10 percent replacement fuels by 2000 and 30 percent by 2010. Under the EPAct, alternative fuels are specifically defined as those, which are "substantially not petroleum" and which yield "substantial energy security benefits and substantial environmental benefits." Important provisions include the following:

A program to promote the development and use of replacement (alternative) fuels in light duty vehicles;

Purchase requirements for federal, state, and alternative fuel provider fleets beginning in 1993;

Purchase goals of 75 percent for fuel provider fleets and 90 percent of all new vehicle purchases by the year 2000;

Incentives in the form of tax deductions for the incremental costs of AFVs and the full costs of refueling facilities; and

A study to determine the economic and technical feasibility of replacement fuels to achieve petroleum reduction goals of 10 and 30 percent, respectively, for the years 2000 and 2010.

Transportation Equity Act for the 21st Century (TEA-21)

TEA 21 was passed into law June 9, 1998. This comprehensive transportation bill includes funding through its Congestion Mitigation and Air Quality Improvement Program (CMAQ). This funding is specifically designated for programs which reduce transportation related emissions in nonattainment and maintenance areas. With funding for 1999 and 2000 at over $1 billion per year, substantial opportunities exist for an array of funded projects, including projects involving the purchase of alternative fuel vehicles. Privately owned vehicles and fleets are eligible for these funds, but these incentives are limited to the incremental costs of alternatively fueled vehicles compared to the cost of a gasoline or diesel vehicle. Public sector vehicles and fleets as well as transit vehicles and educational entities wanting to use alternative fuels can also apply for these funds.

The selection of successful projects and programs fall under a cooperative process involving the State Department of Transportation (CalTrans), local air quality districts and APCDs. New provisions through TEA-21 also allow the funding of Public/Private Partnerships as well as nonprofit entities. Any entity can control the project or program and the public agency involved is no longer required to be the lead entity.

California Regulations

In September 1988, the California Clean Air Act was signed into law. The act defined a framework for air quality planning and regulations and created a new basis for attaining National Ambient Air Quality Standards (NAAQS) required under the CAAA and California's own more strict air quality goals. Because of the enormity of its air pollution problems, California was allowed under the federal Clean Air Act Amendments of 1990 to continue to set its own standards for vehicle emissions.

California Low-Emission Vehicle and Clean Fuels Regulations

In September 1990, the ARB adopted its Low Emission Vehicles (LEV) and Clean Fuels (CF) regulations. These regulations apply to clean conventional and alternative fuels. The ARB took the unprecedented step of requiring a phase-in of the strictest ever motor vehicle emissions standards, including the first-ever mandate of Zero Emission Vehicles (ZEVs).

The ARB set four levels of low-emission vehicle standards and designated them as the following:

- Transitional Low Emission Vehicles (TLEV)
- Low Emission Vehicles (LEV)
- Ultra-Low Emission Vehicles (ULEV)
- Zero Emission Vehicles (ZEV)

In addition, under the regulations, each manufacturer is required to meet a declining emission standard that is mandated for non-methane organic gas (NMOG). The mandate does not specify the number of vehicles in each LEV level category but allows manufacturers to choose the combinations to achieve the fleet average value each year until 2003 (See Table II-7).

A protocol for determining the ozone forming potential of gasoline and alternative fuels was established. "Reactivity adjustment factors" (RAFs) developed under the protocol apply to NMOG emissions and effectively convert the mass based hydrocarbon emission standard before 1992 to an ozone forming potential standard based on the reactivities of individual hydrocarbon class associated with each vehicle fuel.

Table II-7
One Possible Low Emission Vehicle Implementation Schedule Under the LEV I Regulation

Model Year	Conventional Standard	TLEV	LEV	ULEV	Original ZEV Mandate - 9/90	New ZEV Mandate - 3/96
1993	40%					
1994	80%	10%				
1995	85%	15%				
1996	80%	20%				
1997	73%		25%	2%		
1998	48%		48%	2%	2%	voluntary
1999	23%		73%	2%	2%	voluntary
2000			96%	2%	2%	voluntary
2001			90%	5%	5%	voluntary
2002			85%	10%	5%	voluntary
2003			75%	15%	10%	10%

Note: Only the ZEV percentages are mandated. The others are potential percentages that the auto companies can use as goals. The auto companies must attain an across-the-fleet average NMOG emission level each year--see following figure. Table applicable to passenger cars and light-duty trucks < 3,750 lbs. GVW.

In 1998, the ARB amended the LEV regulation. LEV II, as it is known, establishes the super low emission vehicle (SULEV) category, extends fleet average emissions requirements to the year 2010 and tightens particulate standards in the LEV categories. It subjects new sport utility vehicles and light trucks to stringent passenger car standards (See Table II-8).

Other important aspects of these amended regulations include the reduction of the NO_x standard for LEV and ULEV categories to 0.05 grams per mile, increased durability requirements, and lower evaporative emissions for all classes of vehicles. Also, the fleet average NMOG emission standard is extended to 2010 while declining to 0.035 grams per mile, a level which will require manufacturers to produce ULEV, SULEV and lower emission vehicles to comply. Partial ZEV credits are established under LEV II as well. These new provisions allow manufacturers to substitute low emission and/or alternative fuel technologies for electric vehicles up to 60 percent of their ZEV commitment in 2003 (See Table II-9). This provision will encourage hybrid vehicles, alternative fuels, and advanced technology vehicles such as fuel cells. A methanol fuel cell vehicle could be eligible to earn between 0.8 and 1.0 EV credit under the rule while a gasoline SULEV would earn only 0.2 ZEV credit. The credit takes into account full fuel cycle emissions; therefore, low upstream emission fuel options can generate additional partial credits.

The Clean Fuel Outlet Provisions of the ARB's Clean Fuels regulation applies to four alternative fuels. These are methanol, ethanol, propane and natural gas. If manufacturers produce 20,000 dedicated vehicles that operate on any of these fuels, certified to LEV emission standards or better, this would "trigger" the fuel availability provisions of this regulation. Owners/operators of fuel stations are subject to these provisions and must site dispensing equipment and make the alternative fuel available for sale at retail facilities. The regulation makes allowances for existing alternative fuel sites that meet certain "amenity" requirements of the regulation and adjusts the number of required retail sites downward based on the number of vehicles using private fueling facilities. FFVs and bi-fuel vehicles do not count towards the 20,000 vehicle trigger unless they have been emissions certified to a lower LEV standard on the alternative fuel when compared to the certification level on gasoline. Once any one alternative fuel becomes available at 10 percent of the retail gasoline outlets in California, these provisions of the regulation have served their purpose and no longer apply.

Table II-8
One Possible Low Emission Vehicle Implementation Schedule Under the LEV II Regulation

Model Year	Conventional Standard	TLEV	LEV	ULEV	SULEV	New ZEV Mandate - 3/96 ZEV
2004	0	2%	48%	35%	5%	10%
2005	0	2%	40%	38%	10%	10%
2006	0	2%	35%	41%	12%	10%
2007	0	1%	30%	44%	15%	10%
2008	0	1%	25%	44%	20%	10%
2009	0	1%	20%	49%	20%	10%
2010	0	1%	15%	49%	25%	10%

Table applies to passenger cars and light-duty trucks < 3,750 lbs. GVW.

Table II-9
Fleet Average NMOG Exhaust Mass Emission Requirements for Passenger Cars and Light-Duty Trucks (50,000 mile durability Vehicle Basis)

Model Year	Fleet Average NMOG (grms per mile)	
	LEV I	LEV II
1994	0.250	--
1995	0.231	--
1996	0.225	--
1997	0.202	--
1998	0.157	--
1999	0.113	--
2000	0.073	--
2001	0.070	--
2002	0.068	--
2003	0.062	--
2004	--	0.053
2005	--	0.049
2006	--	0.046
2007	--	0.043
2008	--	0.040
2009	--	0.038
2010	--	0.035

Note: Includes passenger cars and light-duty trucks up to 5750 lbs. GVW. Each manufacturer must achieve the NMOG values shown for the mix of models sold each year.

Zero Emission Vehicle Mandate

California's Zero Emission Vehicle mandate was instituted under the Low Emission Vehicle regulation in 1990. It requires vehicle manufactures to phase in electric vehicles into new cars for sale in California beginning in 1998. In 1996, the ARB revised the schedule for electric vehicle phase-in based on delayed availability of advanced batteries not foreseen in 1990. Under the revised schedule of 1996, manufacturers are still required to produce for sale 10 percent of their new passenger cars and light trucks (LDT1) as electric vehicles in the 2003 model year and beyond. The ARB and manufacturers entered into a Memorandum of Agreement (MOA) to ensure progress in developing EVs and to establish a EV demonstration program for model years 1998 through 2002.

Under the MOA, manufacturers agree to produce and demonstrate a total of 4,107 vehicles for these model years. Vehicles which demonstrate advanced batteries with higher specific energy will gain multiple ZEV credits. In addition, should manufacturers choose to introduce ZEVs with 100 miles range or batteries with specific energy equal to or exceeding 50 w-hr/kg, then multiple ZEV credits will be granted. Those vehicles achieving the highest range (150 miles) or battery specific energy equal to or greater than 90 w-hrs/kg combined with the early introduction will earn 3 ZEV credits towards their MOA commitment.

Local Air District Programs

Currently, 35 local air quality districts can pass and enforce local air quality ordinances or regulations that will affect fleets, businesses and individuals. On the next few pages, there is a summation of regulations and incentives for a number of districts.

Bay Area Air Quality Management District (BAAQMD)

The BAAQMD requires large companies to develop a trip-reduction program or an Alternative Emission Reduction Program (AERP), which is updated every two years. The AERP can include clean fuel vehicles in employer fleets (either new or retrofit) or clean fuel buses (transit buses, school buses or shuttles). The employer must demonstrate, however, that the clean fuel vehicles are not being used by the vehicle manufacturer to fulfill the state LEV/ZEV requirements or by the employer to comply with any clean fuel vehicle fleet rule (such as under the National Energy Policy Act).

The BAAQMD administers the Transportation Fund for Clean Air (TFCA). Grant funding is available to public agencies for several types of eligible transportation and motor vehicle related projects. Public agencies may receive grant funding to help fund the purchase of clean fuel school and transit buses. These agencies include cities, counties, school and transit districts, regional agencies and other public entities. Funding may also be available for other demonstrations of alternative fuel vehicles such as passenger cars, pick-up trucks, street sweepers, refuse haulers and parking enforcement vehicles.

The BAAQMD also administers an incentive program co-funded with the California Energy Commission that provides a $5,000 incentive per qualifying electric vehicle.

Imperial County Air Pollution Control District

The Imperial County APCD is in the process of constructing a fast-fill facility natural gas facility for public use at Fairfield and Commercial Streets in El Centro. The Southern California Gas Company will be the billing agency for this project and may be contacted to request fuel access and cards. The facility is expected to be operational by late 1999.

The Imperial County APCD has funds available to pay fleet incremental costs towards the purchase of natural gas vehicles.

Mojave Desert Air Quality Management District (MDAQMD)

The Mojave Desert Air Quality Management District has a competitive grant program aimed toward reducing emissions for mobile sources. This program, the Mobile Source Emission Reductions Competitive Bidding Program, awards funds to organizations capable of effectively reducing mobile source emissions. Public and private entities may submit proposals as sole or joint applicants.

The Competitive Bidding Program normally operates on a two-year cycle, with approximately $500,000 available for projects in each cycle. First, the MDAQMD releases a request for proposals (RFP). Once proposals are received, the Mobile Source Emission Reductions Committee established by the MDAQMD Governing Board reviews them. The Committee then makes project funding recommendations to the Governing Board, and the Board makes final funding decisions. The next regular RFP is scheduled for release in early 2000. For more information regarding the competitive bidding process or to receive a copy of the most recent RFP, please contact the MDAQMD at (760) 245-1661, extension 5597.

Northern Sonoma County Air Pollution Control District

The Northern Sonoma County Air Pollution Control District (District) releases Request for Proposals (RFP) once a year for projects to reduce motor vehicle emissions within their district boundaries. The funding for these projects is from motor vehicle registration fees. To apply for these funds contact the District at 150 Matheson Street, Healdsburg, CA 95448-4908 and request to be placed on the "VPMP RFP" mailing list.

SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT

Sacramento Metropolitan Air Quality Management District (SMAQMD)

SMAQMD has several incentive programs available, many of which have a continuous filing policy for unique and/or innovative alternative fuel and reduced emission projects. Projects are reviewed by the District as they are received. There is no formal application. Contact the SMAQMD Mobile Source Division at (916) 874-4800 for information.

1. Alternative Fuel Incentive Matrix - SMAQMD has continuous filings for incentives ranging from $200 to $5,000 for light and medium-duty vehicles, including motorcycles that use alternative fuels and are certified as low emission vehicles. The qualifying vehicles must be registered by the Department of Motor Vehicles for on-street use and be operated in Sacramento County at least 75 percent of the time.

2. Off-Road Motor Vehicle Incentive Program - SMAQMD has incentives ranging from $1,000 to $14,000 per piece for self-propelled agricultural, construction and mining equipment that is repowered or retrofit with an engine that has reduced emissions, including on-road certified diesel engines. The incentive is calculated based upon horsepower and emission reduction. This program is available to any owner and/or operator of off-road equipment located in the Sacramento Federal Non-Attainment Area, which includes all of Sacramento and Yolo Counties, and parts of El Dorado, Placer, Solano and Sutter Counties.

3. On-Road Heavy-Duty Vehicle Incentive Program - SMAQMD has incentives up to $200,000 per entity for purchase, retrofit or repowering of a vehicle with a engine that has reduced emissions, including on-road certified diesel engines. Eligible on-road heavy-duty vehicles have a gross vehicle weight of 14,000 pounds or greater. The incentive is calculated on horsepower and emission reduction potential. This program is available to any owner and/or operator of on-road equipment located in the Sacramento Federal Non-Attainment Area, which includes all of Sacramento and Yolo Counties, and parts of El Dorado, Placer, Solano and Sutter Counties.

AIR POLLUTION CONTROL DISTRICT
COUNTY OF SAN DIEGO

San Diego County Air Pollution Control District (APCD)

The San Diego APCD continues to offset new and increased emissions from stationary sources with emission reductions from mobile sources. Because of declining potential for offsets from the region's stationary sources, the APCD Board recognized that there was a substantial demand for cost-effective credits from mobile sources. Motor vehicles contribute more than 60 percent of the smog-forming emissions in the San Diego air basin, while industry contributes less than 15 percent.

Rule 27 allows emission reduction credits from motor vehicles to be registered as "credits" in a District "Bank." Industry can withdraw or purchase these credits later to meet State and federal Clean Air Act offset requirements.

The rule specifies five ways mobile source emission credits can be created, including:

- Accelerating vehicle retirement (scrapping program)
- Purchasing low-emission transit buses (primarily compressed natural gas)
- Purchasing zero emission vehicles
- Retrofitting cars, and light- and medium-duty trucks to meet low-emission standards
- Retrofitting heavy-duty vehicles to meet low-emission standards

The rule also provides for other innovative technologies that create valid mobile source emission reductions.

The APCD currently has a program with a private contractor to purchase and scrap 4,000 pre-1982 vehicles. As of December 1998, the program was roughly 75 percent completed and should be completed in late 1999. Rule 27 provides a mechanism to continue the program under private funding.

San Joaquin Valley Air Pollution Control District (SJVAPCD)

The San Joaquin Valley Air Pollution Control District is comprised of the counties of San Joaquin, Stanislaus, Merced, Fresno, Kings, Tulare and the valley portion of Kern. The SJVAPCD currently offers two programs for which AFVs may qualify.

The REMOVE Program (Reduced Motor Vehicle Emissions) allocates funds for projects that will reduce motor vehicle emissions within the SJVAPCD through a competitive request for proposal (RFP) process. This program provides funding on an annual basis and has funded over 200 projects since 1992. Applicants can apply to receive part of the incremental cost of converting their vehicles to an alternative fuel. Only vehicles under 14,000 gross vehicle weight (GVW) qualify for funding. The program does not currently provide funding for fueling infrastructure or bi-fuel conversions. For further information, contact John Villeneuve at (559) 230-5800.

The SJVAPCD also provides incentives toward the differential cost associated with low-emission technology in the Heavy-Duty Motor Vehicle Incentive Program. Funds are available for all eligible new OEM heavy-duty engines, engine replacements and/or retrofits on a first come, first serve basis. Only vehicles over 14,000 GVW qualify for this funding. This program has both on-road and non-road vehicle components. For more information, contact Jeff Findley at (559) 230-5800.

South Coast Air Quality Management District (SCAQMD)

The South Coast Air Quality Management District has a number of programs to support development, demonstration and commercialization of clean alternative fuel vehicle technology. The Clean Fuels Program within the Technology Advancement Office, co-funds development and demonstration of low emission, alternative fuel vehicle technology. Specific technology RFPs are issued, and unsolicited proposals are accepted. To be placed on the Technology Advancement mailing list or to receive proposal guidelines, contact Michelle White at (909) 396-3259 or < mwhite@aqmd.gov>.

The Air Quality Investment Program (AQIP) allows employers subject to Rule 2202 in the South Coast Air Basin to invest annually in a special restricted fund rather than falling under Rule 2202 requirements. The purpose of the AQIP is to reduce emissions equivalent to those which the employer would have to meet under Rule 2202. Funding amount is based upon the total number of employers that choose to pay into the program and varies from year to year. An average over the past three years is $2,450,000 a year. For more information regarding the AQIP, contact Connie Day at (909) 396-3055 or <cday@aqmd.gov>.

The Mobile Source Air Pollution Reduction Review Committee (MSRC) develops an annual work program to fund projects to reduce mobile source emissions. The program currently includes a buydown for ZEV/ULEV/LEV dedicated alternative fuel vehicles, ranging from $1,000 to $5,000. A program is also in place to provide incentives for the purchase of natural gas school buses.

In addition, a heavy-duty vehicle incentive program is proposed for the 1999-2000 fiscal year for full-size transit buses and other heavy-duty vehicles over 14,000 GVW. For more information, contact Ray Gorski at (909) 396-2479 or <rgorsaki@aqmd.gov>.

Federal & State Incentives for Alternative Fuel Vehicles

Most alternative fuel vehicles currently cost more than conventional gasoline fueled vehicles because of the limited number of vehicles manufactured and because of the additional components that must be added (such as storage cylinders or extra fuel tanks). The costs for AFVs should drop as economies of scale are achieved with higher production levels. To offset the current differential or incremental cost of equipping vehicles to run on alternative fuels, various government agencies and some utility companies offer tax credits or deductions and incentives to the purchasers.

Federal Tax Credits and Deductions

The EPAct allows a tax credit of 10 percent of the cost of electric vehicles. The credit is based on the purchase price of the vehicle and may not exceed $4,000. The credit is available to vehicles placed into service after June 30, 1993, and before January 1, 2005. The federal tax credit is reduced by 1/4 in 2002, to a maximum of $3,000; 1/2 in 2003, to a maximum of $2,000; and 3/4 in 2004, to a maximum of $1,000. It expires after 2004.

The EPAct also allows for a maximum of up to $2,000 as a federal tax deduction for clean-fuel vehicles that use clean fuels such as ethanol, methanol, natural gas or propane (liquefied petroleum gas or LPG). The federal tax deduction is based on the incremental cost of equipping the vehicle to use the clean fuel, the amount above the price of a conventional gasoline-only fueled vehicle. The federal deduction is available for vehicles placed into service after June 30, 1993, and before January 1, 2005.

- A $5,000 tax deduction is available for alternatively-fueled trucks/vans weighing between 10,000 and 26,000 pounds.
- A $50,000 tax deduction is available for alternatively-fueled trucks/vans weighing more than 26,000 pounds or for buses that can seat at least 20 passengers.
- The deduction is available for vehicles placed into service after June 30, 1993, and before January 1, 2005.
- A tax deduction of up to $100,000 can be claimed for clean fuel refueling sites (including electricity). The tax deduction is available on sites placed into service after June 30, 1993, and before January 1, 2005.

For information on the federal tax credits or deductions, contact your local Internal Revenue Service Office.

Additional Incentives for AFVs

The ARB administers the Carl Moyer Clean Engine Incentive Program, which will reduce oxides of nitrogen (NO_x) emissions from heavy-duty engines. This Program provides funds to pay for the incremental cost of cleaner on-road, off road, marine, locomotive and stationary agricultural pump engines, as well as forklifts and airport ground support equipment. Both natural gas and methanol heavy-duty engines have been certified to low NO_x emission standards and will be eligible for the funding through participating air pollution control and air quality management districts. For State fiscal year 1999/2000, there is $25 million in funding available. This program tackles the difficult problem of NO_x emissions from heavy-duty vehicles, which contribute about 40 percent of all NO_x emissions from mobile sources throughout the state. The Carl Moyer Program encourages emissions reductions beyond those called for under current laws and regulations, and thus the Program accelerates progress to reduce air emissions and help the State meet federally mandated National Ambient Air Quality Standards under the CAAA.

Check with the California Energy Commission for any additional incentives that may be offered for alternative fuel vehicles. Call the Transportation Technology and Fuels Office at (916) 654-4634.

In addition to the Commission's incentives for alternative fuel and vehicles, investor-owned natural gas and electric utility companies have offered incentives that may be reduced in the future. Recent decisions by the California Public Utilities Commission on how much can be spent by the utilities and the "down-sizing" and "restructuring" of utility companies mean that less ratepayer money may be used toward AFV incentives and rebate programs.

Contact your local air quality district and utility company for information about incentives. Phone numbers for the major air quality districts are listed on the map on page 27.

Clean Cities Program of the U.S. Department of Energy

The Clean Cities Program is a locally-based government/industry partnership, which is coordinated by DOE to expand the use of alternatives to gasoline and diesel fuel. By combining local decision-making with the voluntary action of stakeholders, the grass-roots approach of Clean Cities departs from traditional top-down federal programs. At the local level, the goal of the plan is to establish a sustainable, nationwide alternative fuels market.

Market-Based Solution

The Clean Cities Program thrives on strong local initiative and a flexible approach to the challenge of building alternative fuels markets, providing participants with options to address problems unique to cities and fostering partnerships as the mechanism to overcome these problems. The Clean Cities Program works directly with local businesses and governments, guiding them through each step in the process of building the foundation for a vibrant local organization, including goal-setting, coalition-building and securing commitments. The current and potential members of the Clean Cities network also help each other by sharing local innovations mayor-to-mayor, by addressing and relaying obstacles they encounter in pursuing alternative fuels programs, and by exchanging do's and don'ts among themselves based on experiences in these programs. Thus, the Clean Cities Program can continually pioneer innovations and aspire to make strides nationally as well as locally.

Department of Energy's Clean Cities Program Provides Access To:

New Markets: Alternative fuels and alternative fuel vehicles (AFVs) can benefit both the local and national economy by creating new jobs and commercial opportunities. Such activities as AFV conversions, new technology development, greater use of domestically produced fuels and feedstock all generate business growth and new profit opportunities. From Clean Cities springs new demand for AFV products as program stakeholders pledge to make AFV acquisitions through the year 2005. The Clean Cities Program is working to transform these pledges into firm vehicle purchase or conversion orders while challenging manufacturers to develop product lines that meet the varied needs of the market.

Partnerships: The Clean Cities Program unites public and private sector entities whose common goal is to build the alternative fuels market. Such cooperation has allowed localities to choose the alternative fuels that best serve their communities based on fuel availability, fuel performance, emissions reductions and economic factors. The partnerships fostered through the Clean Cities Program also have led to the expansion of the refueling infrastructure, as fuel suppliers commit to providing the facilities, the fuel and the service crucial to further growth of the AFV market.

Support: The Clean Cities Program provides the platform from which stakeholders can address larger goals. The DOE helps organize and manage the program, but local Clean Cities coalitions provide the momentum necessary to sustain productive programs. For example, program members are encouraged to pursue the clean corridor concept in which the Clean Cities Program establishes links to create regional alternative fuels infrastructures. The Clean Cities Program also serves as a vehicle for the DOE to provide local assistance to federal, state and fuel supplier fleets required by law to make AFV acquisitions or conversions.

Resources: DOE's Clean Cities Hotline at 1-800-CCITIES has experts to answer any questions you have about the program. Their e-mail address is <ccities@nrel.gov>. DOE also has appointed Clean Cities program managers at each of its six Regional Support Offices to assist local alternative fuels market development efforts. In addition, the Clean Cities Program offers a wealth of printed material to help parties build and sustain effective coalitions, including:

- *Partnerships for a Strong Economy* (brochure).
- *The Clean Cities Guide to Alternative Fuel Vehicle Incentives and Laws* (funding resource guide). Up-to-date information on how and where stakeholders can find funding for AFV-related programs, contacts at AFV companies, in government and in other Clean Cities coalitions, plus additional useful information.
- *The Road to Clean Cities*. Step-by-step instructions on how to become a Clean City, including outlines for developing a program plan and drafting a memorandum of understanding among participants.
- *Clean Cities Troubleshooting Guide*. Helpful suggestions on solving the challenges Clean Cities organizations may face after establishment.
- *The Clean Cities Drive*. The program's official quarterly newsletter, providing news on developments across the growing Clean Cities network.
- *Clean Cities Game Plan*: Strategic Plan for the Clean Cities Program.

Additional information on alternative fuels and vehicles, refueling infrastructure, legislation, and other DOE programs can be obtained by accessing DOE's web site at <www.ccities.doe.gov> or by calling DOE's National Alternative Fuels Hotline at 800-423-1DOE(1363).

Clean Cities Accomplishments

As of November 1999, the program had created partnerships in 77 communities throughout the country and is still gaining momentum. These Clean Cities Program feature over 30,000 operational AFVs in reducing oil consumption and tailpipe emissions. The 1,500 plus stakeholder organizations are committed to significant increases in AFV acquisitions and infrastructure investment over the next five years.

How To Join Clean Cities

The following required steps lead +to a Clean Cities designation:

- Appoint Clean Cities Coordinator
- Hold Stakeholder Meetings
- Develop a Program Plan
- Execute Memorandum of Understanding
- Receive Clean Cities Designation

How to Get More Information

To speak with someone about the Clean Cities Program or to receive any of the above publications, access their web site at <www.ccities.doe.gov>, contact the Clean Cities Hotline at 1-800-CCITIES (800-224-8437) or write:

U.S. Energy Department
Clean Cities Program, EE-34
1000 Independence Ave. S.W.
Washington, DC 20585-0121

List of Clean Cities

As of January 1999 (The dates reflect when the cities were awarded the Clean Cities designation).

Abuquerque, NM – (6/1/94)
Albany, NY – (4/26/99)
Atlanta, GA – (9/8/93)
Ann Arbor, MI – (4/19/99)
Austin, TX – (4/18/94)
Baltimore, MD – (10/7/94)
Boston, MA – (3/18/94)
Capitol Cities of Connecticut, CT – (6/21/99)
Central Arkansas, AR – (10/25/95)
Central Indiana, IN – (3/4/99)
Central New York, NY – (6/15/95)
Central Oklahoma, OK – (5/29/96)
Chicago, IL – (5/13/94)
Cincinatti, OH – (1/29/97)
Cleveland, OH – (9/14/99)
Coachella Valley, CA – (4/22/96)
Colorado Springs, CO – (7/13/94)
Corpus Christi, TX – (3/30/98)
Dallas/Ft. Worth, TX – 7/25/95)
State of Delaware, DE – (10/12/93)
Denver, CO – (9/13/93)
Detroit, MI/Toronto, ON – (12/18/96)
East Bay (Oakland), CA – (10/21/94)
Evansville, IN – (1/20/97)
Florida Gold Coast, FL – (5/3/94)
Florida Space Coast, FL – (10/1/99)
Genesee Region, Rochester, NY – (5/28/98)
Hampton Roads, VA – (10/4/96)
Honolulu, HI – (8/29/95)
Kansas City Regional, MO/KS – (11/18/98)
Houston, TX – (9/4/97)
Kansas, SW Area, KS – (3/30/95)
Lancaster, CA – (9/22/94)
Las Vegas, NV – (10/18/93)
Long Beach, CA – (8/31/94)
Long Island, NY – (10/18/96)
Los Angeles, CA – (3/22/96)
Louisville, KY – (10/18/94)
Manhattan Area, KS – (10/4/99)
Maricopa Association of Governments, AZ – (10/8/97)
Missoula, MT – (9/21/95)
New Haven, CT – (10/5/95)
New London, CT – (11/22/94)
Norwalk, CT – (11/21/94)
Norwich, CT – (11/22/94)
North New Jersey, NJ – (10/31/97)
Omaha, NE – (9/18/98)
Paso Del Norte, TX – (11/17/95)
Peoria, IL – (11/22/94)
Philadelphia, PA – (9/22/93)
Pittsburgh, PA – (12/5/95)
Portland, ME – (9/4/97)
Portland, OR – (11/10/94)
Providence, RI – (9/14/98)
Puget Sound, WA – (8/13/98)
Red River Valley, Grand Forks, ND – (8/10/98)
Riverside, CA – (10/24/97)
Rogue Valley, OR – (11/10/94)
Sacramento, CA – (10/21/94)
Salt Lake City, UT – (10/3/94)
San Antonio, TX – (11/10/99)
San Diego, CA – (12/12/96)
San Francisco, CA – (10/21/94)
San Joaquin Valley, CA – (10/21/94)
San Jose (South Bay), CA – (10/21/94)
South Shore, IN – (6/15/99)
Southern California Association of Governments, CA – (3/1/96)
St. Louis, MO – (11/18/94)
State of West Virginia, WV – (10/18/94)
Tucson, AZ – (8/24/99)
Tulsa, OK – (9/22/97)
Washington, DC – (10/21/93)
Waterbury, CT – (11/21/94)
Weld/Larimer/Rocky Mountain National Park, CO – (5/21/96)
Western New York, NY – (11/4/94)
Wisconsin, Southeast Area, WI – (6/30/94)
White Plains, NY – (10/4/94)

Figure II-1
Multi-County and Major Air Quality Management and Air Pollution Control Districts in California

Public Information Contacts

1 Bay Area AQMD, 415-771-6000 - Terry Lee (Director of Public Information)
2 Great Basin APCD, 760-872-8211 - Ellen Hardebeck (APC Officer)
3 Monterey Bay Unified APCD, 831-647-9411 Douglas Quentin (APC Officer)
4 North Coast Unified AQMD, 707-443-3093 - Wayne Morgan (APC Officer)
5 Northern Sierra APCD, 530-274-9360 - Rod Hill (APC Officer)
6 Sacramento Metropolitan AQMD, 916-874-4800 - Kerry Shearer (Information Specialist)
7 San Diego APCD, 858-694-8956 - Chuck Spagnola (Transportation Specialist)
8 San Joaquin Valley APCD, 559-230-6000 - Josette Bello (Public Info & Education Officer)
9 South Coast AQMD, 909-396-3240 - Tom Eichorn (Public Info Officer)
10 Yolo-Solano AQMD, 530-757-3650 - Larry Greene (APC Officer)

California Air Resources Board
Public Information Office
(916) 322-2990 or (818) 575-6858

California Energy Commission
Media & Public Communications Office
(916) 654-4989

Chapter 3
Electric Vehicles

Introduction

This chapter discusses electric vehicle history, technology and purchase/leasing options. Also included are electric vehicle charging options, environmental, health and safety aspects, and future potential.

History of Electric Vehicles

According to the *Green Car Guide*, the first electric car was built by Professor Stratingh in the Dutch town of Gröningen in 1835. However, the electric car became a viable transportation option when Gaston Plante invented (1865) and Camille Faure improved (1881) the electric storage battery. In 1899, a unique streamlined racing car named "La Jamais Contente" brought the potential of the electric car to the world's attention by setting a record and going faster than 62 mph (100 kph).

Although electric cars essentially disappeared from use on roads, electric vehicles have been in continual use since the early 1900s in various applications. They have been at work in industrial plants where internal combustion engine exhaust could endanger worker health, on golf courses where their quiet operation adds to the relaxing environment, on work sites to ferry employees between buildings, and on college campuses.

In recent years, electric vehicles have become an important element of the State's clean air strategy, especially given the increasing number of vehicles with internal combustion engines. Since control devices themselves are not enough to control air pollution, the ARB determined that California needs zero emission vehicles to help offset these emissions.

In 1990, the ARB adopted the Low-Emission Vehicle and Clean Fuels Program. This program required that a percentage of vehicles sold in California be Zero-Emission Vehicles, or ZEVs, starting with 2 percent in 1998 and increasing to 10 percent in 2003. This ZEV requirement for 1998 to 2002 was modified in March 1996, but the 10 percent requirement for 2003 remained. This modification also included a requirement that automakers enter into a Memorandum of Agreement (MOA) to:

- Offset the emission benefits lost due to eliminating the 1998-2002 model year ramp up of ZEVs through participation in a national low-emission vehicle program,
- Continue to invest in ZEV and battery research by demonstrating the most advanced battery technologies that are available,
- Offer ZEVs to consumers based on market demand, and
- Demonstrate the production capability for quantities necessary to meet greater market demand if necessary.

Because advanced ZEV battery technology was not progressing as anticipated, the modification gave automakers more time to meet their targets. To show a good faith effort to achieving the 2003 requirement, major automobile manufacturers began to introduce electric cars.

Advances in battery technology, system integration, aerodynamics, and materials as well as commitments by major vehicle manufacturers are making electric vehicles more practical for California roads. In addition, these advances have expanded the role electric vehicles play in off-road vehicles. Electric vehicles can be found at airports moving luggage, people and planes. Law enforcement is using electric bicycles to expand the range without tiring the rider and to allow quiet approach, and cities are bringing back electric transit buses and trolleys.

In 1995, the Electric Vehicle Association of the Americas estimated a total of 587 highway-operable electric vehicles in California (excluding limited function vehicles such as neighborhood electric vehicles and trolleys). In 1999, the estimate rose to more than 2,000 EVs in operation. The Energy Commission continually updates the information to reflect the new electric cars being offered by automobile manufacturers.

Electric Vehicle Technology

This section describes electric vehicle technology and compares it with the internal combustion engine vehicle.

An EV is propelled by an electric motor and an electronic control module. The electronic control module takes its signal from the accelerator pedal and regulates the amount of current and voltage the electric motor receives from the batteries. The electric energy to the motor causes the torque to turn the wheels of the car.

The two major types of electric drive systems are alternating current (AC) and direct current (DC). AC motors typically are more efficient over a large operational range, but the complicated electronics make the controllers more expensive. DC motors typically require a less complicated controller system and are less expensive, but they tend to be larger and heavier than AC motors. Both technologies are used in today's electric vehicles.

Most electric vehicles employ regenerative braking, slowing the vehicle by capturing kinetic energy and channeling it to the battery pack. Basically, the process of drawing the current from the battery system to the motor that turns the wheels is reversed. During braking, the electronic control module converts the motor to a generator. The momentum stored in the moving vehicle creates a current that is directed back to the battery system where it is stored for future use. Because of friction losses and electrical losses, approximately 60-65 percent of the regenerated energy is available for use. However, this energy can still extend an EVs driving range 5-10 percent. For most stops, the friction brakes are not used until the very last part of stopping, due to the regenerative brakes.

The electric vehicles from the major automotive manufacturers have many of the safety features found in internal combustion engine vehicles such as air bags, power steering and antilock braking systems. Many of the manufacturing materials used are the same. The primary difference between an electric vehicle and an internal combustion engine vehicle is an electric motor instead of an engine, a battery pack and management system instead of a fuel tank, electronic controls instead of an ignition system, and a high-voltage system in addition to a low-voltage system. Electric vehicles can have quicker acceleration because electric motors produce maximum torque at lower speeds than internal combustion engines.

Like gasoline vehicles, electric vehicles have a high-voltage as well as a low-voltage wiring system. The high-voltage system provides energy to the motor and, in some automobile manufacturer's vehicles, to power heating and cooling systems, steering pumps, and some sensors. High-voltage systems range up to 360 volts DC and higher. These high-voltage wires are colored orange in an EV. Major automobile manufacturers use isolated electric busses for both the positive and negative sides of the high-voltage system. This approach prevents electrical current from passing through the frame or chassis to prevent shock. In addition, the major automobile manufacturers have included automatic high-voltage system disconnects as a primary safety feature. These disconnects include a combination of ground fault monitoring, an inertia switch, and/or a pilot circuit. This redundancy adds safety. Manual disconnects are also included to uncouple the high-voltage wiring system from the battery pack.

As far as fuel efficiency, EVs are similar to internal combustion engine vehicles. To compare efficiency between EVs and internal combustion engine vehicles, the entire fuel cycle must be considered. Thus, energy used to extract, produce, and transport gasoline to the pump and the electricity to the plug is added to the energy used by the vehicle. These calculations estimate that EVs are about zero to 25 percent more efficient than gasoline vehicles, and 10 to 30 percent less efficient than diesel vehicles.

Just taking the vehicle efficiency into account, an EV uses 66 percent of the electricity delivered to the charger for forward movement. An internal combustion engine vehicle uses approximately 22 to 33 percent of the gasoline's energy at the pump for forward movement.

Battery management systems monitor the operating condition of the battery pack and are crucial to their optimum performance. Battery management systems monitor parameters such as cell voltage, current and temperature to control the battery's charge/discharge cycles, and preserve battery cycle life.

With respect to battery technology and management systems, the U.S. DOE formed a partnership with Chrysler, Ford, General Motors and the Electric Power Research Institute to form the U.S. Advanced Battery Consortium. The Consortium established battery performance goals to improve the electric vehicles competitiveness with conventional vehicles in performance, price and range.

Electric vehicle technology will likely use advanced lead-acid, nickel metal-hydride, lithium-ion and lithium-polymer batteries in the near term.

Purchase Price of Electric Vehicles

Conflicting estimates abound on the eventual cost to buy and operate an electric vehicle. Some confusion results from inappropriate comparisons of prototype and production vehicle costs. The first prototype Chevrolet Camaros cost $350,000 to produce, about the same as the prototype of the GM EV1. The selling price to the consumer is based partly on the number of units in production runs, the cost of technological improvements, mass production costs, and the amount the consumer is willing to spend on the vehicle. Some cost estimates expect electric vehicles to follow a pattern recently seen in electronic equipment. In the electronic industry, dramatic price reductions occur after introduction. The auto industry has followed a similar pattern due to mass production techniques. In ten years, the wholesale price of a new car fell to $5,500 (1989 dollars), while performance and amenities improved.

Electric Vehicle Charging Stations

The method to recharge differs for each battery type. The electric vehicle charger communicates with the battery management system. An electrical current is delivered from the battery management system in the building and passed through the battery to reform its active materials to their high-energy charge state by reversing the chemical reaction the battery goes through while it is discharging to power the motor.

To recharge, the EV is connected to some type of electric vehicle supply equipment (EVSE) which is connected to the building wiring. The National Electrical Code defines the EVSE as the ungrounded, grounded, and equipment grounding conductors, the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatuses installed specifically to deliver energy from the premise wiring to the electric vehicle. Level 1 charging connects the vehicle to a 120-volt, 15-amp circuit and takes from 10 to 15 hours to recharge the batteries. Level 2 charging connects the vehicle to a 240-volt, up to 40-amp dedicated circuit and takes from 3 to 8 hours to fully charge the batteries, depending on

Table III-1
Leasing vs. Buying

LEASING	BUYING
Lower monthly payments because the consumer is paying for only a portion of the entire cost of the car.	Higher monthly payments since payments are based on the entire cost of the car plus interest to the lending institution.
No risk of resale problems due to technology advancements by the end of the resale period.	The relative newness of the technology and anticipated advancements may make resale of first generation vehicles difficult.
All maintenance and repair costs are covered by the lease agreement.	The purchaser is responsible for any maintenance and repairs required.
Emergency road-side service is included in the lease agreement.	The cost of emergency road-side service is the responsibility of the purchaser.
The lease period does not exceed the estimated warranty period on vehicle components.	The loan term may exceed the time required to replace batteries and other vehicle components.
The lease period does not exceed the estimated life of the current technology.	At the end of the loan period, the purchaser may own obsolete technology.
Mileage restrictions apply.	The purchaser has unlimited mileage use of the vehicle. The downside is that excessive mileage means more depreciation and higher insurance rates.
Physical modifications to the vehicle are not allowed.	The purchaser can repaint the car or do any modifications desired.
Vehicle must be kept for the full term of the lease.	The purchaser has no restrictions to keep the vehicle.
Penalty costs apply for early termination.	The purchaser incurs no additional costs by choosing not to keep the vehicle.

Table III-1 shows the differences between leasing or purchasing an electric vehicle.

battery type. Level 3 charging is the electric vehicle equivalent of a commercial gasoline service station, with recharging accomplished in minutes.

Electric vehicle recharging equipment uses two primary coupling methods, conductive and inductive. In conductive coupling, the connector uses physical metal contact to pass electrical energy. For safety, these metallic contacts are completely covered and inaccessible to the operator. In inductive coupling, AC power is transferred magnetically (induced) between a primary winding on the supply side to a secondary winding on the vehicle side. With inductive charging, the EVSE converts standard power line frequency of 60 Hz to 80,000 to 300,000 Hz. Inductive charging was developed primarily for electric vehicle applications but is being applied to small appliances and even pacemakers to allow recharging without surgery.

Recharging Electric Vehicles

Electric vehicles provide convenience with home recharging. Every morning, the electric vehicle can start with a full charge and no oil drips on the driveway. In the afternoon, the vehicle can leave again with a full charge (if a charging system is provided at the work site). This home or workplace based recharging may deliver the highest value to consumers as a source of cost savings, convenience, comfort and other benefits.

Most EVs will recharge during off-peak hours or overnight. Off-peak recharging makes efficient use of electric power plant capacity that normally would sit idle.

According to the Energy Commission's CalFuels Plan, investor-owned and municipal utilities estimate they can meet the electricity demand for EVs with little or no additions to their generation or transmission systems for the next 15 years. This estimate assumes only about 4.5

percent of EV charging occurs on-peak. Southern California Edison estimates it will need to add about 200 megawatts of capacity by 2008 to accommodate EVs (based on current projections of numbers of vehicles). This amount of additional capacity can be met by saving energy elsewhere through demand-side management rather than building new power plants.

Environmental, Health and Safety Issues

When comparing electric vehicles with internal combustion engine vehicles, most people believe that electric vehicles have an advantage because electric vehicles do not have emissions. However, the power plant that is used to recharge an electric vehicle has emissions. Yet even after these emissions are considered, electric vehicles typically have 90 percent fewer emissions than an internal combustion engine. According to the ARB, "the benefits of EVs in the mandated quantities include direct exhaust, fuel evaporative and fuel marketing emission reduction of 14 tons per day of oxides of nitrogen and non-methane organic gas in the South Coast Air Basin by 2010" (an area of California where the need for emission reductions is greatest).

Several studies have been conducted to quantify the economic benefits of EVs to California. In a recent study, *Driving Out Pollution, The Benefits of Electric Vehicles*, the Union of Concern Scientists calculated that each EV would displace $17,000 of air pollution control costs in the South Coast Air Basin over the life of the vehicle. In Sacramento, up to $8,000 was estimated.

Since electric vehicles are quieter (and silent when idling), traffic noise pollution, a leading source of community noise, is reduced.

EVs need no oil changes, oil filter replacement, emission control adjustments, or tune-ups. EVs produce no oil or gasoline-caused water pollution. And an electric vehicle has an environmentally friendly image. However, EV's do have unique battery maintenance requirements.

The U.S. DOE estimated that 20 percent of total U.S. CO_2 emissions in 1996 were from passenger cars and light duty trucks. CO_2 has been identified as the primary greenhouse gas. An EV emits zero greenhouse gases. Because emissions associated with EV use are from the electricity producer, the potential to reduce greenhouse gases depends on the efficiencies to recharge and use the battery pack, and the fuel used to produce the electricity by the utility. Nationwide, the Argonne National Laboratory calculated reductions from 31 to 46 percent. The Union of Concerned Scientists conducted a study in 1995 that indicated a 71.2 percent reduction in greenhouse gases over the life of the vehicle by using an EV instead of an internal combustion vehicle (modeled in the South Coast Air Basin).

More efficient electricity generation can result in greater reductions. Utilities using renewable energy sources such as hydroelectric, wind, solar, or geothermal—emit almost no greenhouse gases, resulting in EV greenhouse gas emission reductions of almost 100 percent.

More than 25 percent of California's electricity comes from renewable resources. Most of California's electricity is generated from clean-burning natural gas. Less than 1 percent comes from burning petroleum. Over twenty years ago, more than 50 percent of California's electricity came from burning petroleum. The electric utility industry converted to cleaner fuels to minimize the risks due to fluctuations in petroleum supply and price and to help clean the air. California applies the same policy of diversification to the transportation sector by moving to clean, non-petroleum based fuels.

Future Potential for Electric Vehicles

The consumer's experience with the EV1 has verified the viability of EV technology although much depends on whether enough vehicles will be available to consumers in a broader variety of styles.

To address the consumer need for extended travel range in EVs, some automobile manufacturers are offering nickel-metal hydride (NiMH) batteries for the 1999 model year. This battery has extended the range from an average 40-60 miles on a single charge to 80-125 miles. Because NiMH batteries increase the cost of EVs, lead-acid batteries are still available to consumers who do not require the extended range.

Bringing down the cost of the battery packs in EVs has become a recent focus. Important measures are being implemented to further battery technology. The goal is to increase sales of batteries that would lower the cost of battery packs being used in EVs. Thus, making EVs more affordable to the average consumer.

Currently, smaller EVs such as Neighborhood Electric Vehicles (NEVs) have presented themselves as a transportation option. NEVs are designed for low speed local trips in neigborhoods and urban areas, to run errands, commute to and from work or school, and to make local deliveries. Similar to their counterparts, NEVs do not contribute to air pollution. Unlike their counterparts, NEVs are limited in their application so that the potential for commercialization remains to be seen. Most NEVs are not required to meet the complete range of safety requirements set forth by the Federal Motor Vehicle Safety Standards and are restricted to non-highway travel.

Table III-2
California 1999 Model Year Certified Electric Vehicles (March 1999)

Make and Model	Battery Type	Phone Number
Dodge / Caravan	Lead Acid	800-999-3533
Dodge / Caravan	Nickel Metal Hydride	800-999-3533
Ford / Ranger pick-up	Lead Acid	800-258-3835
General Motors / EV-1	Lead Acid	888-462-3848
General Motors / EV-1	Nickel Metal Hydride	888-462-3848
General Motors / S-10 pick-up	Lead Acid	888-462-3848
General Motors / S-10 pick-up	Nickel Metal Hydride	888-462-3848
Honda / EV Plus	Nickel Metal Hydride	888-224-6632
Nissan / Altra EV	Lithium-ion	800-647-7261
Plymouth / Voyager Epic EV	Lead Acid	800-999-3533
Plymouth / Voyager EV	Nickel Metal Hydride	800-999-3533
Toyota / RAV 4 EV	Nickel Metal Hydride	800-331-4331
Solectria/Force	Lead Acid	916-381-3509
Bombardier / Sporte-e	Lead Acid	407-722-4015
Bombardier / Class-e	Lead Acid	407-722-4015

For more information regarding electric vehicles contact the following Web Sites:

Bay Area Action
650-625-1994
internet: www.baaction.org/
ev_project

California Electric
Transportation Coalition
916- 552-7077
e-mail: CalETC@ix.netcom.com

CALSTART/WESTART
626-744-5600
internet: www.calstart.org

Electric Power Institute
650-855-2162
internet: www.epri.com

Electric Vehicle
Association of Americas
415-249-2690
internet: www.evaa.org

Electric Auto Association
internet: www.eaaev.org

Los Angeles Department
of Water and Power
800-552-2334
internet: www.ladwp.com/services/
electran

PG&E
800-684-4648
internet: www.pge.com/cleanair/
electric

Sacramento EV Association
800-537-2882
internet: http://saccityweb.com/seva/

Sacramento Municipal Utility District
916-732-5283
internet: www.smud.org/evs

Southern California Edison
800-438-4636
internet: www.scebiz.com/electroscc/
transport/index.htm

San Diego Gas & Electric
619-654-1103
internet: www.sdge.com/index.html

U.S.Department of Energy
The Alternative Fuels Data Center
800-423-1363
internet: www.afdc.nrel.gov/
index.html

Chapter 4

Ethanol-Fueled Vehicles

Introduction

This chapter discusses the characteristics of ethanol fuel, vehicle history, light and heavy-duty vehicle technology, infrastructure, fuel supply and pricing. Also included are the environmental, health and safety aspects, and the future potential for ethanol vehicles.

Fuel Characteristics and Vehicle History

Ethanol, (CH_3CH_2OH), also called ethyl alcohol or grain alcohol, is a liquid derived from corn, grains, or from a variety of other agricultural products, residues and waste. Ethanol has become a popular alternative fuel for vehicles, especially in the American Midwest. Over four million vehicles have operated on ethanol in Brazil as a result of a government program to produce the fuel from sugar cane.

Ethanol is considered a renewable resource because it can be made from grains or biomass—such as municipal waste and other biological waste materials. When ethanol is produced from waste biomass, the potential benefits can be significant. Ethanol production plants can be developed in conjunction with electric power generation facilities, improving overall efficiency of the plant's operation. Conversion of waste materials to ethanol—such as rice straw, forest residue and municipal solid waste, eliminates the need for disposal such as open-field burning or placing the waste in a landfill. Depending on how it is produced, ethanol can reduce CO_2 emissions, an important greenhouse gas. Many scientists believe greenhouse gas emissions may contribute to global climate change. Ethanol produced from biomass also displaces consumption of carbon-based fossil fuels. Furthermore, ethanol is attractive because it is domestically produced and thereby reduces oil imports.

The earliest forms of alcohol were simple fermented beverages. As early as 6,000 to 4,000 B.C., the art of making crude beers and wine was flourishing in the Middle East. The Chinese were probably the first to distill alcohol directly from fermented (rice) liquor around 800 B.C. By the year 500 A.D., distillation technology had advanced to the point where relatively pure forms of alcohol were used in cosmetics, perfumes and medicines. From the 18th century to the beginning of this century, major discoveries about the chemistry and technology of distillation made it possible to produce ethanol cheaply from a variety of organic materials. In recent history, public interest in alcohol as a transportation fuel changed with periods of war and with the price and supply of oil.

Ethanol's history as a transportation fuel began with Henry Ford and other transportation pioneers. In the 1880s, Ford built one of his first automobiles, the quadricycle, and fueled it with ethanol. The Ford Model T had a carburetor adjustment that could allow the vehicle to run on ethanol fuel that was produced by American farmers. Ford's vision was to "build a vehicle affordable to the working family and powered by a fuel that would boost the rural farm economy."

Rising taxes on ethanol limited its use as a fuel, low gasoline prices, and a "propaganda campaign" by oil producers were factors that kept ethanol and other alternatives from catching on as transportation fuels. During World War I and II in both the United States and in Europe, alcohol fuels were used as a supplement to oil-based fuels. During WWI, vehicle fuels were mixed with 20 percent alcohol and 80 percent gasoline. In the 1930s, there were efforts in the Midwest to encourage the use of ethanol in gasoline. The Nebraska legislature passed a two-cent per gallon refund to motorists who would use alcohol-blended fuels, but the petroleum industry campaigned to cancel the plan. In WWII, ethanol was again used as a blend with gasoline. The government even commandeered whiskey distilleries for alcohol fuel production.

Following WWII, ethanol was unsuccessful as an economically competitive transportation fuel due to the reduction in oil prices. The 1970s oil crises gave birth to the modern "gasohol" era. Currently, ethanol is being used in the U.S. as a blending component of gasoline, commonly referred to as gasohol, usually 10 percent ethanol.

Like flexible fuel vehicles (FFVs) designed for methanol, ethanol FFVs are designed to operate on E85, (85 percent ethanol and 15 percent gasoline). Ethanol FFVs have a modern microprocessor technology that continually adjusts the engine operation, fuel to air ratio, as required by the ratio of ethanol and gasoline in the fuel tank. Therefore, Ethanol FFVs can operate on any combination of the two fuels. FFV technology for ethanol and methanol are similar, but may use different materials for the fuel system and are calibrated differently to match the fuels energy content.

Light-duty Vehicle Technology

The first modern, mass-produced ethanol vehicle in the U.S. was developed by the Chevrolet Division of General Motors. A total of 50 ethanol-optimized 1992 model year Chevrolet Lumina Variable Fuel Vehicles (VFVs) were demonstrated in Iowa, Indiana, and other states. Chevrolet then produced 320 E85 Lumina VFVs in the 1993 model year. Ford and Chrysler have also produced E85 fuel-flexible vehicles. Since 1994, Ford has built E85 Taurus FFVs for sale in the Midwest, and Chrysler has made their 1999 Minivan available (See Table IV-1, page 38).

Not until the 1999 model year have E85 vehicles been certified for sale in California. Ford produced 60,000 Ranger Pickups, and Mazda produced 40,000 pickups for sale in all 50 states.

Because ethanol is corrosive to certain materials, some modifications have to be made to engines and the fuel delivery system to protect fuel system components. While production costs for FFVs are higher than a comparable gasoline vehicle, with the recent increases in production volumes, the manufactures are now selling the FFVs with little or no incremental cost.

Heavy-duty Vehicle Technology

Heavy-duty vehicles generally are equipped with diesel engines, which are compression-ignition. The ability of a fuel to be ignited in compression-ignition engines is characterized by its cetane number. Ethanol has a very low cetane number and is difficult to obtain a spark in a compression-ignition engine. Therefore, diesel engines cannot simply be converted to ethanol operation. Many approaches have been pursued to convert diesel engines to operate on ethanol. The most viable option is through direct-injection of ethanol. Through slight engine adjustments, direct injected ethanol will auto ignite, in spite of its low cetane rating. Where cold start is a problem, glow plugs are used to promote ignition. Detroit Diesel Corporation (DDC) redesigned its 6V-92TA engine, and it has been commercialized and emission certified to operate on ethanol. No other U.S. heavy-duty engine OEM has developed alcohol engine technology to this extent.

Scania, a European manufacturer has developed a heavy-duty ethanol engine that is being demonstrated in 30 transit buses in Stockholm. Heavy-duty ethanol engines are fueled with a variety of high-percentage ethanol fuels including neat ethanol, E100, E95, and E90 blended with gasoline and other hydrocarbons. The DDC 6V-92TA is the most used heavy-duty ethanol engine in the U.S. This engine has been used by the Archer Daniels Midland Corporation since 1992. The power levels of heavy-duty ethanol engines are equivalent to diesel-fueled engines. On an energy equivalent basis, ethanol's fuel economy is somewhat less.

The Los Angeles County Metropolitan Transit Authority (LACMTA) converted a large number of transit buses that were operating on methanol. The buses were converted to ethanol due to engine wear, reliability and a escalating methanol fuel cost. Because of similar engine durability and reliability problems, and DDC not actively supporting these engines, the LACMTA elected to convert these buses to diesel. The DDC ethanol engine, which has been installed in various transit buses and line-haul trucks, is also approximately twice the price of a comparable diesel engine.

Infrastructure

The U.S. has an ethanol fuel infrastructure consisting of approximately 40 refueling stations which support tens of thousands of flexible fueled vehicles. According to the

National Ethanol Vehicle Coalition, the ethanol fueling infrastructure is expected to increase to 130 locations with the addition of 30 refueling facilities in the Chicago area, 30 in Minneapolis, and an another 30 facilities in Colorado by the end of 1999.

California's infrastructure on the other hand is very limited. There is only one E85 fueling facility that is scheduled to be in operation by the year 2000, in Rancho Cucamonga.

The ethanol, used by heavy-duty vehicles (primarily E100), as well as FFVs (E85), is trucked from production or intermediate storage or distribution facilities to refueling stations. Ethanol refueling equipment is similar to gasoline equipment, but the materials differ due to ethanol's unique properties. Gasoline infrastructure equipment must be replaced with ethanol-compatible materials for ethanol distribution.

Fuel Supply

The use and promotion of ethanol in America has been primarily in the Midwest, where excess corn and favorable tax incentives exist. A high percentage of Midwest service stations offer fuel blends containing 10 percent ethanol.

Ethanol production within California is relatively limited. California produces approximately six million gallons of ethanol annually. Most of the ethanol feedstock is from the State's beverage industry and other food industry wastes, such as cheese whey. The production in California may increase substantially if any of the proposed biomass-derived ethanol plants are completed. Two leading projects supported by the Energy Commission include the Gridley Rice Straw-to-Ethanol Project (to convert rice straw and other agricultural wastes) and the Quincy Library Group (to convert forest residue). Other projects around the State have also been proposed.

The use of ethanol in California has been sporadic over the years. Ethanol was blended as an octane booster in the 1980s and early 1990s. However, with the introduction of reformulated gasoline in 1996 and restrictive fuel specifications, ethanol's use has nearly ceased. The exception is a demonstration by Tosco Corp (Tosco). Tosco began using ethanol in its gasoline in 1998, rather than MTBE, to meet the oxygenate requirement. More than seventy stations in the San Francisco Bay Area are dispensing gasoline with ethanol. The demonstration has been successful, and Tosco announced that it is extending the demonstration beyond the original six month period.

Ten percent ethanol blends are also being used in some areas of the country as a winter time oxygenated blend to meet the U.S. Environmental Protection Agency air pollution regulations.

Today's Prices of Ethanol

The production of ethanol is more costly on a per gallon basis than some other alternative fuels, although government tax incentives of about 54 cents per gallon (blender's credit) have kept prices comparatively low. In 1992, the National Renewable Energy Laboratory estimated the potential cost of ethanol production from biomass, using its current advanced technology, at $1.22 a gallon. That cost is falling and is expected to continue to drop in the future due to technology improvements.

The price of ethanol is constrained because of the corn feedstock, which is closely tied to commodity prices for agricultural crops. For example, severe flooding of the Mississippi River in 1993 directly impacted the corn crop in the Mississippi basin. This flooding resulted in a short-term increase in the regional ethanol fuel price.

Ethanol has a lower energy content than gasoline; consequently, more fuel is consumed per mile. A gallon of E85 contains approximately 80,460 Btu/gallon (ethanol = 75,000 Btu/gallon, California reformulated gasoline = 111,400 Btu/gallon). The federal excise and energy tax for ethanol (E100) is $0.13 per gallon. This is less than the federal tax for gasoline, $0.183 per gallon. When the adjustment for energy content is made, the tax is more than gasoline. As a motor vehicle fuel, ethanol receives tax incentives designed to make the price comparable to gasoline.

Environmental, Health, and Safety Issues

Even though ethanol is probably the safest of all the alternative fuels, it is flammable and may contain additives that could be harmful if inhaled or consumed. Ethanol has numerous health and safety advantages. It is less toxic and has a more visible flame than methanol; it does not have to be pressurized to be stored (like gaseous fuels); there is no atmospheric venting problem; it is not cryogenic; and leaks are not as hazardous. Because ethanol has a low vapor pressure and broad flammability range, vehicle fire susceptibility and severity characteristics in case of a crash are different than those of gasoline vehicles.

Future Potential for Ethanol Vehicles

The technology for fueling FFVs with ethanol, particularly E85, is well developed. The cost and availability are important factors that will determine the ultimate success of ethanol as a viable motor fuel in California. When blended with gasoline, emissions are also an issue due to the volatility of this blended fuel that can result in higher evaporative emissions. E85 FFV emissions are competitive, and in some cases, lower than those of gasoline vehicles. Ethanol life-cycle emissions in terms of greenhouse gases are also attractive compared with most fuels.

In the heavy-duty arena, the economics of ethanol-fueled vehicles are not attractive at this time. Ethanol generally costs more than diesel fuel on an energy basis. Therefore, the life-cycle costs of ethanol trucks and buses are higher than diesel trucks and buses. Lowering fuel and vehicle costs, or developing government incentives, may improve the future market prospects for heavy-duty ethanol vehicles.

Table IV-1
Ethanol-fueled Vehicles (July 1999)

YEAR	MAKE	MODEL	PRODUCED OR SOLD
1992	Chevrolet	Lumina VFV	50
1993	Chevrolet	Lumina VFV	320
1995	Ford	Taurus FFV	500
1997	Ford	Taurus FFV	67
1998	Ford	Taurus FFV	144
1998	Chrysler	Minivan FFV (Outside of CA)	152,736 / 138,794
1999	Ford	Ranger Pick-up FFV	To be determined
1999	Ford	Taurus FFV	To be determined
1999	Mazda	B3000 FFV	To be determined

Ethanol Contacts

Government

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Production Permit Information
Bureau of Alcohol,
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www.eren.doe.gov

U.S. Department of Treasury
Wine, Beer & Spirits Regulations
Bureau of Alcohol,
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Wichita, KS 67202
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Chapter 5
Methanol-Fueled Vehicles

Introduction

This chapter discusses the characteristics of methanol fuel, vehicle history, light and heavy-duty vehicle technology, infrastructure, fuel supply and pricing. Also included are the environmental, health and safety aspects, and the future potential for methanol vehicles.

Fuel Characteristics and Vehicle History

Methanol (methyl alcohol), a colorless flammable liquid, often referred to as "wood alcohol," is usually made from natural gas and is another substitute for gasoline as a transportation fuel. Its high octane and performance characteristics, and the reduction of reactive emissions, have made it a popular choice as an alternative fuel for fleet and private vehicle use.

Methanol has been used for more than 100 years as a solvent and a chemical building block to make consumer products such as plastics, plywood, and paint. It was first discovered in 1823 by condensing gases from burning wood into a liquid. Consumers use methanol directly in windshield washer fluid, gas-line antifreeze, and as model airplane fuel.

Methanol can be produced from just about anything containing carbon, including natural gas, coal, and biomass. Because methanol can be produced from these North American resources, methanol offers energy security benefits by being a clean, and potentially renewable alternative to petroleum-based fuels.

Typically, methanol is produced using high temperature steam and pressure, and a catalyst that converts natural gas, or methane, into the liquid methanol. Methane gas (a greenhouse gas) given off by decomposing vegetable matter in landfills may also be tapped as a source for methanol production. A research and demonstration project in Southern California, funded by the Energy Commission and the SCAQMD, uses biomass to produce methanol in what is known as the Hynol process.

Methanol's power, performance, and safety have also made it the fuel of choice for Indianapolis 500 racing cars since 1965 because of its high flash point. In the event of an accident, a methanol fire can be extinguished with water, while water on gasoline spreads fires. Methanol also provides racing cars with high octane and high performance, while burning at cooler temperatures than gasoline.

Methanol sold for light-duty fuel-flexible vehicles is actually M85 (a blend of 85 percent methanol and 15 percent unleaded gasoline). The gasoline is added to provide color to a flame, should there be a fire involving M85, and to enhance the starting ability in cold weather. M85 is an interim step to the use of M100, or neat methanol, which offers greater air quality benefits. M85 has an octane rating of 102, compared to 92 for premium unleaded, and 87 for regular unleaded gasoline. With this higher octane is an increase in engine horsepower of about seven to ten percent, or more, depending on the vehicle and its optimization for methanol.

Because it is a liquid, M85 can be distributed and stored in the liquid distribution system much like gasoline.

Light-duty Vehicle Technology

The Energy Commission has been testing alcohol-powered vehicles since 1978. But it was only in the mid-1980s when the fuel-flexible vehicle technology was created, first by Ford and followed closely behind by General Motors (GM), that the number of vehicles began to increase dramatically. It was not until the 1990s, however, that the vehicles were available for sale to fleets and the general public.

Fuel-flexible vehicles are vehicles specially designed by the auto manufacturers to use M85 or regular unleaded gasoline in any combination from a single tank. The vehicles have a special sensor on the fuel line that can detect the ratio of methanol to gasoline that is in the fuel lines. The sensors communicate to the on-board computer which automatically adjusts the vehicle's fuel delivery ratio and ignition timing to compensate for the different fuel mixtures.

Alcohol is corrosive, especially to rubber and plastic parts. A number of other parts on the fuel-flexible vehicle's fuel-delivery system are made of more robust material to be compatible with methanol. These parts include the fuel tank, fuel lines, fuel injectors, fuel pumps and filters. Parts that are tolerant to alcohol fuels must be substituted on the auto manufacturers' assembly line in place of typical gasoline components that would come in contact with the alcohol fuel.

Cars can be retrofitted to operate on M85, but there are no assurances of air-quality or emissions benefits from doing so. Currently, there are no methanol conversion kits certified by the ARB; therefore, it is not practical to retrofit cars to operate on M85 because they may not meet emission regulations. Fuel-flexible vehicles are specially suited to burning methanol as efficiently as possible and run cleaner than using gasoline. Vehicles not specially outfitted to use methanol can also be damaged. Gasoline vehicles using even a small amount of methanol may be rendered inoperable.

Since 1978, the Energy Commission— in association with Chrysler, Ford Motor Company, General Motors, Honda, Mazda, Mercedes-Benz, Mitsubishi, Nissan, Toyota, Volkswagen, and Volvo— have sponsored demonstration programs to test M85-fueled vehicles in public and private fleets. Two American auto companies offered fuel-flexible vehicles for sale to fleets and the public in the 1995 model year, but only Ford Motor Company continued to offer FFVs for sale for the 1996 through 1998 model years.

Currently, more than 13,000 cars, along with a small number of school and transit buses and trucks, operate on methanol in California.

Ford: Ford Motor Company produced its first flexible fuel vehicle (FFV) in 1987, when they designed a few Crown Victoria LTD models to operate on methanol, gasoline, or any combination of the two fuels. Between the years 1987 and 1989, Ford produced 200 more Crown Victoria FFVs that were used in various public fleet demonstrations. In 1991, they produced 178 Taurus FFVs and in 1992, 183 Econoline FFV vans were put into service.

In 1993, Ford produced 2,500 1993 flexible fuel Tauruses, 2,145 of which came to California. The Taurus was the first FFV to be certified by the California Air Resources Board as a Transitional Low Emission Vehicle (TLEV). For additional Ford FFV sales, refer to Table V-1, page 46.

Hertz Rent-A-Car, a subsidiary of Ford, Budget and Avis car rental companies have helped put FFVs in the hands of the public more than many other efforts. Following a pilot program by Avis with 20 Chevrolet Luminas, the three auto rental car companies in Sacramento each purchased 100 Ford Taurus FFVs, with assistance from a Sacramento Metropolitan Air Quality Management District program. The use of FFVs in rental fleets was a success, and the companies purchased additional FFVs in 1994. Hertz announced in November 1994 that it was purchasing 400 1995 Taurus FFVs for use at its airport rental fleets in the Los Angeles area. Hertz also installed methanol refueling tanks and dispensers at four Los Angeles area airport locations to fuel the vehicles with M85.

The cost of the Ford Taurus FFV for the 1995 and 1996 model years were equal to their gasoline-fueled counter-parts. The 1997 and 1998 model year Taurus FFV's were priced slightly less than gasoline models. Ford continues to produce FFVs, but only those that can run on E85 (85 percent ethanol and 15 percent unleaded gasoline).

General Motors: Following a test fleet of 20 Chevrolet Corsicas in 1988 and 212 Chevrolet Luminas in November 1991, General Motors and the Energy Commission announced the availability of Chevrolet Variable Fuel Vehicle (VFV) Luminas for purchase by public and private fleets, as well as members of the general public. A total of approximately 1,192 Luminas were sold to California fleets in early 1992 and 73 in 1993.

Because of a major body redesign of the Lumina, VFVs were not offered in the 1994 and 1995 model years. GM has also not discussed any plans for future methanol-powered vehicles since these early models.

Chrysler: At the 1991 Greater Los Angeles Auto Show, Chrysler announced that it would build 2,500 "A-body" cars for model year 1992 (Plymouth Acclaims and Dodge Spirits) to run on methanol. The FFVs were offered for sale in California to fleets and the general public. The flexible fuel/methanol option was offered to the purchaser at no extra cost. With government incentives, this option made the Chrysler FFV less expensive than a gasoline model. The other auto companies followed suit, with no extra charge for the FFV option.

Chrysler later announced that nearly all of the 910, 1993 model year Acclaims and Spirits were purchased by the U.S. General Services Administration (GSA), out of a total of 1,119 that came to California. All Chrysler Spirit/Acclaims FFVs were certified as Transitional Low Emission Vehicles by the California Air Resources Board.

In the 1994 model year, nearly all of the 1,751 Acclaims and Spirits were sold to the GSA. Chrysler's 1994 LH series (Chrysler Concord, Dodge Intrepid, and Eagle Vision), were offered with the methanol option. Because it was not certified by the ARB, however, the flexible fuel LH was not offered in California in 1994, except for a few experimental models.

Chrysler sold 920 Dodge Intrepid and Chrysler Concorde FFVs in the 1995 model year. The ARB-certified this vehicle as a TLEV.

Chrysler, however, has not offered methanol FFVs since the introduction of the Intrepid/Concorde models in 1995, and has made no announcements of their future intentions regarding methanol-fueled vehicles.

Foreign Auto Companies: Foreign auto companies have also produced fuel-flexible vehicles. Volkswagen has produced more than 50 fuel-flexible Jettas in the early 1990s. Honda, Mazda, Mercedes-Benz, Mitsubishi, Nissan, Toyota and Volvo have all produced a limited number of demonstration or experimental vehicles. It is unknown what marketing plans, if any, that foreign car companies have for their flexible fuel vehicles as these vehicles are not in production currently.

Vehicle Maintenance and Repairs: FFVs are completely warranted by the original equipment manufacturers' factory warranties. Some auto companies even offered extended warranties for methanol FFVs. For example, Ford's 1993 Taurus had a six year, or 60,000 mile warranty, which included free oil changes.

The repair and maintenance costs are similar to gasoline vehicles, with the exception of oil changes. A special oil is needed for FFVs using M85. Because the special oil is produced in limited quantities, it is more expensive than regular oil. Changes in this special lubricant additive with enhanced neutralizing capabilities are recommended every 3,000 to 6,000 miles depending on the vehicle model.

Heavy-duty Vehicle Technology

Heavy-duty methanol vehicles are trucks and buses equipped with compression-ignition diesel engines. The diesel engine and the vehicle chassis are produced by individual manufacturers. Heavy-duty methanol engines fueled with M100 usually use a lubricant additive. Gasoline is not used as an additive because it is not needed for cold start. Fuel is injected into the combustion chamber and ignited by the high temperature of the compressed air charge. M85 has been used to fuel the methanol-fueled school bus Detroit Diesel Corporation (DDC) 6V-92TA engines because of the availability of M85 fueling stations as well as safety concerns. DDC 6V-92TA, a transit bus engine which has been demonstrated in truck applications, is the only available commercial heavy-duty methanol engine. Although this engine achieves power levels equivalent to diesel counterparts, fuel efficiencies are typically 5 percent below that of diesel engines. The higher fuel cost and a smaller range are considerations for methanol fueled heavy-duty vehicles. The first generation 6V-92TA methanol-fueled engines had technical, reliability, and durability issues which were resolved. According to some fleet operators, including the Los Angeles County Metropolitan Transit Authority, the methanol engine reliability is not comparable to diesel standards.

Methanol reduces NO_x and particulate emissions in heavy-duty applications. The DDC 6V-92TA methanol engine was certified to the ARB and U.S. EPA transit bus engine emission standards which were to be enforced by 1991. Since these standards could only be met by methanol engines or particulate trap-equipped diesel engines, they were delayed until 1993. By 1993, new diesel engine technology was introduced with new 4-stroke diesel engines (the Series 50 for buses and Series 60 for Class 8 trucks) which met the standards without particulate traps. This new line of diesel engines replaced the 2-stroke engines, including the methanol 6V-92TA.

Approximately 550 commercialized DDC methanol 6V-92TA engines have been built and delivered for use in transit buses. At one time, the Los Angeles County Metropolitan Transit Authority used 330 6V-92TA methanol engines in transit buses. These engines were converted to operate on ethanol and since have been converted to diesel. About 150 of the DDC methanol engines were installed in school buses built for the Katz California Safe School Bus Clean Fuel Efficiency Demonstration Program by Carpenter Corporation and Crown Coach. These engines were fueled with M85 and M100.

Because the price of the 6V-92TA methanol engine was double that of its diesel counterpart, it is not currently being marketed. In addition to the increased cost of the engine, a methanol compatible fuel system with a heat exchanger in the fuel recirculation system was required. Conservatively, the incremental cost of a methanol-fueled transit bus is approximately $12,000.

Infrastructure

The Energy Commission entered into10-year agreements with several motor fuel retailers — ARCO, Chevron, Exxon, Mobil, Shell, Texaco, Ultramar (Beacon), and a number of independents — to operate a methanol retail fuel network throughout California. These agreements called for the motor fuel retailers to install, operate, and maintain the M85 equipment at their retail service stations. The Energy Commission supplied the methanol fuel storage and dispensing equipment. A large percentage of tanks at service stations in California are methanol compatible. Some local air quality districts require that newly installed double-walled tanks and equipment are methanol-compatible.

The cost of installing M85 fueling is roughly equivalent to the cost of a gasoline dispensing system—$80,000. If an underground tank is already methanol-compatible, the cost for installing the equipment is substantially less, ranging from $9,000 to $28,000 depending on whether existing product lines must be replaced. Many private fleets have installed methanol fueling facilities, and the Energy Commission has provided assistance with design and equipment specifications and has produced an installation and maintenance manual. To accommodate fuel storage conversions, the EPAct provides a $100,000 federal tax deduction for alternative fuel storage and dispensing equipment.

There have been 61 retail M85 fueling locations installed since 1988 supplying the fuel to over 16,000 vehicles. (See Chapter 12 for the remaining locations). Most of these fueling locations are strategically located near participating fleets and along well-traveled thoroughfares such as interstates and freeways. Under an agreement with Caltrans, road signs displaying a fuel dispenser with a letter "M" on it and the word "Methanol" are located along freeways and surface streets to direct motorists to methanol stations. In addition, the Energy Commission published a Methanol Fueling Guide, with maps locating all retail M85 fueling stations in California.

To access these facilities, the M85 dispensing systems are equipped with credit card, ATM-style electronic readers maintained and billed by Fuelman/Gascard (Gascard). The card is similar to an electronic automated teller banking card, but it is good only for dispensing methanol. This dedicated card prevents improper fueling of gasoline vehicles with methanol. Gascard bills fleets directly for the methanol dispensed, provides written printouts of vehicle fuel usage, including mileage to help compute miles-per-gallon, and pays each oil company directly for fuel dispensed. This approach alleviates the need for a fleet owner to carry several separate oil company credit cards and allows one single monthly payment, regardless of company. To obtain an M85 fueling card please contact:

Fuelman/Gascard
2720 Loker Ave., West, Suite G
Carlsbad, CA 92008
1(800) 326-7762

As of November 1999, the M85 locations at retail service stations in California have been reduced to 30, due to the expiration of the ten-year agreements with the motor fuel retailers. It is anticipated that with the expiration of the Arco, Exxon, and Shell Agreements — by January 2000 the M85 retail fueling sites in California will be reduced to 14. In addition to retail facilities, there are approximately 50 private methanol fueling sites operated by Caltrans, public and private fleets, and school and transit districts.

Fuel Supply

Since the program's creation, methanol has been produced for California's demonstration program from natural gas in Canada and the U.S. Gulf Coast. Methanol has been supplied by a number of companies including: Beaumont Methanol Corporation, Enron Petrochemicals Company, Hoescht Celanese Chemical Group, Intermountain Chemical Inc., Methanex Corporation, and Novacor Chemical USA, through an organization called the California Fuel Methanol Reserve (CFMR). The CFMR was established to insure an adequate supply of fuel grade methanol be supplied at attractive pricing, thereby assisting the initiation of a fuel methanol market. Methanex, the only participating supplier, delivers methanol to storage terminals in Northern and Southern California. From these terminals, the methanol is blended with unleaded regular gasoline and transported to the retail network and non-retail program participants.

Today's Prices of Methanol

The cost of M85 in California, sold through the California Methanol Fuel Reserve, is determined by the price of the methanol fuel, which is set by agreement between the methanol producers and the Energy Commission, based on a gasoline equivalent formula.

Added to the wholesale price of methanol are the current federal excise tax, state excise, and sales taxes; transportation charges; cost of gasoline added to the methanol to make M85; and the dealer margins. Dealer "margins," the charge service station dealers add to the cost of the fuel, may be as high as 20 to 25 cents per gallon, or more, due to the low volume sales at some stations. Add these all together and drivers of methanol-powered vehicles are seeing pump prices of $0.879 to $1.15 per gallon. A gallon of M85 contains approximately 64,735 Btu/gallon (methanol = 56,500 Btu/gallon, California unleaded gasoline = 111,400 Btu/gallon). Because it takes about 1.6 gallons of M85 to provide the same amount of energy as a gallon of gasoline, methanol vehicles have less mileage range than their gasoline counterparts. This equates to a gasoline gallon equivalent price of $1.56 to $1.96 per gallon (based on energy content of 1.6 gallons of methanol equal to a gallon of gasoline).

Larger fuel tanks and the ability to use unleaded gasoline in these fuel-flexible vehicles—- which run on methanol, gasoline, or any combination of the two from a single tank provide extended range when necessary.

The federal excise and energy tax for methanol (M100) is $0.093 per gallon. This tax is less than the federal tax for gasoline, $0.183 per gallon. The California Fuel Use Tax for methanol is $0.09 per gallon. This tax is exactly half the $0.18 gasoline tax. When the adjustment for energy content is made, the tax is comparable to gasoline. As in other motor fuels, California sales tax is calculated to the price of M85 after excise taxes are added.

Environmental, Health, and Safety Issues

Methanol, like all motor vehicle fuels, is dangerous and should be treated with due caution and respect. The same precautions used with gasoline must be taken when using M85. M85, like gasoline, should not be siphoned from a vehicle fuel tank or ingested as it can be fatal. If M85 is splashed on the skin, it should be washed off immediately. Clothing should be changed and laundered as soon as possible if M85 is spilled on them.

Methanol is a clean-burning liquid fuel. The simple chemical structure of the methanol molecule (CH_3OH) is largely responsible for the "clean" combustion aspect of the fuel when it is used in motor vehicles. Methanol should be thought of as an environmentally friendly fuel with other alternative fuels in comparison to gasoline.

M85 fuel produces about one-half the ozone produced from gasoline. That is, a gram of gasoline emissions from a vehicle tailpipe into a polluted urban region will yield twice the ozone resulting from a gram of M85 emissions. Most methanol vehicles on the road today are not designed to take advantage of this unique characteristic, (ARB regulations are fuel neutral, thus allowing manufacturers to certify vehicles to gasoline on a gram for gram basis, the same "reactivity" adjusted emission level). However, the automakers could exploit this low ozone potential during the emissions certification process should they choose to do so.

With regard to toxic air contaminants, M100 and M85 fuels produce lower overall toxic emissions relative to gasoline when these emissions are weighted for cancer risk. The cancer causing emissions of concern are benzene, 1-3 butadiene, formaldehyde, and acetaldehyde. Methanol vehicles emit lower levels of all these toxic air contaminants with the exception of formaldehyde. In addition, the higher toxicity of benzene and especially 1-3 butadiene overwhelm the toxicity associated with higher formaldehyde from M100 and M85 fuels, resulting in 50 percent and greater reductions in cancer risk. The U.S. EPA has determined that methanol is not a carcinogen, reproductive or mutagenic hazard, and not a threat to a fetus.

With respect to formaldehyde, all internal combustion engine vehicles today emit some amount of formaldehyde. With new catalytic converter technology, the amount of formaldehyde emitted by a FFV is reduced dramatically. Research by Carnegie Mellon University indicates that formaldehyde emissions can be kept in check by catalytic converter technology. The ARB has established a formaldehyde emissions standard for all motor vehicles. The FFVs sold in California meet ARB's standard for formaldehyde.

Recently, there also have been concerns about groundwater contamination. Methanol is water-soluble and, as such, can be quickly diluted in large bodies of water to levels that are safe for organisms. M85 spills should not lead to environmental effects worse than petroleum fuels, and in many cases, the recovery rates are faster. While the behavior of M85 spills continues to be a valid research topic, it is more important to determine cleanup procedures for M85 or M100 methanol spills. Current California regulations for underground fuel storage tanks require that the tanks be double-walled. The likelihood of an undetected leak of M85 or any other fuel occurring from these tanks is, therefore, extremely low.

Future Potential for Methanol Vehicles

As far as the driver is concerned, light-duty methanol FFVs are more acceptable than other alternative fuel vehicles because they operate similar to gasoline vehicles. FFVs are technologically advanced, their performance is acceptable, achieve low emissions, and their cost is equivalent to that of their gasoline counterparts. One deterrent is that methanol costs more than gasoline on an energy-equivalent basis. The major problem that the fuel faces today is that methanol producers commitment to build a viable methanol fuel market has diminished. This lack of commitment is a stark contrast to the price of CNG and LNG and the natural gas industry's commitment to support CNG and LNG vehicles.

Because of these same issues, the future of commercialized methanol-fueled heavy-duty vehicles is bleak. Methanol fuel and methanol heavy-duty engines cost significantly more than diesel counterparts. Although the use of methanol-fueled heavy-duty vehicles would significantly reduce NO_x and particulate emissions, especially in urban area transit buses, the high incremental costs resulted in the elimination of production of heavy-duty methanol engines.

Methanol is also an excellent liquid fuel that can be reformed in fuel cells into hydrogen. The hydrogen is then used to produce electricity to power a vehicle. Work is underway to demonstrate methanol as a practical source of energy for new generation fuel cells. For additional information, refer to Chapter 9, "Fuel Cell Technology."

Table V-1
Summary of Methanol Flexible Fuel Vehicle Sales in California

Year	Make	Model	Sales
1992	Chevrolet	Lumina FFV	1,192
1992-93	Dodge/Plymouth	Spirit/Acclaim	2,036
1993	Chevrolet	Lumina FFV	74
1993	Ford	Taurus FFV	2,145
1994	Ford	Taurus FFV	2,016
1994	Dodge/Plymouth	Spirit/Acclaim	1,751
1995	Ford	Taurus FFV	1,152
1995	Dodge/Chrysler	Intrepid/Concorde	920
1996	Ford	Taurus FFV	1,511
1997	Ford	Taurus FFV	629
1998	Ford	Taurus FFV	390

Methanol Contacts

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Ford Motor Company
Alternative Fuel Vehicle Hotline
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Chapter 6

Compressed Natural Gas Vehicles

Introduction

This chapter discusses the characteristics of compressed natural gas (CNG), vehicle history, light and heavy-duty vehicle technology, infrastructure, and fuel supply. Also included are fuel pricing, environmental, health and safety aspects, future potential for natural gas vehicles, and current certified vehicles and engines.

Fuel Characteristics and Vehicle History

CNG is a high pressure form of natural gas, the same fuel that is used in many households for cooking and heating. It is a combustible, gaseous mixture of simple hydrocarbon compounds, usually found in reservoirs formed by porous rock 3,000 to 15,000 feet below the earth's surface.

Natural gas is an independent fossil fuel, it can also be found with crude oil. Natural gas is not a petroleum product and is primarily composed of methane (CH_4), with minor amounts of ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}) and pentane (C_5H_{12}). Natural gas is abundantly available in North America. Because natural gas is a fossil fuel, there is a finite supply with reserve estimates of 120 years at current levels of consumption.

Natural gas has been used for many years in stationary internal combustion engines with high efficiency and reliability. Because of its domestic availability, low cost, and clean-burning combustion characteristics, it has become one of the leading alternatives to gasoline and diesel as a motor vehicle fuel. The major difficulties with natural gas in transportation applications have been onboard fuel storage and vehicle range. Because of its very low energy density, natural gas must be either compressed or liquefied, increasing its energy density, to make it a viable transportation fuel.

Most commercial natural gas has a heating value from 960 to 1,120 Btus per cubic foot, with a rough average of 1,025 Btu/cubic foot or 102,500 Btus per therm. The heating value of natural gas depends on the proportion of gases making up the mixture. Natural gas has a very high research octane number (RON), approximately 125. Comparatively, the RON for propane is approximately 91, and for gasoline, it is 82 to 97. The RON is used to describe the antiknock quality of a marketed fuel. Natural gas has a high ignition temperature, about 1,200 degrees Fahrenheit, compared to 600 degrees for gasoline.

Light-duty Vehicle Technology

There are two types of light-duty CNG vehicles or fuel systems currently being produced: dedicated vehicles which operate exclusively on natural gas and bi-fuel vehicles which have fuel systems for both natural gas and gasoline.

Vehicle fuel systems for bi-fuel and dedicated natural gas vehicles are very similar. The main difference is that the gasoline fuel system is left intact on the bi-fuel vehicle. Both bi-fuel and dedicated CNG vehicles are equipped with high pressure storage cylinders capable of storing natural gas at 3,000 psi to 3,600 psi. This high pressure gas is reduced to about 100 psi before being discharged or injected into the engine intake manifold and finally burned in the engine cylinders.

Natural gas vehicles, like many of the alternative fueled vehicles, typically have a shorter driving range than their gasoline counterpart. This limitation is a direct result of lower energy density and packaging the high pressure storage cylinders in the vehicle. Driving range of a dedicated natural gas vehicle is 150 to 250 miles, approximately half that of their gasoline counterparts. For bi-fueled natural gas vehicles, the driving range is less of a problem because they are equipped with two separate fuel systems, gasoline and natural gas, and can have a 300-mile driving range.

A few light-duty CNG vehicles are being produced by the original equipment manufacturers (OEM) and can be purchased at new car dealerships. After market CNG conversion kits for gasoline vehicles are also available and are approved by the ARB for sale in California. Currently, CNG vehicle production and sales levels are low because OEM CNG vehicles cost between $4,000 and $5,000 more than their gasoline counterparts. Depending on the equipment, retrofitting a gasoline vehicle can be in this same cost range. Currently, there are approximately 13,000 NGVs in California. The future of light-duty CNG vehicles will depend on increasing vehicle sales, mandates, purchase, and fuel incentives, and economic decisions. For a list of ARB-certified NGVs, refer to Table VI-1, page 52.

Heavy-duty Vehicle Technology

The heavy-duty sector includes vehicles that have a GVW of 14,000 pounds or higher and are generally powered with diesel engines. In the U.S., most diesel engine manufacturers are involved in heavy-duty natural gas engine projects. Cummins, Detroit Diesel, and John Deere are currently offering commercialized, certified heavy-duty natural gas engines for trucks, as well as school and transit buses. Two types of engine operating cycles are currently being used for heavy-duty CNG engines. The first is spark ignited which uses a spark plug to ignite the natural gas fuel mixture in the combustion chamber, similar to a light-duty automobile engine. The second is compression pilot ignition. This technology injects a small amount of diesel along with natural gas into the combustion chamber. The heat generated by compressing this mixture ignites the diesel fuel that in turn ignites the natural gas mixture, operating much like a conventional diesel engine.

Heavy-duty natural gas engines have significantly lower emission levels than diesels. They achieve low particulate matter and low NO_x emissions. This fact is significant because in urban bus applications, visible particulates are offensive to the public. Air pollution control agencies receive more complaints regarding smoky emissions than any other vehicle issue. Lower CNG emissions are also important because, recent ARB and U.S. EPA research has indicated that diesel engine particulate emissions may be more carcinogenic than previously postulated. This lower CNG exhaust emissions factor has generated interest and use of CNG transit buses as the basis of mobile emission reduction credit sales.

Natural gas trucks, like many of the alternative fueled vehicles, typically have a shorter driving range than their diesel counterpart. This shorter range is a result of natural gas having a lower energy density and difficulty in packaging the high pressure storage cylinders on the truck. The truck driving range can be increased by adding additional storage cylinders, but the added weight will reduce the amount of product the vehicle can carry.

Currently there are more than 250 school buses operating as part of California's Safe School Bus Clean Fuel Efficiency Demonstration Program. These buses are powered by the following CNG engines:

- GMC 427 cubic inch V-8 engine converted by Tecogen to operate on CNG. This seven liter spark ignited engine develops 194 Bhp at 4,000 rpm, with a compression ratio of 10.5:1.
- Tecodrive 7000T CNG engine (Tecogen) rated at 222 Bhp at 3,600 rpm.
- John Deere Series 450 6081 HFN engine. This 8.1 liter engine is rated at 250 Bhp and 800 foot pounds of torque.

The prices of these heavy-duty natural gas engines vary. Because of the substantial premium for development costs, prices for heavy-duty natural gas engines are nearly double that of a comparable diesel engine. The incremental cost for each heavy-duty CNG vehicle can range from $20,000 for a fleet of small buses to $60,000 for a large unique CNG demonstration truck. For a list of certified CNG heavy-duty engines, refer to Table IV-2, page 53.

Infrastructure

Natural gas vehicle fueling abilities can range from a very small slow-fill for refueling of private vehicles or large fast-fill for refueling a fleet of heavy-duty vehicles. Slow-fill systems are simpler in design and cost less than fast-fill stations. However, slow-fill stations require several hours to refuel compared to the two-five minutes needed with fast-fill systems. CNG is generally provided to refueling stations owned by a local distribution company (LDC), a private fleet, or a public refueling company. The LDC obtains the gas from a producer through a pipeline company.

Fast-fill CNG refueling stations accomplish gas compression, drying, and filtration, storage and dispensing. The gas compressors are expensive and consume significant electric or gas engine power. There are several fast-fill CNG station designs that can include smaller compressors and larger gas storage tanks or larger compressors with reduced storage capacity. The selection generally is driven by the fleet refueling schedule requirements. CNG refueling dispensers are similar to gasoline or diesel dispensers, except the nozzles have positive-connect pressure fittings.

Currently, there are over 100 public and 90 private NGV fueling facilities within California. This number is expected to exceed 260 by the end of 1999.

Fuel Supply

Natural gas supplies are expected to remain plentiful for the next several decades. The total resource base, or gas recoverable with today's technology for the lower 48 states, is estimated to be about 975 trillion cubic feet. This amount is enough to meet current consumption needs for more than 50 years. Natural gas costs less than petroleum and is domestically available. This fuel accounts for approximately one-fourth of the energy consumed in the U.S., supplying natural gas for commercial and industrial processes, home heating, and electricity generation. Transportation consumes about three percent, primarily to power compressors on natural gas pipelines.

CNG vehicle advocates have the support of pipeline companies, natural gas local distributing companies and producers.

Extensive CNG vehicle programs have been implemented by Southern California Gas, Pacific Gas and Electric, and other California gas companies. Recently, these programs were cut back in response to legislation which introduced more competition into the utilities' business.

CNG as a transportation fuel is not limited by the availability of the feedstock. It is, however, hampered by the number of refueling stations. CNG is currently available at approximately 1300 refueling stations throughout the U.S. These stations allow drivers of CNG-dedicated vehicles to successfully drive across the country without geographic restrictions. Dual fuel CNG vehicles with CNG and gasoline or diesel fuel systems can drive without restrictions by switching from CNG to gasoline (or diesel).

Today's Prices of CNG

Today's prices of CNG are generally less than gasoline or diesel fuel, on an equivalent energy basis, even when the CNG compressor station costs are considered. Although CNG is exempt from federal excise tax, it is subject to a federal energy tax of $0.0485 per 100 standard cubic feet (scf), which is approximately $0.056 per gasoline gallon equivalent. State taxes on CNG vary considerably.

In California, CNG is taxed at approximately $0.07 per gasoline gallon equivalent, compared to $0.18 per gallon for gasoline. Even though CNG fuel is comparatively less, the cost of the light-and heavy-duty vehicles is substantially more than their gasoline and diesel counterparts. Only in a minimal number of high-mileage fleet vehicle applications are the fuel cost savings adequate to amortize the CNG vehicle capital costs.

Environmental, Health, and Safety Issues

Natural gas is non-toxic and poses limited health concerns. Because of its high pressure, there are safety issues associated with the use of CNG. CNG is stored on vehicles at a maximum pressure of 3,600 psi which provides about one-forth the energy density of gasoline. Natural gas must be compressed prior to transferring it to vehicles and special high-pressure tanks are used to safely contain the CNG on the vehicle. These cylindrical tanks are constructed of high-strength steel, aluminum wrapped with a composite material, or all-composite materials. The National Fire Protection Association, American National Standards Institute, and other control agencies have established strict standards for CNG equipment. A few mishaps with ruptured tanks have occurred as a result of corrosion that caused the pressure relief devices to vent gas prematurely. There have been no major "on-road" CNG vehicle accidents in the United States.

CNG vehicles do require some safety procedures that are not required for gasoline or diesel vehicle. Gasoline and diesel fuels are heavier than air and stay near the surface. On the other hand, natural gas rises up because it is lighter than air. Maintenance facilities that have been designed to maintain gasoline and diesel vehicles must be modified to provide adequate maintenance procedures that accommodate these CNG characteristics.

During extraction, processing, accidental releases, or vehicle emissions, natural gas can potentially create adverse environmental impacts. CNG is primarily methane, a greenhouse gas. The release of any greenhouse gas into the environment is of concern because it can contribute to global climate change.

Future Potential for Natural Gas Vehicles

CNG is a viable alternative fuel for light-duty vehicles. The U.S. is one of the world's largest producers and consumers of natural gas. Interest in natural gas as a transportation fuel has increased in recent years because it burns cleanly and it has an active and well-financed constituency of advocates. The disadvantage of CNG is that the high vehicle prices are not offset by the low fuel prices. CNG's future potential in the light-duty vehicle market will depend on public acceptance of reduced vehicle range, technology advances, increased sales volume to reduce equipment prices, and future regulatory action. As sales increase and technology improves, the incremental cost of CNG vehicles is expected to decrease.

The future potential for heavy-duty CNG vehicles will depend on several factors. Compared to diesel fueled engines, CNG has significantly lower emissions. CNG generally is less expensive per Btu than diesel fuel.

However, as in light-duty applications, the heavy-duty CNG vehicle costs substantially more than diesel vehicles. Despite this fact, heavy-duty CNG vehicle life-cycle economics are better than light-duty vehicle economics. Because of the increased fuel consumption, the additional capital costs can be amortized. At this time, emissions-certified OEM heavy-duty natural gas engines are not available in horsepower ranges suitable for all applications. Heavy-duty engines that are currently available are less efficient than the diesel counterparts. The range limitations as well as the additional tank, fuel, and space needed with CNG fuel create challenges.

Table VI-1
Natural Gas Vehicles (June 1999)

Year	Make	Model	Certification
1995	Chrysler	B2500 Ram (Van)	LEV
1995	Dodge/Plymouth	Caravan/Voyager Minivan	ULEV
1995	Dodge	Ram 1500 Pick-up	ULEV
1996	Dodge/Plymouth	Caravan/Voyager Minivan	ULEV
1996	Dodge	2500 Ram Pick-up	ULEV
1996	Dodge	B2500 Ram Van/Wagon	ULEV
1996	Dodge	B3500 Ram Van/Wagon	ULEV
1996	Dodge	Dakota Pickup	ULEV
1996	Ford	Crown Victoria LTD	ULEV
1996	Ford	F-150, F-250 Bi-fuel Pickup	Tier-1
1996	Ford	Econoline 250, 350 bi-fuel Van	Tier-1
1997	Ford	Crown Victoria LTD	ULEV
1998	Ford	Crown Victoria LTD	ULEV
1998	Ford	Contour bi-fuel	T-LEV
1998	Chevrolet	Cavalier bi-fuel	LEV
1998	Honda	Civic GX	ULEV
1998	Ford	Ford E-250, E-350 (Dedicated)	SULEV
1999	Ford	Crown Victoria LTD	ULEV
1999	Ford	Contour bi-fuel	T-LEV
1999	GMC	Sierra Pick-up bi-fuel	LEV
1999	Chevrolet	CK Pick-up bi-fuel	LEV
1999	Chevrolet	Cavalier bi-fuel	LEV
1999	Honda	Civic EX	ULEV
1999	Toyota	Camry	ULEV
1999	Ford	F-150 Pick-up and S-cab bi-fuel	ULEV
1999	Chrysler	B3500 Van	SULEV
1999	Ford	F-250, E-250, E-350	SULEV
1999	Ford	E-350 Club Wagon	SULEV

Table VI-2
Natural Gas Heavy-Duty Engines (July 1999)

Model Year	Manufacturer	Liter Displacement
1998	Baytech	4.3
1998	Cummins	11
1998	Cummins	5.9
1998	Cummins	8.3
1998	DDC	8.5
1998	John Deere	6.8
1998	John Deere	8.1
1998	Power Systems	11.9
1998	Power Systems	10.3
1999	Baytech	4.3
1999	Cummins	5.9
1999	Cummins	8.3
1999	Cummins	11
1999	DDC	12.7
1999	DDC	8.5
1999	John Deere	6.8
1999	John Deere	8.1
1999	Power Systems	7.2

Compressed Natural Gas Contacts

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Fuel Providers

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160 West Elm Street
Coalinga, CA 93210
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City of Long Beach
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Clean Air Transportation
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Chapter 7

Liquefied Natural Gas Vehicles

Introduction

This chapter discusses the characteristics of liquefied natural gas, vehicle history, light and heavy-duty technology, infrastructure, fuel supply and pricing. Also included are the environmental, health, and safety aspects, and the future potential for liquefied natural gas vehicles.

Fuel Characteristics and Vehicle History

Liquefied natural gas (LNG) is primarily composed of methane, CH_4, and is a viable alternative fuel to compressed natural gas (CNG), gasoline, and diesel. Natural gas becomes a liquid when cooled to cryogenic temperatures about -260°F. LNG has a higher storage density than CNG, is domestically available, has the benefits of low cost, and is clean burning. When used as a motor fuel, LNG is stored at its boiling point on the vehicle as a saturated liquid. The tank pressure determines the actual fuel temperature. The typical storage pressure of LNG is 50 pounds per square inch gallon (psig) at which the fuel temperature is -220°F. In this state, LNG has an energy density of approximately 230 percent of CNG at 3,000 psig and about 55 percent of diesel fuel.

Natural gas may be liquefied at the fuel station site but is typically delivered by tanker truck from remote liquefaction plants. Highly insulated tanks are installed on board the vehicle to store the fuel. Over the years, the technology for LNG fuel tanks has evolved. Tanks are constructed as concentric stainless steel containers, similar to a thermos bottle. The space between the internal and external container is evacuated and typically contains a reflective layered super insulating material.

Light-duty Vehicle Technology

No automobile manufacturers currently offer LNG light-duty vehicles. Because privately owned light-duty vehicles may occasionally remain unused for weeks at a time, LNG is not an appropriate fuel type. When LNG vehicles are parked indoors for long periods of time, pressure builds up in the tanks induced by heat transfer. This leads to combustible gas venting after storage periods as short as one week.

Although safe self-service fueling station systems have recently become available, refueling vehicles with LNG requires knowledge and expertise. Training large numbers of light-duty LNG fueled vehicle owners on refueling procedures would be difficult to achieve.

Heavy-duty Vehicle Technology

LNG is the fuel choice for most large natural gas fueled Class 8 (33,000 – 80,000 lb. GVWR) trucks and all natural gas fueled locomotives. Some large transit bus and medium-duty truck fleets also use LNG.

Heavy-duty vehicle chassis and engines are generally manufactured by separate companies. Diesel engines are generally the engine of choice for these vehicles and natural gas engines are typically based on popular diesel engine configurations. The two types of heavy-duty natural gas engines currently available are spark ignition and pilot injection dual fuel. A third type, compression ignition direct injection, is under development.

Most heavy-duty LNG trucks are produced by replacing the diesel fuel tanks on an existing or new truck chassis with LNG tanks and fuel system components and either installing a new OEM natural gas engine or converting the existing diesel engine. This mechanical work is usually carried out by a full-service truck or engine dealer, but a few OEM truck chassis manufacturers are showing interest in installing natural gas engines and LNG fuel systems as part of their new truck assembly process. Conversely, the bus manufacturer usually assembles LNG buses with a natural gas engine and LNG fuel system. Currently, there are six manufacturers of heavy-duty natural gas engines; eight manufacturers of LNG fuel tanks and vehicle fuel system components; and five OEM transit bus manufacturing companies offering LNG buses.

LNG provides longer vehicle range with smaller and lighter tanks relative to CNG but a shorter range than diesel vehicles. This point is significant for heavy-duty vehicles because range and payload capability usually impact profit margins. Heavy-duty natural gas vehicles appear to have an energy-based fuel economy of at least 15 percent lower than equivalent diesel vehicles, although engine technologies to improve fuel economy are under development. Heavy-duty natural gas engines have been developed to produce some of the power output ratings of popular diesel engines. Heavy-duty natural gas engines have also achieved significantly lower NO_x and particulate emission levels than the diesel counterparts.

Compared to equivalent diesel vehicles, the incremental costs for LNG vehicles depend on the quantity of vehicles purchased, their equipment options, as well as other factors. The approximate incremental price of LNG transit buses is between $30,000 to $40,000 vs. ($50,000 to $60,000 with CNG) with quantity purchases. The incremental price of a Class 8 tractor equipped with a LNG engine and fuel system can be $35,000. These incremental costs should decrease as market development and production increase.

The Interstate Clean Transportation Corridor (ICTC) coordinates the activities of interested stakeholders to establish LNG fueling infrastructure along major highway corridors in the western states to supply heavy fuel consuming long-haul trucks as well as local users. The ICTC will link Las Vegas, San Diego, Los Angeles, the San Joaquin Valley, San Francisco, Sacramento, Reno, and Salt Lake City.

During the 1970s, San Diego Gas and Electric Co. provided LNG fuel for fleets, including shuttle buses at the San Diego Zoo. San Diego Gas and Electric dismantled its LNG plants in the late 1970s, which ended these LNG vehicle projects. Currently, LNG is provided to California truck and bus fleets from liquefaction plants in Wyoming, Kansas, Colorado, and Arizona.

Infrastructure

Fuel supply options for LNG vehicle projects have included central liquefaction facilities (typically pipeline gas processing for peakshaving), on site liquefaction and imported LNG. In the larger centrally located liquefaction plants, LNG can be economically trucked to operators. In Willis, Texas, Praxair has a large liquefaction plant that provides fuel to LNG fleets in El Paso and Houston. Some centrally located, existing gas-processing plants could produce LNG. Unfortunately, these processing plants are not conveniently located near any California LNG vehicle fleets. More than 50 North American gas utilities liquefy and store gas for reevaporation during peak demand periods. Some of this product could be used to fuel LNG vehicles.

On-site liquefaction reduces the cost of transporting LNG from distant processing facilities. This on-site process is similar to a CNG station, except the liquefier replaces the compressor. The economical competitiveness for onsite liquefaction is still being evaluated.

Imported LNG has not become economically feasible for California vehicle projects. The operating U.S. LNG import terminals are located in Everett, Massachusetts and Lake Charles, Louisiana. Both terminals are too far away for imported LNG to be economically trucked to California for LNG vehicle fuel. Some imported LNG does not meet the high methane content (97 percent) typically required by heavy-duty natural gas engine manufacturers for performance and durability.

An LNG refueling station generally consists of a fuel transfer system, a storage tank, and dispenser equipment. Although there are many design variations, generally either a pump or differential pressure is used in the fuel transfer system. The dispenser has a refueling connector, a cryogenic hose, and a metering control system. The design of all LNG transfer and dispensing systems is to minimize or eliminate vapor venting to the atmosphere. LNG refueling is faster than CNG, but the hoses and connectors used for LNG are more cumbersome.

There are currently a few installed LNG-to-CNG refueling stations (LCNG or L/CNG). These stations provide fuel supply flexibility for both CNG and LNG vehicle refueling. For CNG refueling, these stations actually store natural gas as LNG, increase the pressure to 3,000 psig or higher using much less energy than CNG compression, and then vaporize and dispense it into CNG vehicles.

Fuel Supply

Presently, there are very few LNG refueling stations, but LNG production capability exceeds demand. Public access LNG stations are virtually non-existent. Most LNG refueling stations are at heavy-duty vehicle fleet locations that refuel on-site.

The delivery of less-than-truckload LNG quantities increases the cost of transport. One of the limitations for small LNG vehicle pilot projects is the cost of LNG refueling stations. These costs have been a deterrent until the recent lease options available for LNG storage and refueling facilities. There are currently two lease facilities, available in California. Cryenco manufactured a portable skid-mount unit that is leased through Jack B. Kelley Inc., a cryogenic gas trucking company based in Texas. This leasing opportunity may resolve the refueling limitations. As public access LNG fueling infrastructure becomes established for long-haul trucking, the economic availability of LNG in small quantities will improve.

Petroleum, chemical, and natural gas companies; LNG importers and natural gas local distribution companies (LDCs) have made investments in advancing LNG as a motor vehicle fuel. Included in the list of promoters are Praxair and Air Products, specialty gas and chemical companies. Praxair has a liquefaction plant in Willis, Texas that supplies LNG as a fuel. Air Products has focused mainly on the LNG for the railroad locomotive market.

Significant natural gas reserves, as well as existing gas processing plants that can produce LNG, are owned by Chevron, Exxon, and Amoco. Because these plants are not near potential California LNG vehicle fleets, significant transportation would be needed.

Local distributing companies (LDC) play an important role in the LNG arena because they can provide significant financial opportunities. Some LDCs with peakshaving facilities strive to sell LNG or promote LNG vehicle development. Because the LDC funding source is rate based, using these funds for supporting LNG as a motor vehicle fuel is met with some opposition. Ratepayers generally prefer that rate based funds be used for residential and industrial natural gas consumption rather than supplying fuel to natural gas vehicles.

Today's Prices of LNG

On an energy-equivalent basis, the price of LNG can be higher or lower than gasoline or diesel fuel. The price is highly dependent on geographic location, purity, transportation, quantity purchased, and competitive forces. The retail price of any fuel in a commercial environment must ultimately include the amortized cost of the equipment required to store and dispense it. This makes it especially important to achieve high usage of highly capital-intensive equipment. Because the equipment to store and dispense LNG costs less per unit of energy dispensed than equivalent CNG equipment, LNG fuel stations should be able to compete economically with CNG fueling stations with lower use levels. However, since LNG is primarily used in heavy-duty and heavy fuel consuming vehicles such as large trucks, transit buses, refuse collection trucks and railroad locomotives, the large quantities of fuel dispensed from large centrally-operated fleet locations can be relatively cost effective compared to diesel fuel.

In 1997, the federal government revised the excise tax on LNG to approximately $0.12 per LNG gallon, the energy equivalent of gasoline at about $0.18 per gallon. This revision removed a long-standing inequity. Previously federal excise taxation for LNG was at the same rate per gallon as gasoline, without recognizing LNG's lower energy density.

The State of California taxes LNG at $0.06 per gallon. This is approximately $0.09 per gasoline equivalent gallon, compared to $0.18 per gallon of gasoline. Heavy fuel consuming vehicles over 12,000 lb. can pay a flat rate of $168 per year. Without this flat rate incentive, a typical LNG truck using 33,333 gallons of LNG to travel 100,000 miles (at 3 miles per LNG gallon) would pay $2,000 in California State fuel excise taxes. This is a saving of $1,832.

As a substantial market for the fuel develops, LNG prices can be expected to decline. This would secure a more affordable LNG refueling infrastructure and could enable economic use of large liquefaction plants.

Environmental, Health, and Safety Issues

Because LNG is a non-toxic fuel, there are not many health issues. However, the public does not have general knowledge about or experience with the use of LNG (and other cryogenic liquids). The freezing temperature of the fuel can cause cryogenic burns or frostbite if it comes in direct contact with the skin. California law (Title 8) requires that "only qualified persons shall be permitted to operate natural gas transfer or fueling equipment."

Natural Gas is primarily methane, a greenhouse gas. Thus, using any natural gas fuel has the potential of creating adverse environmental impacts. Without adequate safety controls, direct releases of methane to the environment can potentially occur during the extraction and processing of natural gas and crude oil, from accidental releases of pipeline gas in distribution systems, at fueling hook-ups, tank venting, as well as tailpipe emissions. The pressure buildup from heat transfer, if the vehicle is unused for periods of more than a week, can result in tank venting. This tank venting can cause safety and environmental concerns for global greenhouse warming.

An unused LNG vehicle parked for long periods will vent flammable gas. The primary LNG vehicle safety issue is the concern that a vehicle parked indoors will vent a flammable mixture in the vicinity of an ignition source. This problem is essentially eliminated if LNG is restricted to frequently driven fleet vehicles, which are serviced in properly designed facilities, by trained personnel. Los Alamos National Laboratories conducted a safety analysis on LNG vehicles and calculated that for most accident scenarios LNG vehicles were rated safer than gasoline vehicles. However, LNG vehicles were rated less safe than diesel vehicles. The safety reputation of LNG has been plagued by a 1944 accident at a LNG plant located in Cleveland which caused 128 deaths. Experts agree that this incident of tank structural failure was due to the low temperature (resulting in weakening of the steel used in that system) and does not apply currently to LNG systems used in motor fuel applications today.

Future Potential for LNG Vehicles

The future potential for LNG is in heavy-duty vehicles where range and payload are critical. CNG is better suited for light-duty vehicles where range and payload are not major issues. Medium-duty applications may be appropriate for both natural gas fuel types. The specialized equipment and procedures needed for LNG vehicles and refueling facilities are currently available.

Although the vehicle and refueling facility costs are high, the current price of LNG is close to diesel fuel on an energy-equivalent basis. As a motor fuel, LNG is available from a number of fuel suppliers, but long-distance transportation is costly. LNG vehicle engines, fuel systems, and other equipment, as well as, LNG refueling stations are available.

Because of the additional cost of LNG vehicles and refueling facilities, the life-cycle cost of LNG vehicles is higher than diesel counterparts. This life cycle cost issue should improve as the LNG motor vehicle market develops and incentives based on emission benefits become available.

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Chapter 8

Propane/LPG-Fueled Vehicles

Introduction

This chapter discusses the characteristics of liquefied petroleum gas, vehicle history, light and heavy-duty vehicle technology, infrastructure and fuel supply. Also included are pricing, environmental, health, and safety aspects of the fuel and future vehicle potential.

Fuel Characteristics and Vehicle History

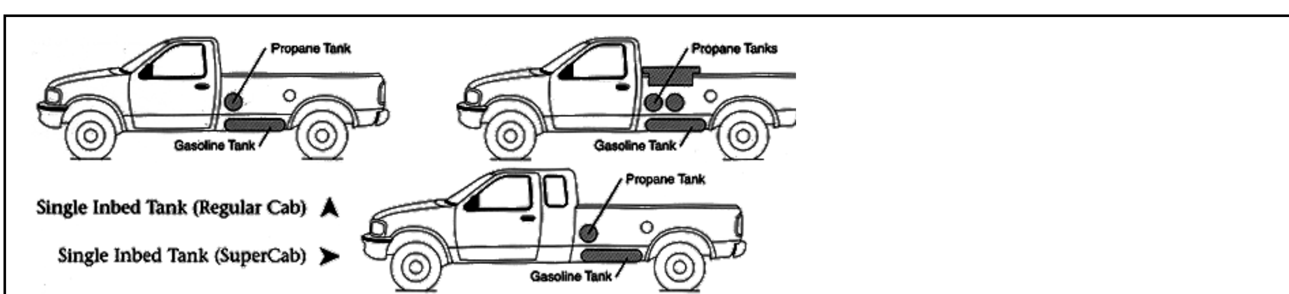
Propane is a gas in its natural state and is derived from petroleum refining and natural gas production. It turns to liquid under moderate pressure and is stored in vehicle fuel tanks at about 200 pounds per square inch at 100 degrees Fahrenheit. When liquid propane is drawn from the tank, it changes back to a gas before it is burned in the engine.

As a motor vehicle fuel, propane is referred to as liquefied petroleum gas (LPG), which is actually a combination of hydrocarbons like propane, ethane, and butane. LPG is gaseous at ambient conditions but liquefies at moderate pressures. In the U.S., about half of the LPG, a non-renewable fossil fuel, obtained today is a by-product of natural gas processing and the remainder comes from crude oil refining. LPG combustion produces small amounts of particulate and sulfur emissions. One gallon of LPG contains less energy than a gallon of gasoline (82,485 Btus for LPG compared to 111,400 Btus for gasoline).

LPG has been used as a fuel since 1912. In the U.S. today, LPG is the third most commonly used transportation fuel, ranked only behind gasoline and diesel. More vehicles use LPG than all other alternative fuels combined.

LPG has been used around the world as a transportation fuel for more than 60 years. More than four million LPG-fueled vehicles are in service throughout the world in light, medium and heavy-duty applications. Approximately 300,000 vehicles in the U.S., mostly in fleets, are fueled with LPG. These include school buses in Kansas City and Portland; taxicabs in Las Vegas; sheriff and police cars; and dozens of fleets throughout California. The estimates have placed the number of LPG fueled vehicles in California as high as 32,793, according to the Energy Information Agency of the DOE.

Figure VIII-1
LPG Fuel Tank Placement



Light-duty Vehicle Technology

The majority of LPG vehicles are gasoline (spark-ignition) engines. Converting diesel (compression-ignition) engines to LPG is a more complex process. The two existing light-duty LPG engines are either dedicated, operating exclusively on LPG, or bi-fuel, operating on either LPG or gasoline. The majority of LPG-fueled engines are specially manufactured converted gasoline engines. The LPG-fueled light-duty vehicle also performs like a gasoline vehicle, especially because of driving range.

LPG is stored on-board in liquefied form under moderate pressure, approximately 160 pounds per square inch. It has about 86 percent of the energy of gasoline, so it requires more storage volume to provide the same driving range. LPG, however, provides the longest driving range of any alternative fuel. The low cost of on site refueling makes LPG-fueled vehicles popular for industrial and fleet applications.

Before 1996, most LPG on-road vehicles generally used after-market equipment. Ford, GM, and Chrysler have produced LPG vehicles in the past, and are continuing to produce vehicles as OEM fully warranted vehicles. Canada has been the testing ground for some prototype Chrysler LPG vehicles. The cost of converting a light-duty vehicle from gasoline to LPG ranges from $1,500 to $3,000.

Emission testing of OEM-produced LPG vehicles indicates reductions in CO, NO_x, and non-methane hydrocarbons relative to gasoline vehicles in some applications. However, the refueling operation can be a significant source of LPG hydrocarbon emissions when a type of refueling valve, known as an outage valve, is used. U.S. EPA regulations are expected to prohibit the use of these valves in the future.

Heavy-duty Vehicle Technology

LPG use in medium and heavy-duty fleet vehicles is a popular application because they consume larger volumes of fuel than light duty vehicles. The larger volume of fuel helps offset the incremental cost of either a converted engine or the purchase of a new factory produced vehicle. Currently, GM offers a 7.4 liter LPG engine (dedicated) in the Topkick and Kodiak medium-duty trucks. This same chassis will be available in late 1999 with a Bluebird school bus body. GM's products use IMPCO fuel systems and are certified at LEV emission levels. A new 8.1 liter LPG engine is also planned for the near future.

Ford discontinued their popular F-700 medium-duty LPG powered chassis at the end of 1997. However, plans are to return this chassis to market with the LPG option in the new F-750 for the 2001 model year. The engine selection has not been finalized. Meanwhile, November 1999 is the target date for introduction of Ford's Super Duty F-350, F-450 and F-550 LPG-fueled trucks. All are powered by the 6.8 liter V-10 bi-fuel engine using the GFI fuel system with a ULEV emission level target.

Freightliner offers the Cummins 6B LPG engine (195 horsepower rated) in its medium duty chassis. This same engine is available in the El Dorado National and other brand buses as well as Ottawa yard dog (Dock Fork Lifts). It is certified at LEV emission levels.

Converting diesel engines to LPG operation are possible, but not economically practical. One diesel-LPG technology under development is the Caterpillar 3126 engine. In this technology, LPG and diesel are used at the same time and in varying proportions, depending on the engine load and speed. If successful, this engine may become a candidate for more robust heavy-duty applications.

LPG-fueled heavy-duty vehicles compensate for the less energy per gallon of LPG than gasoline or diesel fuel by installing slightly larger on-board fuel tanks. This improves LPG's driving range. Low maintenance costs, fuel savings, and lower emissions are some of the benefits of LPG trucks. In Orange County, California, as part of a demonstration project, transit buses were equipped with the Cummins L-10 engines converted to use CNG, methanol and LPG. After emissions testing, the LPG bus engine was found to have the lowest emissions.

Converting a conventional gasoline heavy-duty truck to LPG has been a long-standing practice. However, recent regulations by U.S. EPA and ARB make conversions more costly due to more stringent certification procedures. These procedures are aimed at ensuring that the positive emission benefits of LPG are delivered over the useful life of the vehicle. The cost of converting a conventional heavy-duty gasoline fueled truck to LPG can be partially offset by incentives offered under the EPAct. Many states and local governments also offer incentives for use of LPG vehicles.

In the international arena, various heavy-duty engine manufacturers supply LPG engines. To date, none have elected to bring those engines to the North American market.

Infrastructure

LPG's infrastructure is well established. In the U.S., there are more than 10,000 public LPG refueling stations. For motor vehicle refueling, there are about 700 public access LPG refueling stations in California. Fleet users with independent refueling stations can purchase LPG at wholesale from distribution centers or at discounted prices from public-access refueling stations. It is available to the general public at retail prices from public-access refueling stations. Although the LPG infrastructure is well established, many of the retail outlets need dispenser technology and appearance upgrades. Modern gasoline-type dispensers with fuel management systems are readily available for LPG applications.

LPG refueling stations consists of a storage tank, a transfer pump, metering and dispensing equipment, and a hose with a coupling which connects with the coupling on the vehicle fuel tank. LPG vehicle fuel tanks are filled to about 80 percent of the liquid capacity to allow room for liquid expansion if the temperature increases. All LPG vehicle tanks have an automatic stop-fill device, generally a float-actuated valve. New light-duty Ford pickups rely solely on an automatic stop-fill device. This device eliminates any discharge of fuel while the vehicle is being filled. Furthermore, it complies with U.S. EPA regulations, which limit any fuel discharge to two cubic centimeters per hose disconnect (the same permitted for gasoline). Some vehicles continue to use a "fixed level outage gauge" (a small tube that extends into the tank to the 80 percent level). This gauge will eventually be phased out. Refueling an LPG vehicle takes approximately the same amount of time as refueling with gasoline.

Figure VIII-2
Propane Dispenser

Fuel Supply

LPG is produced as part of crude oil refining and natural gas processing. In either case, the production of LPG is non-discretionary. Non-discretionary means that when a refinery plans to make gasoline, diesel fuel, heating oil, and jet fuel in the production process LPG is not only a natural derivative but is the first product that occurs as a result of "refining" crude oil. In the case of natural gas processing, the heavier hydrocarbons that naturally accompany natural gas as it leaves the ground are LPG, butane, ethane, and pentane. These liquefied petroleum gases must be removed from the raw natural gas stream, leaving mostly methane before entering the natural gas pipeline distribution system.

In the U.S., the production of LPG is approximately 30 billion gallons per year. Ninety-two percent of all of the LPG supply is domestic, the supply is reliable and relatively free from foreign market disruption. California is one of the largest LPG producing states. About 60 percent of the total production are from crude oil and 40 percent from natural gas processing. California imports some supply from other states in the winter and exports supply to other states and other countries in the summer.

From the refinery, propane, plus the other light hydrocarbons contained in LPG, is transported by truck, railcar, or pipeline to LPG sales and distribution centers. In addition to its application as a motor vehicle fuel, LPG is used for home barbecues, recreational vehicle appliances, as well as heating and cooking in areas where natural gas is not available.

Today's Prices of LPG

Uniquely, LPG satisfies many markets ranging from small heating torches to huge industrial applications. Each market has its own needs and competing fuels. Pricing established by fuel producers and distributors reflect efforts to profitably satisfy customer demand in these various markets, while remaining competitive with other fuels. When used as a motor vehicle fuel, prices vary depending on size of delivery, annual volume, time of year, whether the purchase is at the fleet or retail level, applicable taxes, and where the purchase is made.

Over the years, the pre-tax wholesale price of LPG has been about 75 percent of the price of gasoline on an energy-equivalent basis. LPG price fluctuations generally track changes in gasoline and diesel fuel price fluctuations. Vehicle fleet operators can purchase LPG at significant discounts from bulk LPG wholesalers, as well as public access LPG refueling stations. The price of LPG is posted relatively high at some public access stations because of small quantity sales to fill recreational vehicle appliance tanks and barbecues. Fleet operators typically use an individual proprietary tank on site, a relatively inexpensive investment. This tank is frequently provided by the propane supplier under a modest lease plan. LPG operators without their own refueling facilities will generally find (in descending order) the most favorable prices at LPG dealer owned stores and distribution centers, gasoline service stations with LPG tanks with posted motor fuel prices, and retailers such as rental yards and campgrounds.

Depending on the state, LPG is taxed as a liquid fuel like gasoline and diesel, at different per gallon rates. The current federal motor fuel vehicle excise tax is $0.13 per gallon. California state taxes are collected in one of two ways, either $0.06 per gallon with each fill or an annual fuel permit. The cost of the annual permit is based on vehicle weight. For example, the fee for all passenger cars, other vehicles with special automobile license plates are the following:

- Vehicles of 4,000 lbs. or less is $36,
- Vehicles more than 4,000 lbs., but less than 8,001 lbs. is $72,
- Vehicles more than 8,000 lbs., but less than 12,001 lbs. is $120, and
- Vehicles 12,001 lbs. or more is $168.

As in all other motor fuels, California sales tax is added to the price of LPG.

Environmental, Health, and Safety Issues

LPG is a relatively safe fuel because it is non-toxic, it has good luminosity, and it does not have to be stored at extremely high pressure or low temperatures. Storage and transportation of LPG in sealed; pressurized tanks eliminate evaporation emissions or spillage. Because it vaporizes when released and is not water soluble, LPG does not pollute underground water sources. LPG motor vehicle fuel tanks have relatively thick-wall steel construction and are much less prone to rupture and fires than gasoline fuel tanks in the event of a vehicle crash.

Conversely, LPG has some other safety issues. The weight of LPG vapors at ambient temperatures is approximately 150 percent the weight of air. If there is a leak, LPG vapors tend to settle against the ground and are invisible. There are also safety and emission issues associated with outage value usage. Incorrect use of outage valves during refueling could cause excess LPG vapor discharge. Leaks are also not visible; however, an odorant is added to make leaks more detectable.

State regulations vary regarding propane vehicle operation and refueling stations. Boston and New York do not allow LPG vehicles in tunnels. Some Provinces in Canada do not allow LPG vehicles in enclosed parking garages.

Future Potential for LPG Vehicles

LPG, when used in the transportation sector, has the potential to improve air quality and reduce our dependence on foreign petroleum. LPG, a relatively economic and convenient motor vehicle fuel, is currently used to fuel more light-duty vehicles than all other alternative fuels combined. In California, the supply is sufficient for expanded use since summer surpluses are exported out-of-state and out of the country.

Conversions of conventional gasoline engines have long been the practice in California. ARB regulations now require “fully certified” conversion equipment including onboard diagnostics capability for each engine family. Manufacturers of conversion equipment have difficulty making a business case for investing in the certification procedures without assurances of growing demand. Consequently, if no aftermarket certified equipment is brought to market, the LPG vehicle selection will be limited to that provided by the vehicle manufacturers.

For the 1999 model year, Ford is offering its F-150 and F-250 bi-fuel LPG pickups certified to ULEV. In the year 2000, Ford will offer their F-350, F-450, and F-550 trucks with a 6.8 liter, V-10 engine certified to ULEV.

For a current list of Approved Alternative Fuel Conversion Systems, contact the ARB Certification Branch at (626) 575-6800 or call the ARB Public Information Office at (800) 242-4450.

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Chapter 9

Fuel Cell Technology

Introduction

This chapter discusses the characteristics of fuel cells, light and heavy-duty vehicle technology, infrastructure, supply and pricing. Also included are environmental, health, and safety aspects, and the future potential for fuel cell vehicles.

Fuel Cell Characteristics

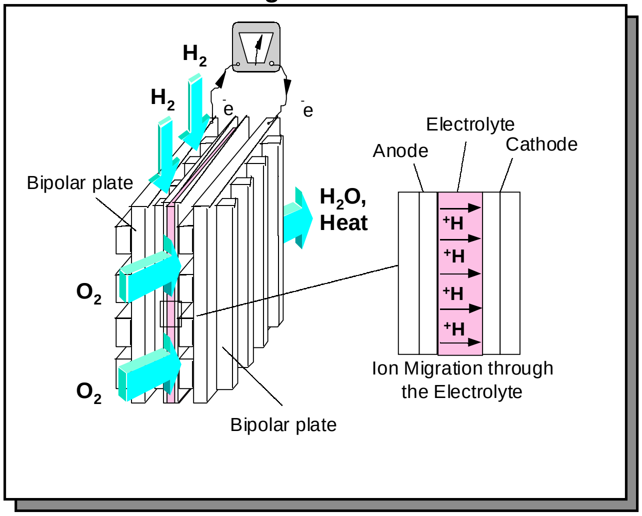
The fuel cell is a power-generating system for electric vehicles that converts the chemical energy of hydrogen and combines it with oxygen to produce electric energy, heat, and water. The fuel cell system is restored with chemical energy rather than electrical recharging. Vehicles powered by fuel cells have many of the advantages of electric vehicles without the disadvantage of limited range or battery replacement and recharging. Because many components used in the electric vehicle are also found on fuel cell vehicles, they can be considered a type of hybrid electric vehicle. However, fuel cells differ from batteries because fuel cells do not store energy but rather use energy stored in a fuel carried on a vehicle.

Some form of hydrogen is required for all fuel cell vehicles. Fuel cell systems can operate on hydrogen produced from on-board reformers fueled with hydrogen-rich fuels such as gasoline or methanol. These on-board reformer systems are complex. Reformation uses heat and catalysts to strip the hydrogen molecules from the carbon. The carbon is combined with oxygen (from air or water) to convert it to carbon dioxide. Trace pollutants can be formed in that process.

Lower emissions as well as higher energy efficiency favor fuel cell powered engines over internal combustion engines. Fuel cells also offer greater traveling range than battery-powered vehicles. The following are the six principle types of fuel cells identified by the specific electrolytic conducting materials:

- Alkaline Fuel Cell (AFC) - extensively used in the space program; they are very efficient yet very expensive and, therefore, considered impractical for transportation applications.
- Phosphoric Acid Fuel Cell (PAFC) - well suited for stationary power applications and possibly for transit bus applications.
- Proton Exchange Membrane Fuel Cell (PEMFC) - considered the leading fuel cell type for vehicle applications, uses hydrogen in a gaseous state or a liquid hydrogen carrier, and feeds hydrogen directly into the fuel cell (See Figure IX-1).

Figure IX-1
Proton Exchange Membrane Fuel Cell



- Molten Carbonate Fuel Cell (MCFC) - operates at a high temperature (600^o C) and is considered to be expensive and difficult to operate.

- Solid Oxide Fuel Cell (SOFC) - operates at a very high temperature (1000^o C) and is considered expensive and difficult to operate.

- Zinc Fuel Cell (ZFC) - very similar to the zinc-air battery in principle and application; it is still in early development for vehicle applications.

At the present time, the PEMFC is the most viable candidate for vehicle applications as it operates at relatively low temperature (80^{o}C) and can easily use a liquid fuel to provide an acceptable driving range. The fuel processor/reformer, the device that produces the hydrogen from hydrogen-rich fuels, is now being aggressively developed. The fuel processor/reformer must be capable of rapidly converting the vehicle fuel to hydrogen on demand, in a very pure state, as the fuel cell catalyst can be compromised by contamination, decreasing its efficiency over time. In the past several years, the fuel cell stacks, which produce the electric energy from the processed/reformed fuel, have become significantly refined to the point where their use in vehicles, both light- duty and heavy-duty applications, is a viable option.

Presently, the second most suitable fuel cell for transportation applications, primarily for heavy-duty vehicle applications, is the PAFC. Long warm-up times are required before the PAFC is operational at 200^o C, but it appears to be more tolerant of contamination in the fuel used to operate the fuel cell.

Fuel Cell (Fuels)

As mentioned previously, elemental hydrogen is the fuel directly used in the fuel cell to produce electric power for vehicles. The hydrogen can be placed and stored on the vehicle itself or it can be provided to the fuel cell stack by a fuel processor/reformer, which effectively pulls the hydrogen out of the on-board fuel and supplies the fuel cell stack.

For decades, hydrogen has been produced from natural gas and other hydrocarbon fuels in methanol and chemical plants and oil refineries. Steam Reforming (SR) and Partial Oxidation (POX) are the two methods for commercial production of hydrogen. These two commercial production approaches are being developed for on-vehicle hydrogen production and now hold the most promise for fuel cell vehicle commercialization.

With the use of a copper/zinc catalyst, SR of methanol can occur at lower temperatures. In a steam reformer system, heat is generated by a catalytic burner for the reformer catalyst. The catalyst temperature is 260^{o}C. Methanol and steam enter the catalyst, and the mixture is converted to hydrogen, carbon dioxide, and carbon monoxide. By reacting with steam and low levels of oxygen, the level of carbon monoxide is lowered to below 50 parts per million (PPM). This cleaned-up product gas is provided to the fuel cell, and unrelated hydrogen is burned in the burner to provide heat energy for the reformer.

Work is now underway to develop a direct injected methanol fuel cell that requires no reformer. The development is supported by the cooperative work at NASA’s Jet Propulsion Laboratory in Pasadena, the University of Southern California, Caltech, and the Los Alamos National Laboratory. This technology is simpler (without fuel processor), can be more compact, and is capable of near-zero emissions. However, the progress has been slow in developing the methanol steam reformer PEM.

The key to reformation is breaking the attachment between the hydrogen and the carbon in the fuel. This bond is strong, and a significant amount of energy must be supplied to release the hydrogen. One method of providing this energy is to burn or POX of the fuel, increasing the temperature enough to break the bond. A POX system can operate on a variety of hydrocarbon or hydrogen-rich feedstocks including gasoline, LPG, natural gas, methanol, and ethanol. Operating on a variety of hydrocarbons would be one advantage that POX reforming has over low temperature methanol steam reforming.

Epyx Corporation, a Massachusetts based unit of the international Arthur D. Little consultants, is perhaps the leading developer of the of the Partial Oxidation fuel processing technology. The Epyx Multi-Fuel Processor TM is a catalyst-based device, now in development, that is expected to produce hydrogen from several different fuels, such as those listed above.

Light-duty Vehicle Technology

Because of the rapid advancements in fuel cell technology, many major automobile manufacturers are developing PEMFC systems for light-duty vehicles. In a cooperative, cost-shared development program with the U.S. DOE, three major U.S. manufacturers are actively pursuing fuel cell transportation technology. In addition, European and Japanese auto manufacturers have accelerated their fuel cell development activities and now expect to produce light-duty fuel cell vehicles in the 2003-2005 time frame. Of the most notable, DaimlerChrysler, Ford, and Ballard Power Systems have formed a well-publicized cooperative effort to commercialize fuel cell drive trains for cars, buses, and trucks.

DaimlerChrysler has introduced its prototype fuel cell NECAR vehicles. In NECAR I, the fuel cell and tank occupies the entire cargo area of a small Mercedes van. In March 1999, DaimlerChrysler unveiled the first zero-emission fuel cell vehicle that has space for a driver and passengers. The car can reach a top speed of 90 miles per hour, can travel nearly 280 miles on a fill up, and can carry up to five passengers. This latest version carries the fuel cell engine in a typical engine compartment. The fuel cells themselves are several times more powerful than those in the first model. The first NECAR vehicles were configured for dedicated hydrogen operation. The NECAR 3 is an A-Class car proof of concept prototype vehicle, equipped with a methanol steam reformer feeding hydrogen to the fuel cell. In the NECAR 3, the reformer/ fuel cell system is large enough that the vehicle does not require any battery storage for supplemental power.

The NECAR 4, announced in March 1999, is also a Mercedes-Benz A-class compact car chassis, but it uses liquid hydrogen stored in cryogenic cylinder to fuel the fuel cell. The NECAR 4 reaches a top speed of 90 mph and can travel nearly 280 miles before refueling. NECAR is the latest of five fuel cell concept cars which have each presented solutions to the most challenging technical problems for bringing the fuel cell vehicle to the commercial market.

In the year 2000, DaimlerChrysler plans to replace the concept car with NECAR X, which will operate on methanol. DaimlerChrysler announced that it will offer up to 40,000 fuel cell powered vehicles for sale to the public by the year 2004. Other automobile companies, including Ford Motor, General Motors, Toyota, and Honda, also plan to market fuel cell vehicles by 2004.

Ford Motor Company, as part of the unique fuel cell alliance with DaimlerChrysler, is developing its P2000 vehicle powered by a hydrogen fuel cell. Ford's offering takes advantage of the advanced lightweight vehicle platform developed to meet the goals of the U.S. DOE's Partnership for a New Generation of Vehicles (PNGV) program, which include a vehicle that can achieve 80 miles per gallon. The P2000 fuel cell vehicle offers the same interior space as the Ford Taurus while weighing less than 3200 pounds and providing 100 horsepower.

The DaimlerChrysler, Ford and Ballard alliance has taken a large step toward the commercializing of fuel cell vehicles with the initiation of the California Fuel Cell Partnership, announced in April 1999. The Partnership includes automakers, Ballard Power Systems, as well as motor fuel retailers ARCO, Shell, and Texaco, and the ARB, and the Energy Commission.

Toyota has produced a fuel cell powered RAV4 prototype operating on methanol. To power the fuel cell, hydrogen is generated by a low temperature SR. Toyota's prototype is a hybrid design concept with a range of approximately 310 miles.

In 1998, General Motors announced that it would have a production-ready methanol fuel cell by 2004 and presented a methanol fuel cell-powered Sintra van at the March 1998 Geneva Auto Show.

In April 1999, Toyota and General Motors announced an alliance to cooperate on developing 21st century vehicles including fuel cell powered light-duty vehicles for the 2004-2005 production years.

Heavy-duty Vehicle Technology

Beginning in 1991, Georgetown University has managed the longest operating fuel cell powered transit bus program. They began with three PAFC fuel cell applications with a methanol SR. This project was originally co-funded by the U.S. DOE, U.S. DOT, and the SCAQMD. The Georgetown fuel cell bus project is in the fourth phase. In May 1998, Georgetown introduced a commercial fuel cell transit bus powered by a 100kW PAFC engine fueled with methanol. This transit bus has a 350 mile range.

In addition, the cities of Vancouver, British Columbia and Chicago, Illinois are each operating three fuel cell buses as part of their transit fleets. These buses, fueled on compressed hydrogen at 3,600 psi, are operating in urban transit routes and in regular service. They constitute the first trial of this technology in a real commercial environment. Ballard Power Systems, the developer of the Proton Exchange Membrane (PEM) fuel cell technology propulsion systems, is targeting the introduction of a competitive commercial fuel cell bus by 2002.

Ballard Power Systems has been a leader in PEMFC for heavy-duty vehicle applications. They have built prototype dedicated hydrogen buses that have become commercialized. Direct hydrogen fueling eliminates the need for a reformer and allows the fuel cell engine to operate with supplemental batteries. Their current bus has a range of 250 miles and carries 60 passengers.

Daimler-Benz unveiled the NEBUS in 1997. It is a dedicated hydrogen fueled passenger bus powered by the 205 kW Ballard PEMFC engine and is being demonstrated at various transit agencies in Germany.

The performance of the fuel cell transit buses are similar to their diesel powered counterparts. Because of the additional weight of the batteries and fuel cell power plant, hybrid buses weigh approximately 1000 kg more than conventional buses. In some applications, such as the Georgetown bus with the IFC PAFC power plant, the weight is significantly more. Even with the additional weight, the design acceleration performance can be attained. Because heavier vehicles can experience some braking difficulties regenerative braking equipment can be installed to alleviate this issue.

Infrastructure and Supply

Providing fuels for fuel cell vehicles, depending on the fuel to be used, represents a hurdle that can be challenging, equivalent to that faced by those developing the fuel cell and reformer technologies. Many of the auto manufacturers now developing fuel cell vehicle prototypes are storing hydrogen on the vehicle, either in compressed or liquefied form. On-Board hydrogen storage optimizes the fuel cell operational efficiency and refines vehicle driveability through the normal driving cycle. However, the auto manufacturers are also diligent in their efforts to perfect the fuel processor/reformer as a necessary component for commercialization and consumer acceptance of fuel cell vehicles.

The direct use of hydrogen in the fuel cell vehicle presents several major obstacles that will not be easily surmounted. These obstacles include:

- Energy density - Hydrogen as an element has less energy density than many other potential fuels (one-third the density of natural gas when each is compressed at 3,000 psi).
- Supply - the supply of sufficient quantities of hydrogen to fuel tens of thousands of FCVs in the 2004-2005 time frame is not certain and would require substantial capital investment and lead time to establish central hydrogen production facilities.

Distribution infrastructure -The establishment of adequate distribution pipelines as well as a sufficient number of retail fueling outlets for dedicated hydrogen FCVs is both logistically improbable and prohibitively capital intensive— even if permitting of these facilities was achievable.

An alternative distribution scenario involves the trucking of liquid hydrogen from central production facilities to fuel dispensing facilities, where cryogenic liquid pumps are used to achieve the high pressure needed to load the gaseous hydrogen fuel onto buses or other heavy-duty vehicles. The case for providing hydrogen fuel to non-retail, large transit or commercial fueling facilities is far easier to envision than the large number of retail hydrogen fueling facilities that would be required for passenger-car refueling. Retail hydrogen fueling facilities would require high capital station costs and potential difficulty in permitting hydrogen fueling in the retail environment.

For the challenges expressed above, developers are looking to the more conventional, liquid fuels, or “hydrogen-carriers,” to be the source of hydrogen for fuel cell vehicles. While the infrastructure for liquid fuels is not without challenges, many of the fuels designated as having good potential for fuel cells can use the existing liquid-fuel distribution and infrastructure system now in place for conventional fuels. Liquid fuels with good potential are the following:

- Methanol- Produced from natural gas, methanol is touted as being one of the best, if not the best, “hydrogen carrier” for fuel cell vehicles. Production facilities have recently been built to accommodate the demand for MTBE production. As MTBE is phased out in California, and possibly other states, the supply potential remains substantial for FCV introduction in the 2004-2005 time frame. Methanol can use the existing petroleum distribution infrastructure with minor modification. Fuel dispensing facilities can be easily modified to accept methanol in the retail-fueling environment.
- Gasoline- Gasoline in fuel cell vehicles will be quite different from that commonly used today. There will likely be a new fuel specification, excluding sulfur for example. Even though this fuel will need to be segregated from existing gasoline used in internal combustion engines, the same distribution and infrastructure system can be used. Large capital investment for new, additional production facilities will be required.

Today’s Prices of Fuel Cells

The U.S. DOE has focused its attention on fuel cell and reformer costs. It is important that fuel cell systems are in the same cost range as their conventional counterparts. At the current time, the cost of hydrogen derived from natural gas is approximately $1.00/100scf. Hydrogen costs about fifty percent more than diesel fuel, on a cost per mile basis.

When examining the cost of fuel cells, it is necessary to address the vehicle fuel economy. Compared with conventional vehicles, fuel cell powered vehicles will have a better fuel economy, achieving as much as 80 miles per gallon. These improvements in fuel economy are attributed to the fuel cell power system as well as the vehicle weight reductions. In vehicles equipped with POX systems, fuel consumption could be 30 percent below conventional vehicles. Vehicles equipped with methanol SRs will be more efficient.

Environmental, Health, and Safety Issues

Emissions from fuel cell vehicles have virtually no negative environmental impact. However, the manufacturing process must be evaluated when determining the overall impact of this technology. Although fuel cell vehicles emit only water vapors from the fuel cell stack, minor emissions will result while operating on-board reformers and auxiliary equipment. The fuel cell vehicles operating on hydrogen or methanol are eligible for a full or partial Zero Emission Vehicle (ZEV) credit and, therefore, are considered a very promising alternative for the future. This is especially true as fuel reformers, which provide the hydrogen to the fuel cell stack, are being optimized for emissions as they are being perfected and reduced in size. It is expected that the fuel cell systems will easily achieve the near-Zero, if not outright Zero, emissions level existing now with battery-powered electric vehicles.

Limited information is available on fuel cell vehicle health and safety issues. Safety issues will depend on the specific fuel supply option being used. All transportation fuels require rigorous health and safety regulations for dispensing, distributing and storing. All feedstock fuels have fire codes that provide fuel producers and retailers clear guidelines on the hardware and operation of the facility. However, safety regulations for hydrogen gas may need to be developed or reviewed.

Unique safety issues must be addressed for on-board reformers. The internal temperature of a POX reactor can reach 1000^{o}C and on-board reformer systems generate steam or steam fuel mixtures at pressures as high as four atmospheres. A thorough evaluation of the health and safety issues are still needed. Limited battery use and disposal issues can also apply to fuel cell powered vehicles.

Future Potential for Fuel Cell Vehicles

While fuel cell vehicles will not be commercially available for several years, they can play a pivotal role in displacing conventionally fueled internal combustion engines with more efficient zero emission or near zero emission vehicles. To accomplish this benefit, however, significant cost reductions must be realized. Space restrictions and weight barriers must also be addressed. Over the long term, fuel cell vehicles can have an important and beneficial impact on California. Automakers may well use the fuel cell technology to meet ZEV requirements. Significant efficiency gains can be achieved, depending on the specific technology and fuel used. In addition to air quality and energy efficiency improvements, fuel cell vehicles offer the potential to move away from petroleum-based and other fossil fuels.

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Chapter 10

Other Clean Alternative Fuels

Introduction

This chapter discusses other alternative fuels and how they may hold promise for future use. These fuels include biodiesel, synthetic diesel, dimethyl ether, hydrogen (in both fuel cells and internal combustion engines), and hybrid vehicles.

Biodiesel

Biodiesel is the generic name for a variety of diesel fuel alternatives based on methyl esters of vegetable oil or fats. Biodiesel fits under the category of a renewable fuel because it is made from agricultural feedstocks such as soybean or rapeseed. Research on soy-based diesel is taking place in the U.S., while European countries have been focusing on rapeseed derived biodiesel. Other possible feedstocks for biodiesel include bio-oils from corn, cottonseed, peanut, sunflower, canola, and rendered tallow (animal fat). The NREL is testing aquatic plants, such as microalgae, for possible lipid (oil) production.

The fuel is made by a catalytic chemical process called trans-esterfication, using an alcohol (such as methanol) and a catalyst. Methanol is mixed with sodium hydroxide and then with soybean oil, letting the glycerine that is formed to settle. This process forms fatty esters, which are then separated into two phases, which allows easy removal of glycerol in the first phase. The remaining alcohol/ester mixture called methyl soyate is then separated, and the excess alcohol is recycled. The esters are sent to the clean-up or purification processes which consists of water washing, vacuum drying, and filtration.

The final fuel closely resembles conventional diesel fuel, with higher cetane number (a number that rates its starting ability and antiknock properties). Energy content, viscosity and phase changes are similar to petroleum-based diesel fuel. The fuel is typically blended with 20 percent low-sulfur diesel fuel.

The fuel is essentially sulfur free, emits significantly less smoke, hydrocarbons, and carbon monoxide. Nitrogen oxides (NO_x) emissions are similar to or slightly higher when compared to diesel. Biodiesel has a high flash point and has very low toxicity if digested. It is also biodegradable.

The biggest drawback of biodiesel is cost. The cost of the fuel is determined by the feedstock being used, and the fuel is estimated at $2.50 to $6.00 a gallon due to small-scale production and feed stock costs. The U.S. DOE and Agriculture (USDA) have estimated that large-scale production using today's technology could reduce biodiesel costs to $1.50 to $1.60 a gallon, and biodiesel from microalgae may cost as low as $1.00 a gallon. A recent example is the 1998 contract price to the Massachusetts Bay Transportation Authority. The contract price of a twenty percent blend of biodiesel was quoted to be $1.31 per gallon (not including federal tax).

Other drawbacks are that vehicle fuel lines and other components that would come in contact with the fuel would have to be changed because biodiesel can dissolve some rubber. The fuel also clouds and stops flowing at higher temperatures than diesel, so fuel-heating systems or blends with diesel fuel would be needed in lower temperature climates.

Research activities are underway in the U.S. to use biodiesel, especially for urban transit. Research is being sponsored by the U.S. EPA, the U.S. DA and U.S. DOE, as well as other private organizations, state, and local governments. Research has been conducted for both light-duty and heavy-duty applications (See Table X-1).

Table X-1
Some Early Biodiesel Demonstration Programs in the United States

Location	Research Done By	Vehicle	Purpose
Columbia, MO	Univ of Missouri	3/4-ton truck	Emissions, power
Columbia, MO	Phil Blom	Heavy-duty tractor	General
Jefferson City, MO	Missouri Soy Assn.	3/4-ton truck	General
Kansas City, MO	Interchem	Toyota Camry	General
St. Louis, MO	City of St. Louis	100 vehicles	Emissions, general
St. Louis, MO	Mass Transit	47 transit buses	Emissions
Sioux Falls, SD	Mass Transit	2 transit buses	Emission
State of Ilinois	Dept. of Trans.	2 Light-duty + 6 snowplows	General
City of Gardena, CA	Municipal Bus Lines	2 transit buses	Emissions

Biodiesel has been well demonstrated with transit managers compared to other alternative fuels, according to a story in *Urban Transport News*. A survey showed that biodiesel ranks second behind CNG gas in popularity.

One-fifth of transit managers surveyed by the St. Louis-based Fleishman-Hillard Research, in a survey for the National Biodiesel Board, rank biodiesel as the top choice alternative fuel for transit buses. The survey found that one in six transit managers expects to use biodiesel over the next two years. The National Biodiesel Board (NBB), which promotes and researches soy-based biodiesel, is funded by the United Soybean Board. The survey also noted that awareness of biodiesel has nearly tripled in the last two years.

According to *Urban Transport News*, survey respondents most frequently mention that the primary advantages of biodiesel fuel are smoke reduction and that biodiesel does not require engine alterations.

Before biodiesel can be a major fuel for vehicle use in the United States, the price needs to become much more competitive with diesel.

Biodiesel Blends (B-20)

The latest congressional amendment to EPAct declares that a “B-20” blend of 20 percent biodiesel and 80 percent ordinary petroleum diesel is an “alternative fuel,” even though B-20 is eighty percent petroleum.

The Agricultural Appropriations Bill Title 13, enacted as part of the 1999 Omnibus Appropriations Act, allows federal and state fleet managers to meet EPACT’s alternative fuel vehicle acquisition requirements by using biodiesel at blends of 20 percent and higher. According to the NBB, the use of biodiesel would produce credits to offset up to 50 percent each year of vehicle acquisition requirements. For each 450 gallons of biodiesel used per year, fleets would get one credit for one vehicle purchase.

Synthetic Diesel

From November 1997 and most of 1998, perhaps the most exciting news on new alternative fuels came from a host of companies, from majors to new public entrepreneurs. They are joining what may become the worldwide effort to develop synthetic crude oil and liquid petroleum products from previously unused natural gas reserves economically.

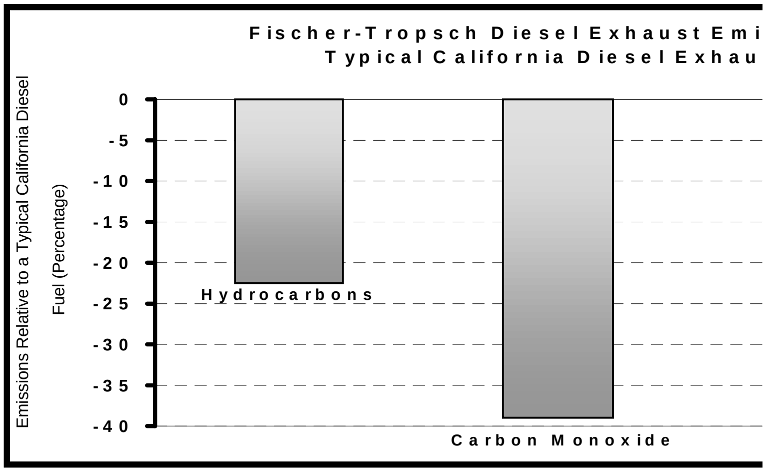
If these efforts are successful, gas reserves located far from end-user markets could be converted into high-grade, extremely clean liquid petroleum products, potentially opening up new energy supply options for the future.

The Gas-To-Liquids (GTL) process requires low-cost natural gas, less than $1 per million Btus, to be competitive with traditional diesel fuel. Typical residential natural gas costs $4 per million Btus. Some remote natural gas sources, called “stranded gas,” that are not otherwise economically available may be ideally suited to this process.

The new and improved process dates back from a process invented in l923 by German scientist Franz Fischer and Hans Tropsch. Today this process is referred to as the “Fischer-Tropsch” process or GTL for converting gases into liquids yielding synthetic fuels.

A growing number of oil refineries are exploring GTL processes to convert remote natural gas resources into synthetic fuels such as diesel, gasoline, and methanol. Synthetic diesel fuel appears to be the most economical fuel product from the GTL process, compared to producing other fuels such as gasoline or methanol. The

Figure X-1
Southwest Research Institute, AIChe, Emissions Performance of Fischer-Tropsch Diesel Fuels, March 1997



preliminary testing of a diesel engine, fueled with 100 percent synthetic diesel fuel, shows significant emissions reduction potential, compared to typical California diesel (See Figure X-1). When blended with conventional diesel fuel, the resulting mix is an improved "premium diesel" fuel regarding emissions and cetane number. Blending diesel fuels too high in aromatics or sulfur with GTL fuel can easily meet California's stringent diesel fuel standards. Because GTL fuels typically have extremely low levels of aromatics and sulfur, GTL process improvements are moving quickly, improving the produced GTL fuel to a competitive level of $15 to $20 dollars per barrel.

While no facilities for producing the fuel exists, or are expected, in California, synthetic diesel was used to a limited extent in 1993-98 as a feedstock in some California refineries. A handful of GTL plants are operating today with several more being considered for construction worldwide. A preliminary estimate is for 60,000 – 120,000-b/d new GTL fuel capacity may be available by 2005. California refiners may show greater interest in obtaining synthetic diesel fuel as an option for clean diesel fuel production without costly refinery modifications. Cost reductions in the GTL technology may also result in many unutilized gas fields being developed in the future. While it is difficult to quantify the volume of worldwide production that may make an inroad to California, the premium qualities of the fuel, strict diesel fuel standards and its initial use in the State suggest that a market may be found here.

Dimethyl Ether

DME, CH_3OCH_3, is an oxygenated hydrocarbon which is the simplest compound in the class of ethers. It is generally produced from natural gas but almost any carbon based feedstock can be used, including crude oil, coal, crop residues, oil sands, wood, or straw. Throughout the world, about 100,000 to 150,000 tons of DME are produced annually.

Currently, the main use for Dimethyl Ether (DME) is as a propellant in aerosol spray cans. However, its environmental characteristics and its high cetane number, greater than 55, make DME a viable alternative to diesel fuel in compression-ignition engines. As a motor fuel, when compared to diesel, DME is a clean fuel due to its low particulate matter (PM) emissions. DME contains no sulfur and when used in a diesel engine, its NO_x emissions, which are similar to ordinary diesel, can be significantly reduced by modified fuel injection systems and using exhaust gas recirculation. Dimethyl ether has approximately one half the energy content of diesel fuel.

Under standard atmospheric pressure, DME is a gas. However, under moderate pressure, it becomes a liquid similar to LPG. DME fuel is stored at approximately 100 psi. Because its vapor pressure is similar to LPG, DME is suitable for automotive applications. Like LPG, DME requires a pressurized vehicle fuel system and a pressurized fuel distribution system. LPG storage tanks are adequate for DME. Compared with diesel fuel, DME has poor lubricity and poor viscosity. Research is being conducted on the use of commercial lubricant additives.

At the present time, large-scale transportation fuel production and infrastructure do not exist for DME. Storage and transportation costs are excessive; therefore, fuel costs remain high. Initial demonstrations are underway by Volvo Trucks and Volvo Buses. A new Volvo engine has been developed that is fueled by DME. Other proponents of DME in automotive applications include

Amoco, AVL Powertrain Engineering, Navistar, and Halder Topsoe. NKK, a Japanese company, has also conducted road tests of a DME-fueled diesel truck and tout DME as a potentially viable alternative to diesel fuel, as well as a replacement fuel for LPG.

Hydrogen

Hydrogen is being researched as both a fuel for internal combustion engines and as an energy carrier for fuel cells. The work continues on the use of hydrogen fuel in the Wankel engine, but the primary focus of current programs is for hydrogen use in fuel cells.

In a fuel cell, a catalyst promotes the separation of hydrogen into free electrons and protons. A proton exchange membrane keeps the electron from passing through. The electrons are conducted as electrical current to power a motor. The electrons are then routed to join with the protons in the presence of oxygen to form water.

Hydrogen is the most abundant element in the universe, comprising about 75 percent of the mass of the universe. When combusted it creates only water vapor as a by-product.

Although hydrogen is abundant as an element in many compounds, it must be in its uncombined form to use. Generating hydrogen typically requires significant amounts of energy or has energy conversion losses that increase its cost. Hydrogen can be produced through several methods.

- Natural Gas Steam Reforming: Natural gas is exposed to high temperature steam to produce hydrogen, carbon monoxide, and carbon dioxide. The carbon monoxide is converted with steam to produce more hydrogen and carbon dioxide. Conversion efficiency is about 70 to 75 percent. Natural gas steam reforming is the most common method of producing hydrogen.

- Electrolysis: Electric energy is used to split water into hydrogen and oxygen gas ($2H_2O$ + electricity ® $2H_2$ + O_2). Electricity produced from renewable sources such as solar, wind, and hydropower can be used. This process conversion efficiency appears to be less than sixty five percent at best.

- Biomass Gasification and Pyrolysis: Pyrolysis, the process of thermal decomposition in the absence of oxygen and its high temperature counterpart, gasification, can be used on fossil fuels or biomass to produce hydrogen.

- Photoelectrolysis: Sunlight is absorbed in a semiconductor and splits water molecules into hydrogen and oxygen.

- Photobiological Process: Plants and certain microbes produce hydrogen gas during photosynthetic activities. This process will require catalysts and engineered systems to reach adequate production efficiencies.

Major issues with the use of hydrogen as a fuel are production, infrastructure costs, and on-board vehicle storage.

The most direct method of supplying hydrogen would be in its gaseous form. However, no established infrastructure exists for gaseous hydrogen fueling. Estimates of gaseous hydrogen infrastructure costs are in the hundreds of billions of dollars, but this cost may be misleading due to the construction of a nationwide hydrogen pipeline system. The construction of this system is comparable to the natural gas pipeline network. Dr. C.E. Thomas of Directed Technologies, Inc., in work conducted for Ford Motor Company and the U.S.DOE, showed hydrogen may be delivered to the fuel cell vehicle at a lower cost by producing and installing steam methane reformers or electroyzers at the fueling station or fleet garage.

Off-board, or stationary, reformers can operate more efficiently than on-board, or vehicle mounted, reformers. Through various filtering techniques, the off-board reformer overcomes the problems of dilution of the hydrogen with carbon dioxide and possibly nitrogen during the reforming process. Off-board reformers would use liquid fuels or natural gas through existing distribution systems as the feedstock for hydrogen production.

One problem with off-board reforming is that hydrogen has such a low energy density that even when compressed, its storage on the vehicle requires at least four times the space of a conventional gas tank. Liquid hydrogen also requires a double-walled tank to keep the fuel at –423^{o}F, and cooling the hydrogen is energy intensive, using one-third of the energy of hydrogen to change form. However, these two options may still provide adequate onboard storage for fuel cell vehicle use.

On-board reformers could supply hydrogen to the fuel cell using a liquid fuel that can be stored on vehicles with conventional tanks and supplied through the existing fuel infrastructure. However, on-board reformers are still in the development phase.

Hybrid Vehicles

Hybrid electric vehicles (HEVs or "hybrids" for short) are vehicles that use two sources of motive energy, electrical and mechanical, to propel the vehicle. As their name implies, the vehicles combine the efficiency of electrical drive systems with the longer driving range gained from liquid or gaseous fuels. An HEV typically has an electrical storage device such as a battery, flywheel, or ultracapacitor in combination with a mechanical device such as an internal combustion engine, gas turbine, or fuel cell.

The two different HEV configurations are series or parallel hybrids. In a series configuration, the internal combustion engine, turbine, or fuel cell is used to generate electricity to charge the batteries, flywheel, or ultracapacitor. The drivetrain is powered solely from the motor connected to the electrical storage device (See Figure X-2). The benefits of a series configuration are reduced engine power cycling because the engine never idles, a transmission may not be needed, and more options are available for mounting the engine and vehicle components.

In a parallel configuration, the drive system can be powered simultaneously by the motor or by the mechanical device. In this configuration, during acceleration, hill climbing, or passing both the electric motor and mechanical device, can provide power to the drivetrain. Once the vehicle reaches cruising speed, the vehicle just relies on the mechanical device to maintain speed. A parallel configuration could be set up to use an engine for highway driving and the power from the electric motor for accelerating (See Figure X-3). Some benefits of the parallel configuration are the vehicle has more power since both the engine and the motor can supply power simultaneously, a generator isn't needed, and it can be more efficient since power is directly coupled to the road, which reduces energy conversion losses.

HEVs have several advantages over traditional internal combustion engine vehicles.

- If an internal combustion engine is used, the engine can be smaller because it shares the workload with the electrical motor. This provides weight reductions that can result in greater fuel economy.

- The engine can be optimized to operate within a specific speed range where fuel economy is greatest and emissions are least.

- The addition of liquid or gaseous fuels provides greater driving range than what could be obtained from just batteries alone. Coupled with higher fuel efficiency, a hybrid with an ICE can drive even farther than today's internal combustion engine vehicles before refueling.

- Regenerative braking can help minimize the energy lost when slowing down the vehicle.

These advantages are offset by the added complexity of the hybrid vehicle and higher additional costs due to the dual fuel systems. A hybrid vehicle also still produces emissions from the non-electric portion of the fuel.

As HEV emissions can be nearly as clean as electric vehicles and can use alternative fuels to drive the mechanical system, HEVs have the ability to help clean the air and reduce the use of fossil fuels.

In 1998, Toyota Motor Company began marketing the first commercial production HEV in Japan. In late 1999, Honda will introduce the INSIGHT, hybrid electric vehicle. This gasoline-electric hybrid will go on sale for less than $20,000. The two-seater has a 1.0-liter, three-cylinder VTEC-E engine that gets a boost from an electric motor on acceleration. The INSIGHT will achieve fuel economy in excess of 70 mpg, while achieving ultra low emission vehicle status. The Honda Insight will be the first hybrid sold in the United States. General Motors, Ford and Chrysler Corporation are working with the U.S. DOE on independent hybrid electric vehicle programs.

Figure X-2
Series Hybrid Vehicle

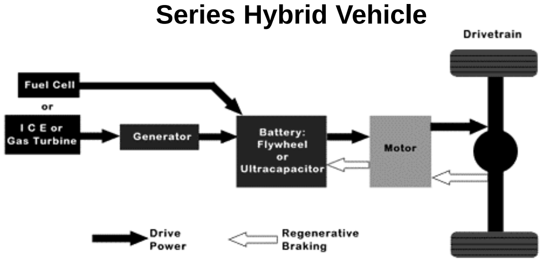
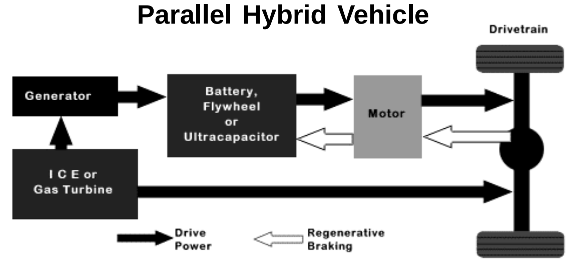


Figure X-3
Parallel Hybrid Vehicle



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Chapter 11

California Safe School Bus Clean Fuel Efficiency Demonstration Program

Introduction

This chapter discusses the four phases of the Katz Safe School Bus Clean Fuel Efficiency Demonstration Program and the school bus safety features that were introduced.

Program Overview

The California Legislature determined that many school buses operating in California were not fuel efficient and did not meet the federal safety standards enacted in 1977. To assist in alleviating this problem, the Katz Safe School Bus Clean Fuel Efficiency Demonstration Program (School Bus Demonstration Program) was established by Part 10.2, Section 17911 et. sequentia of the California Education Code (AB 35). The program provides local educational agencies with new, more efficient, less polluting, and safer buses through the use of alternative fuels and advanced diesel technology.

AB 35 provided $60 million in Petroleum Violation Escrow Account funds (PVEA) to fund the initial program. These PVEA funds, collected and dispersed by the federal government, are fines paid by oil companies that allegedly overcharged consumers in the 1970s. Additional funding was included in Chapter 957, Statutes of 1991 (AB 85) and by the Budget Acts of 1989, 1990, and 1991. Chapter 66, Statutes of 1992 (AB 1049) increased this funding level for this four-phase program to $100 million.

This program allows school districts to upgrade their fleets in a cost-effective manner and replace buses that were built before the 1977 Federal Motor Vehicle Safety Standards (FMVSS). The older buses being replaced will not be allowed to transport school children or workers within California. Most of these buses will either be “parted out” or scrapped.

To help achieve the objectives of the program, at least 35 percent of the replacement school buses have to be powered by low-emission, clean-burning fuels such as methanol, CNG, or electricity.

Program Phases

Phase 1 of this program began in 1990 with the purchase of one hundred sixty-three buses (103 advanced diesel, 50 methanol, and 10 CNG). The total expenditures for this phase were approximately $25 million that included buses and infrastructure support provided to 14 school districts and consortia.

Crown Coach, Inc. of Chino, California, built the l03 advanced technology, high-efficiency diesel and 50 methanol-powered buses. Both bus types were 78-passenger, rear engine transit style buses.

The engines for the advanced diesel and methanol buses were manufactured by Detroit Diesel Corporation (DDC). These engines were 6V-92 (two-stroke engines that utilize the Detroit Diesel Electronic Control system rated at 253hp @ 2100 rpm and 775 foot pounds of torque @ 1200 rpm). The two engines are similar in design, but the methanol application incorporates several unique features. Some of these are a consequence of the higher auto-ignition temperature of methanol as compared to diesel fuel. For example, methanol engines incorporate a glow plug system to heat the cylinders for cold start and to assist in partial-load operation. The compression ratio of the engine has been increased from 17:1 to 23:1 to increase the heat of compression and improve ignition characteristics.

In addition, a bypass blower system regulates the supercharger input and determines the amount of scavenged air supplied to the cylinders over the engine operating range. The bypass blower system allows some of the exhaust gases to be retained in the cylinders to provide additional heat and improve ignition under partial load conditions.

DDC recommended the use of a proprietary fuel additive, lubrizol, manufactured by Lubrizol Corporation for use with methanol fuel. Lubrizol acts as a lubricant and has the added benefit of increasing fuel injector life. This additive is mixed by the school districts at a rate of 0.06 percent by volume.

To allow for equivalent driving range with the lower energy content of methanol fuel, the methanol buses are equipped with a 757 liter (200-gallon) fuel tank, as compared to the 378 liter (100-gallon) fuel tank on the diesel buses. This increases the Gross Vehicle Weight Rating (GVWR) by about 544 kg (1200 pounds). The total GVWR is 16,420 kg (36,200 pounds) for the diesel and 16,964 kg (37,400 pounds) for the methanol.

Other changes made for the methanol buses are the addition of a methanol compatible remote fuel pump and a return fuel cooler to reduce the risk of vapor lock in the fuel system.

Bluebird Body Company of Fort Valley, Georgia built ten 66-passenger conventional buses that were distributed by Golden State Bus Sales of West Sacramento, California.

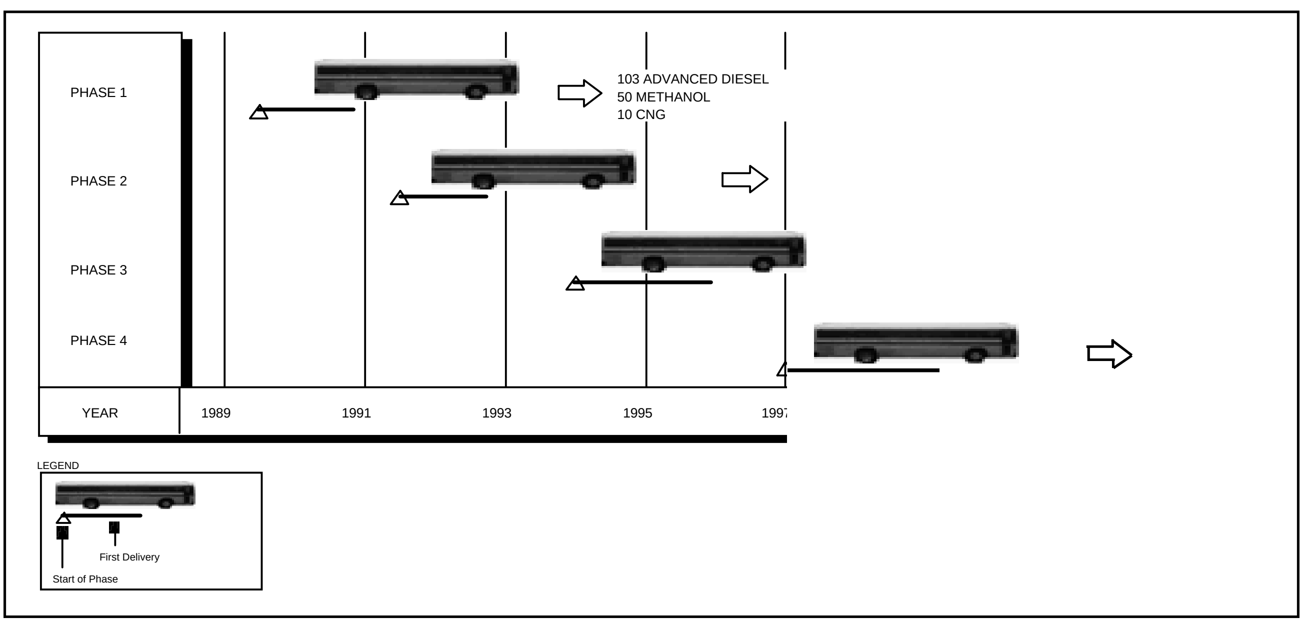
These buses utilize General Motors chassis and are powered by GMC 427 cubic inch V-8 engines converted by Tecogen of Waltham, Massachusetts and use compressed natural gas (CNG).

Tecogen, a division of Thermo Power Corporation, purchased the rights from General Motors to develop and market the CNG version of their seven liter spark ignited engine, the Tecogen 7000L. This engine is dedicated to operate only on CNG and develops 214 Bhp at 4,000 rpm and 318 foot pounds of torque @ 2400 rpm. The compression ratio has been increased from the standard 8:1 to 10.5:1 to accommodate the anti-knock properties of the CNG. The standard exhaust gas recirculation system has been removed, and emissions standards are met by using a 3-way catalyst. The fuel metering system is a positive-flow progressive throttle body.

The fuel storage system is composed of six fiberglass-reinforced steel cylinders that hold a combined total of 35.7 cubic meters (1,260 cubic feet) of CNG at 3,000 psi. These cylinders provide enough fuel for an approxiate 300 mile operating range. There are several safety features which ensure protection of the fuel lines, valves, and vent the passengers compartment from any escaped gas.

The Tecogen natural gas engine and Detroit Diesel's methanol engine were both certified by the U.S. EPA and the ARB as meeting the 1994 heavy-duty vehicle emission standards. The monitoring of this phase continued until 1995.

Figure XI-1
School Bus Phase Introduction



Phase 2 began in 1992 with the purchase of four hundred buses (200 advanced diesel, 100 methanol, and 100 CNG), with the last buses being put into service in 1993. The total expenditures for this phase were approximately $45 million, which included both buses and infrastructure support provided to 47 school districts and consortia. The delivery of these buses began in 1992 and was completed in the fall of 1993. Monitoring this phase began in 1992 and concluded in 1998.

Thomas Built Buses Inc., supplied 200 advanced diesel 78-passenger, rear engine transit style Westcoaster buses with the Caterpillar 3116TA 6.6 liter, 403 cu^3 engine and developing 249 Bhp @ 705 foot pounds of torque @ 1890 rpm. The mechanically controlled engine has a catalytic converter to satisfy the 1994 ARB emission standards.

The 100 Phase 2 methanol fueled buses built by Carpenter Manufacturing Inc. were originally a spin-off design of the Phase 1 Crown Coach 78-passenger buses. After many modifications, the bus became a new product line for Carpenter using the DDC 6V-92TA and developing 253 Bhp. Improvements were made to the air-fuel mixture and the fuel injectors. The Carpenter bus used two 378 liter (100-gallon) tanks for the fuel supply in place of one large tank, as in Phase 1.

For Phase 2, Bluebird supplied 100 CNG transit style, rear engine, 78-passenger All American buses, using a turbocharged Tecodrive 7000T CNG engine rated at developing 245 Bhp @ 3,600 rpm and 423 foot pounds of torque. As @ 2200 rpm in Phase 1, the six CNG fuel tanks are located under the chassis outside the frame rails. The rear-mounted engine, however, required additional cooling for heat dissipation.

Phase 3 began in 1994 by expanding the program based on findings from Phases 1 and 2, with the purchase of two hundred and fourteen buses (107 advanced diesel and 107 CNG). The total expenditures for this phase were $21 million, which provided buses for forty-eight educational agencies.

Bluebird Body Company supplied the 214 transit style, rear engine, 78-passenger All American buses for this phase.

The 107 natural gas-powered buses are powered by John Deere Series 450 6081 HFN engines. John Deere developed this engine to operate on CNG and installed an advanced electronic control system. This bus has four CNG cylinders located between the frame rails for added safety. This 8.1 liter (496 cubic inch) engine is rated at 250 Bhp and 800 foot pounds of torque. This natural gas engine has been undergoing in-service testing in California school districts since February of 1995.

The 107 advanced technology diesel buses, use Caterpillar CAT 3126TA engines. This engine is an improved version with a displacement of 7.2 liters (439 cubic inches) and 250 Bhp @ 1300 rpm and 860 foot pounds of torque @ 1300 rpm.

The computerized electronic control module on the 3126 offers better fuel economy and emissions control than its predecessor in Phase 2. Much of the improved efficiency for the engine comes from the hydraulic electronic unit injection fuel system, which has a nine percent fuel economy increase over the mechanical system on the Phase 2 Caterpillar 3116.

Buses for this third phase were delivered by February 1997.

Phase 4, the final phase of this program, in 1998, committed approximately $5 million to purchase 49 CNG transit type, Blue Bird buses. These buses will be distributed to 18 local educational agencies, several which participated in earlier phases, during the summer and fall of 1999.

These 49 natural gas buses are powered by John Deere Series 450 6081HFN engines. This 8.1 liter engine is rated at 250 horsepower and 800 foot pounds of torque and is identical to the Phase 3 engine. These buses were delivered to the educational agencies between April and November of 1999. With the addition of the Phase 4 buses, the total number of buses operating in the School Bus Demonstration Program is 826.

Safety Features

Fire suppression system - The engine compartments of all program buses are equipped with dry-chemical automatic fire suppression systems activated by temperature sensors. The system turns off the fuel supply to the engine and floods the engine compartment with sufficient material to extinguish a fire.

Emergency exits - The number of emergency exits has been increased from two to six and includes a left side, floor level emergency door located midway between the front and rear, a right side floor level emergency door located in the right rear of the bus behind the rear axle, a rear emergency window, and the main entrance door. Two roof exit hatches provide passive ventilation. All doors are equipped with warning lights, markings and buzzers and are free of passenger seats. To provide for a more rapid evacuation, window size has been increased and the entrance door is equipped with an emergency release.

Traffic warning systems - A stop arm and an eight-light warning system have been added to the Phase 2 buses to help alert other drivers that the bus have come to a complete stop and that children may be crossing the roadway.

Transit design - All but 10 of the Phase 1 buses utilize a transit-style design, which places the driver at the very front of the bus. This provides the driver with greater visibility and awareness of the surrounding road conditions.

Braking systems - The Phase 2, 3, and 4 buses are equipped with an anti-lock braking system to compensate for wheel slip or lockup and provide for better controlled vehicle response during emergency situations.

Automatic parking brake - Each of the Phase 2, 3, and 4 buses are equipped with a parking brake shifter that automatically applies the brake when the bus is shifted into park.

Seats - The seats are constructed of flame retardant material, and the seat backs have been raised and are fully padded with polyurethane foam to prevent head injuries in the event of impact.

Natural gas leak detectors - Methane sensors have been placed in the engine and passenger compartments of some of the CNG buses to provide an early warning system in the event of a natural gas leak.

Methanol and CNG buses were crash tested to address fuel tank safety concerns. The safest placement of fuel tanks has been between the frame rails. However, for many alternative fuel designs, this placement requires a major re-design of an existing bus. The first placement of fuel tanks for CNG buses was outside the frame rails. The CNG bus design for Phases 1 and 2 are retrofitted with crash cages on either side of the frame to protect the CNG tanks. For added safety, Phase 3 and 4 had the CNG fuel cylinders located between the frame rails. Advanced diesel and methanol buses have had the fuel tanks located between the frame rails since the beginning of the School Bus Program.

Program Conclusions

The Katz Safe School Bus Clean Fuel Efficiency Demonstration Program has successfully accomplished its primary objective of replacing pre-1977 school buses with vehicles that meet or exceed the current FMVSS. These vehicles also operate with greater efficiency and produce fewer adverse air emissions.

This program has also set the standards for all future school buses to be provided with a variety of fuel options, a wide range of safety features and fuel efficiency.

For additional information, please refer to the Safe School Bus Clean Fuel Efficiency Demonstration Program Second Interim Status Report or contact:

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(916) 654-4685

internet: http://www.energy.ca.gov/

Chapter 12

Locations of Alternative Fuel Facilities

Methanol Fueling Locations in California
(As of August 15, 2000)

Northern California

Cordelia
〈 Chevron
4490 Central Way

Fresno
〈 Texaco
3808 N. Blackstone Ave.

Modesto
〈 ENVIROSAFE
1217 S. 7th Street

North Highlands
〈 ULTRAMAR
4250 Madison Ave.

San Fransico
〈 OLYMPIAN
2690 Third St.

Woodland
〈 RAMOS OIL
597 N. East St.

Southern California

Diamond Bar
〈 Chevron
150 S. Diamond Bar Blvd.

Norwalk
〈 TEXACO
10710 Alondra Blvd.

Thousand Oaks
〈 GTE CALIFORNIA
112 Lakeview Canyon Rd.

Natural Gas Fueling Locations in California

(As of June 30, 1999, compiled by California Natural Gas Vehicle Coalition)

Northern California

Arvin
City of Arvin (Pvt.)
205 Langford Avenue

Auburn
PG&E #14 (Pub.)
333 Sacramento Street

Belmont
PG&E #21 (Pub.)
1970 Industrial Way

Chico
PG&E #30 (Pub.)
11239 Midway

Clovis
Clovis Unified School District (Pub.)
1450 Herndon Avenue

Concord
PG&E #1
1030 Detroit Avenue

Cupertino
PG&E #35 (Pub.)
10900 N. Blaney Avenue

Davis
PG&E #20
316 L Street

Delano
City of Delano (Pub.)
725 South Lexington Street

Fresno
Fresno City Yard (Pub.)
E and El Dorado Street

CSU, Fresno (Pub.)
On Chestnut, North of Barstow

Visa Petroleum (Pub.)

Grass Valley
PG&E #27 (Pub.)
West McKnight Way

Hanford
Kings Country Yard (Pub.)
11827 South 11th Avenue

Hayward
PG&E #9 (Pub.)
24300 Clawiter Road

Lemoore
NAS Lemoore, (Pvt.)
BLDG 765

Lodi
E.F. Kludt & Sons (Pub.)
1126 East Pine Street

Merced
PG&E: Merced Service Center (Lmt.)
3185 'M' Street

Modesto
W.H. Breshear's (Pub.)
428 7th Street

Monterey
City of Monterey (Pub.)
25 Ryan Ranch Road

Oakland
PG&E #2 (Lmt.)
4801 Oakport Road

City of Oakland (Lmt.)
7101 Edgewater

Reedley
Kings Canyon USD (Pvt.)
675 West Manning

Sacramento
PG&E #4 (Lmt.)
5555 Florin-Perkins Road

Sacramento International Airport (Pub.)
7001 Airport Blvd

Interstate Oil Company (Pub.)
8221 Alpine Avenue

PG&E #5 (Pub.)
2001 Front Street

Olympian Oil (Pub.)
4420 Northgate Blvd

Salinas
PG&E #17 (Pub.)
390 Griffin Street

San Francisco
PG&E #33 (Lmt.)
536 Treat Avenue

San Jose
PG&E #11 (Lmt.)
308 Stockton Avenue
San Jose Unified School District (Pub.)
Highway 87 & Curtner on Northbound On-ramp

San Rafael
PG&E #12 (Lmt.)
1220 Anderson Drive

San Ramon
UPS/Pinnacle (Pub.)
4500 Norris Canyon Road

Sanger
Gibbs Automated Fuel (Pub.)
3555 S. Academy Avenue

Santa Cruz
PG&E #28 (Lmt.)
615 7th Avenue

Santa Rosa
PG&E #19 (Pub.)
3965 Occidental Road

South San Francisco
Olympian Oil (Pub.)
190 East Grand Avenue

Stockton
PG&E #16 ((Pub.)
4040 West Lane

Temecula
City of Temecula (Pub.)
41981 Avenida Alvarado

Vacaville
PG&E #34 (Pub.)
158 Peabody Road

Visalia
SoCal Gas: (Pub.)
320 N. Tipton Avenue

Woodland
BC Stocking Station (Pub.)
341 Industrial Way

Southern California

Alhambra
City of Alhambra (Lmt.)
900 South New Avenue

Anaheim
City of Anaheim (Lmt.)
517 Claudina Street

Disneyland: #1, 2, & 3 (Pvt.)
1313 South Harbor Blvd

MESA: Anaheim Super Shuttle (Pvt.)
1430 South Anaheim

Shell Oil: Anaheim (Pub.)
3125 Orangethorpe Avenue

SoCal Gas #13: Anaheim Headquarters (Pub.)
1919 South State College Blvd

Bakersfield
PG&E #10 (Pub.)
4101 Wible Road

Fleet Card Fuels, Inc. (Pub.)
3305 Gulf Street

Banning
City of Banning (Lmt.)
176 East Lincoln

Carlsbad
San Diego Gas & Electric: North Coast (Pub.)
5016 Carlsbad Avenue

Chatsworth
Los Angeles County Metropolitan Transit Authority (Pvt.)
9201 Canoga Avenue

Chula Vista
Southbay Transit (Pvt.)
3650 Main Street

US Post Office (Pvt.)
750 3rd Avenue

City of Industry
UNOCAL: Industry 1 (Pub.)
948 South Azusa Avenue

Colton
Colton School District (Pvt.)
777 West Valley Blvd & G Streets

Compton
SoCal Gas #1(Pub.)
701 North Bullis Road

Corona
US Post Office (Pub.)
414 West Grand Boulevard

Coronado
Naval Air Station Exchange (Lmt.)
Alameda Blvd & 2nd Street

Covina
City of Covina (Lmt.)
534 Barranca Avenue

Diamond Bar
South Coast Air Quality Management District (Lmt.)
21865 East Copley Drive

Downey
SoCal Gas #11 (Pub.)

Center
9420 East Firestone Blvd

Edwards AFB
Edwards Air Force Base (Pvt.)
Main Entrance Gate

El Cajon
UNOCAL (Pub.)
1090 W. Main Street & Marshall Avenue

El Centro
City of El Centro (Pub.)
Corner of Commercial & Fairfield

El Monte
City of El Monte (Pvt.)
3525 Cleminson Street

Encinitas
Shell Oil (Pub.)
160 Encinitas Blvd

Escondido
San Diego Gas & Electric: Northeast (Pvt.)
1623 Mission Road

Shell Oil (Pub.)
780 W. El Norte Parkway & Nutmeg Street

Fountain Valley
County Sanitation Districts of Orange County (Pub.)
10844 Ellis Avenue

Garden Grove
SoCal Gas #2 (Pub.)
12631 Monarch Street

Gardena
Metropolitan Transit Authority: Div. 18 (Pvt.)
450 West Griffith

Los Angeles Unified School (Pvt.)
18421 Hoover Street

Glendale
SoCal Gas #8 (Pub.)
5610 San Fernando Road

Goleta
Santa Barbara APCD (Lmt.)
4433 Calle Real

Hawthorne
City of Hawthorne (Pvt.)
4422 1/2 126th Street

Huntington Beach
US Post Office, Huntington (Pub.)
6771 Warner Avenue

Indio
Desert Sands Unified School District (Pvt.)
82-879 Highway 111

Sunline Indio (Pvt.)
83255 Highway 111

Industry
Los Angeles County Sanitation (Pvt.)
2800 Workman Mill Road

Irvine
US Post Office, Irvine (Pvt.)
15642 Sand Canyon Avenue

City of Irvine (Pub.)
15029 Sand Canyon Road

Lancaster
Antelope Valley School District (Pub.)
670 West Avenue, L8

LAX
United Airlines
6020 Avion Drive

Lompoc
Lompoc Unified School District (Lmt.)
1301 North A Street

Long Beach
Long Beach Gas Company #3: Port/SERRF Plant (Lmt.)
120 Henry Ford Avenue

Long Beach Gas Company #4: El Dorado Park (Lmt.)
2750 Studebaker Road

Long Beach Gas Company #2: LB Police Dept. (Pub.)
400 West Broadway

Long Beach Gas Company #1: Spring Street (Pub.)
2400 East Spring Street

Los Angeles
SoCal Gas: Olympic (Lmt.)
2424 East Olympic

SoCal Gas #12: Crenshaw Base (Lmt.)
3124 West 36th Street

United Parcel Service (Pvt.)
3000 East Washington

MTA: Mission (Pvt.)
742 North Mission Road

LA County: County Internal Services Division (Pub.)
1100 North Eastern Avenue
LAX (Pub.)
104th Street & Aviation Blvd

Shell Oil: Olympic (Pub.)
1520 South Santa Fe Avenue

Montebello
Chevron (Pub.)
1500 N Paramount

Moreno Valley
Shell Oil: Moreno Valley (Pub.)
12441 Heacock Avenue

Norwalk
Unocal (Pub.)
14960 S. Carmenita St

Oceanside - Camp Pendleton
US Marine Corp Base: #1 (Pvt.)
US Marine Corp Base: #2 (Pvt.)
US Marine Corp Base: #3 (Pvt.)

Ontario
ERX Logistics (Pvt.)
2151 Vintage

City of Ontario (Pub.)
14235 South Bon View Avenue

UPS (LNG & CNG) (Pub.)
1735 South Turner Avenue

Oxnard
South Coast Area Transit (Pvt.)
301 East 3rd Street

MacValley Oil (Pub.)
100 Del Norte Blvd

SoCal Gas: Oxnard #2 (Pub.)
1650 Mountain View Court

SoCal Gas #6: Oxnard (Pub.)
1600 Patton Court

Palm Desert
Waste Management of the Desert (Pub.)
41575 Eclectic Street

Palm Springs
Palm Springs Airport (Pub.)
3400 E. Tahquitz Canyon Way (Airport)

Paramount
Braun Linen (Pvt.)
16514 South Garfield

Pasadena
Calstart (Pvt.)
3360 East Foothill Boulevard

Dydee Diaper Service (Pvt.)
40 East California

Morrow & Holman (Pvt.)
266 Monterey Road

Perris
Eastern Municipal Water (Pvt.)
2270 Trumble Road

March Air Force Base (Pvt.)
15055 Highway 395

Pico Rivera
SoCal Gas #9: Pico Rivera (Pub.)
8101 S. Rosemead Blvd

Point Magu
Navy-Point Magu (Pvt.)
NAWS Pt. Magu: Gas Station Bldg. #631

Pomona
Cal Poly Pomona (Pvt.)
2740 South Campus Drive

Port Hueneme
Navy-Port Hueneme (Pvt.)
621 Pleasant Valley

Poway
POWAY School District (Lmt.)
13626 Twin Packs Road & Midland Drive

Rancho Cucamonga
Rancho Cucamonga: SBWVV (Pub.)
12672 4th Street

Riverdale
South West Public Schools Transportation Agency (Lmt.)
20900 Hazel Avenue

Riverside
Riverside Transit Authority (Pvt.)
1825 3rd Street

UC, Riverside (Pvt.)
3401 Watkins Drive

Merit Oil (Pub.)
1751 E. 3rd St

SoCal Gas #5 (Pub.)
4495 Howard Ave

San Bernardino
Omnitrans (Pvt.)
1700 W. Fifth Street

County of San Bernadino (Pub.)
210 North Lena Road

San Diego
Chula Vista City School (Lmt.)
84 East 'J' Street & Hilltop Drive

Naval Station: 32nd Street (Pvt.)
Cummings & 4th Avenue

San Diego Gas & Electric (Pvt.)
120 Imperial Avenue

North County Transit (Pvt.)
303 Via Del Norte and Via Del Monte

San Diego Gas & Electric: Centre City (Pvt.)
3365 'F' Street & 33rd Street

San Diego Transit: Kearney (Pvt.)
4630 Ruffner & Opportunity

San Diego Gas & Electric: Miramar
Yard (Pub.)
6875 Consolidated Way & Commerce Avenue

San Diego Gas & Electric: Service Center (Pub.)
5488 Overland Avenue & Clairmont Mesa Blvd

Shell Oil: Airport (Pub.)
2521 Pacific Highway

Mobil Oil: Rancho Penasaquitos (Pub.)
12849 Rancho Penasaquitos Blvd

Texaco (Pub.)
2445 Otay Center Drive & Siempre Viva Rd

San Luis Osbispo
J.B.Dewar #1 (Pub.)
75 Prado Road

San Marcos
San Marcos Unified School (Pvt.)
215 Mata Way

San Pedro
SoCal Gas #7 (Pub.)
755 West Capital Drive

Santa Ana
L&N Uniform: #1 (Pvt.)
1602 East Edinger

Santa Barbara
City of Santa Barbara (Lmt.)
630 Garden Street

SoCal Gas #14 (Pub.)
630 Montecito Street

Santa Barbara County Facility (Pub.)
4430 Calle Real

Santa Maria
J.B.Dewar #2 (Pub.)
2310 Meredith Lane

Santa Monica
City of Santa Monica (Lmt.)
2500 Michigan Avenue

GTE (Pvt.)
2943 Exposition Blvd

SoCal Gas #3: Santa Monica (Pub.)
1701 Stewart Street

Simi Valley
Simi Valley Transit (Pvt.)
490 West Los Angeles Street

Sun Valley
Los Angeles County Metropolitan Transit Authority: #1 (Pvt.)
11900 Brandford Street

Los Angeles Unified School District (Pub.)
11247 Sherman Way

Thousand Palms
Sunline Transit (Pub.)
32-505 Harry Oliver Trail

Torrance
City of Torrance (Pub.)
20500 Madrona Avenue

Tulare
City of Tulare (Pub.)
3989 South K Street

Twentynine Palms
US Marine Corp (Pub.)
Entry Gate, Condor Road

Van Nuys
SoCal Gas #4 (Pub.)
16645 Saticoy Street

Vandenberg
Vandenberg Air Force Base (Pvt.)

Vernon
Los Angeles Dept. of Transportation 3 (Pvt.)
2921 Leonis Blvd

Vista
Vista School District (Pvt.)
1234 Arcadia Avenue & Laguna Lane

Unocal: Vista (Pub.)
636 Sycamore Ave

Walnut
Walnut School District (Pvt.)
880 South Lemon Avenue

Westwood
UCLA (Pub.)
741 Circle Drive

Whittier
Whittier School District (Pub.)
13200 Mulberry Drive

Note: Not all sites have full public access. Some are private; some have limited public access by arrangement with the local natural gas utility company. Please contact the local utility company in advance regarding specific locations.

For more information and updated lists, contact the Natural Gas Vehicle Coalition at (916) 448-5036.

Key

(Pub.) = public access
(Lmt.) = limited access
(Pvt.) = private, no access

Glossary

AROMATICS – A group of hydrocarbon fractions forming the basis of most organic chemicals.

AFTER-MARKET - broad term that applies to any change after the original purchase, such as adding equipment not a part of the original purchase. As applied to alternative fuel vehicles, it refers to conversion devices or kits for conventional fuel vehicles.

ALTERNATIVE FUELS - as defined by the EPAct the fuels are methanol, denatured ethanol, and other alcohols, separately or in mixtures of 85 percent by volume or more (or other percentage not less than 70 percent as determined by U.S. DOE rule) with gasoline or other fuels; CNG; LNG; LPG; hydrogen; “coal-derived liquid fuels;” fuels “Other than alcohols” derived from “biological materials;” electricity, or any other fuel determined to be “substantially not petroleum” and yielding “substantial energy security benefits and substantial environmental benefits.”

ALTERNATIVE FUEL VEHICLE (AFV) - motor vehicles that run on fuels other than petroleum-based fuels. As defined by the EPAct, this excludes reformulated gasoline as an alternative fuel.

BI-FUEL VEHICLE - a vehicle with two separate fuel systems designed to run on either fuel, using only one fuel at a time. These systems are advantageous for drivers who do not always have access to an alternative fuel refueling station. Bi-fuel systems are usually used in light-duty vehicles.

BIODIESEL - a biodegradable transportation fuel for use in diesel engines that is produced through the transesterfication of organically-derived oils or fats. It may be used either as a replacement for or as a component of diesel fuel.

BIOMASS – Energy resources derived from organic matter. These include wood, agricultural waste, and other living-cell material that produce heat energy through direct combustion. They also include algae, sewage, and other organic substances that may be used to make energy through chemical processes.

BRITISH THERMAL UNIT (Btu) - a standard unit for measuring heat energy. One Btu represents the amount of heat required to raise one pound of water one degree Fahrenheit (at sea level).

CERTIFICATION - process by which a motor vehicle, motor vehicle engine, or motor vehicle pollution control device satisfies the criteria adopted by the ARB for the control of specified air contaminants from vehicular sources (Health & Safety Code, Section 39018). Certification constitutes a guarantee by the manufacturer that the engine will meet certain standards at 50,000 miles; if not, it must be replaced or repaired without change.

CLEAN FUEL VEHICLE - is frequently incorrectly used interchangeably with “alternative fuel vehicle.” Generally, refers to vehicles that use low-emission, clean-burning fuels. Public Resources Code 25326 defines clean fuels, for purposes of the section only, as fuels designated by ARB for use in LEVs, ULEVs or ZEVs and include, but are not limited to, electricity, ethanol, hydrogen, liquefied petroleum gas, methanol, natural gas, and reformulated gasoline.

CLUNKERS - also known as gross-polluting or super-emitting vehicles, i.e., vehicles that emit far in excess of the emission standards by which the vehicle was certified when it was new.

COMPRESSED NATURAL GAS (CNG) - natural gas that has been compressed under high pressure, typically between 2,000 and 3,600 pounds per square inch, held in a container. The gas expands when released for use as a fuel.

CONVERSION - device or kit by which a conventional fuel vehicle is changed to an alternative fuel vehicle.

CONVERTED VEHICLE - a vehicle originally designed to operate on gasoline that has been modified or altered to run on an alternative fuel.

CORPORATE AVERAGE FUEL ECONOMY (CAFE) - a sales-weighted average fuel mileage calculation, in terms of miles per gallon, based on city and highway fuel economy measurements performed as part of the federal emissions test procedures. CAFE requirements were instituted by the Energy Policy and Conservation Act of 1975 (89 Statute. 902) and modified by the Automobile Fuel Efficiency Act of 1980 (94 Statute. 1821). For major manufacturers, CAFE levels are currently 27.5 miles per gallon for light-duty automobiles. CAFE standards also apply to some light trucks. The Alternative Motor Fuels Act of 1988 allows for an adjusted calculation of the fuel economy of vehicles that can use alternative fuels, including fuel-flexible and dual-fuel vehicles.

DIMETHYL ETHER - an oxygenated hydrocarbon which is the simplest compound in the class of ethers. It is generally produced from natural gas but almost any carbon-based feedstock can be used including crude oil, coal, crop residues, oil sands, wood, or straw.

DUAL-FUEL - refers to a vehicle with two separate fuel systems and operate on two different fuels at the same time. An example of a dual-fuel vehicle is a diesel/CNG truck that burns both fuels at the same time during certain conditions to reduce the overall emissions.

E10 (GASOHOL) - a mixture or 10 percent ethanol, 90 percent unleaded gasoline.

E85 - a mixture or 85 percent ethanol, 15 percent unleaded gasolines.

ENERGY/FUEL DIVERSITY - policy that encourages the development of energy technologies to diversify energy supply sources, thus reducing reliance on conventional (petroleum) fuels; applies to all energy sectors.

ENERGY/FUEL SECURITY - policy that considers the risk of dependence on fuel sources located in remote and unstable regions of the world and the benefits of domestic and diverse fuel sources.

ETHANOL (also know as Ethyl Alcohol or Grain Alcohol, CH_3CH_2OH) - a liquid that is produced chemically from ethylene or biologically from the fermentation of various sugars from carbohydrates found in agricultural crops and cellulosic residues from crops or wood. Used in the U.S. as a gasoline octane enhancer and oxygenate, it increases octane 2.5 to 3.0 numbers at 10 percent concentration. Ethanol can also be used in higher concentration (E85) in vehicles optimized for its use.

ETHYL TERTIARY BUTYL ETHER (ETBE) - an aliphatic ether similar to MTBE. This fuel oxygenate is manufactured by reacting isobutylene with ethanol. Having high octane and low volatility characteristics, ETBE can be added to gasoline up to a level of approximately 17 percent by volume. ETBE is used as an oxygenate in some reformulated gasolines.

EV (ELECTRIC VEHICLE) - a vehicle powered by electricity, usually provided by batteries but may also be provided by photovoltaic (solar) cells or a fuel cell.

FLEXIBLE FUEL VEHICLE (FFV) - a vehicle that can operate on either alcohol fuels (methanol or ethanol) or regular unleaded gasoline or any combination of the two from the same tank.

FUEL CELL - an electrochemical engine with no moving parts that converts the chemical energy of a fuel, such as hydrogen, and an oxidant, such as oxygen, directly into electricity. The principal components of a fuel cell are catalytically activated electrodes for the fuel (anode) and the oxidant (cathode) and an electrolyte to conduct ions between the two electrodes, thus producing electricity.

GASOHOL - in the U.S., gasohol (E10) refers to gasoline that contains 10 percent ethanol by volume. This term was used in the late 1970s and early 1980s but has been replaced in some areas of the country by terms such as E-10, Super Unleaded Plus Ethanol, or Unleaded Plus.

HYBRID VEHICLE - usually hybrid EVs, a vehicle that employs a combustion engine system together with an electric propulsion system. Hybrid technologies expand the usable range of EVs beyond what an all-electric-vehicle can achieve at this time with batteries only.

HYDROGEN – (H_2) A colorless, highly flammable gaseous fuel.

ILEV (Inherently Low Emission Vehicle) - term used by federal government for any vehicle that is certified to meet the ARB's Low Emission Vehicle standards for non-methane organic gases and carbon monoxide and ULEV standards for nitrogen oxides and does not emit any evaporative emissions.

INFRASTRUCTURE - generally refers to the recharging and refueling network necessary to successful development, production, commercialization, and operation of alternative fuel vehicles, including fuel supply, public and private recharging and refueling facilities, standard specifications for refueling outlets, customer service, education and training, and building code regulations.

LEV (LOW EMISSION VEHICLE) - a vehicle certified by the ARB to have emissions from zero to 50,000 miles no higher than 0.075 grams/mile (g/mi) of non-methane organic gases, 3.4 g/mi of carbon monoxide, and 0.2 g/mi of nitrogen oxides. Emissions from 50,000 to 100,000 miles may be slightly higher (See Table in Chapter 2.)

LNG (LIQUEFIED NATURAL GAS) - natural gas that has been condensed to a liquid, typically by cryogenically cooling the gas to minus 327.2 degrees Fahrenheit (below zero).

LPG (LIQUEFIED PETROLEUM GAS) - a mixture of gaseous hydrocarbons, mainly propane and butane that change into liquid form under moderate pressure. LPG or propane is commonly used as a fuel for rural homes for space and water heating, as a fuel for barbecues and recreational vehicle, and as a transportation fuel. It is normally created as a by-product of petroleum refining and from natural gas production.

M85 - a blend of 85 percent methanol and 15 percent unleaded regular gasoline, used as a motor fuel.

M100 - 100 percent (neat) methanol used as a motor fuel in dedicated methanol vehicles such as some heavy-duty truck engines.

METHANE (CH_4) - the simplest of hydrocarbons and the principal constituent of natural gas. Pure methane has a heating value of 1,1012 Btu per standard cubic foot.

METHANOL (also known as Methyl Alcohol, Wood Alcohol, CH_3OH) - a liquid formed by catalytically combining carbon monoxide (CO) with hydrogen (H_2) in a 1:2 ratio, under high temperature and pressure. Commercially, it is typically made by steam reforming natural gas. Also formed in the destructive distillation of wood.

METHYL TERTIARY BUTYL ETHER (MTBE) - an ether manufactured by reacting methanol and isobutylene. The resulting ether has a high octane and low volatility. MTBE is a fuel oxygenate and is permitted in unleaded gasoline up to a level of 15 percent. It is one of the primary ingredients in reformulated gasolines.

NGV (NATURAL GAS VEHICLE) - vehicles that are powered by compressed or liquefied natural gas.

OFF-ROAD - any non-stationary device, powered by an internal combustion engine or motor, used primarily off the highways to propel, move, or draw persons or property, and used in any of the following applications: marine vessels, construction/farm equipment, locomotives, utility and lawn and garden equipment, off-road motorcycles, and off-highway vehicles.

ORIGINAL-EQUIPMENT MANUFACTURER (OEM) - refers to the manufacturer of complete vehicles or heavy-duty engines, as a contrast to remanufacturers, converters, retrofitters, up-fitters, and repowering or rebuilding contractors who are overhauling engines, adapting or converting vehicles or engines obtained from the OEMs, or exchanging or rebuilding engines in existing vehicles.

OXYGENATE -a term used in the petroleum industry to denote octane components containing hydrogen, carbon, and oxygen in their molecular structure. Includes ethers such as MTBE and ETBE and alcohols such as ethanol or methanol. The oxygenate is a prime ingredient in reformulated gasoline. The increased oxygen content given by oxygenates promotes more complete combustion, thereby reducing tailpipe emissions.

PARTICULATE MATTER (PM) - Unburned fuel particles that form smoke or soot and stick to lung tissue when inhaled. A chief component of exhaust emissions from heavy-duty diesel engines.

PROPANE - See LPG (Liquefied Petroleum Gas).

RATE-BASING - refers to practice by utilities of allotting funds invested in utility Research Development Demonstration and Commercialization and other programs from ratepayers, as opposed to allocating these costs to shareholders.

REFORMULATED GASOLINE (RFG) - a cleaner-burning gasoline that has had its compositions and/or characteristics altered to reduce vehicular emissions of pollutants.

REID VAPOR PRESSURE (RVP) - a standard measurement of a liquid's vapor pressure in pounds per square inch at 100 degrees Fahrenheit. It is an indication of the propensity of the liquid to evaporate.

RETROFIT - broad term that applies to any change after the original purchase such as adding equipment not a part of the original purchase. As applied to alternative fuel vehicles, it refers to conversion devices or kits for conventional fuel vehicles. (Same as "aftermarket".)

TAME (TERTIARY AMYL METHYL ETHER) - another oxygenate that can be used in reformulated gasoline. It is an ether based on reactive C5 olefins and methanol.

TLEV (TRANSITIONAL LOW EMISSION VEHICLE) - a vehicle certified by the ARB to have emissions from zero to 50,000 miles no higher than 0.125 grams/mile (g/mi) of non-methane organic gases, 3.4 g/mi of carbon monoxide, and 0.4 g/mi of nitrogen oxides. Emissions from 50,000 to 100,000 miles may be slightly higher (See Table in Chapter 2.)

ULEV (ULTRA-LOW EMISSION VEHICLE) - a vehicle certified by the ARB to have emissions from zero to 50,000 miles no higher than 0.040 grams/mile (g/mi) of non-methane organic gases, 1.7 g/mi of carbon monoxide, and 0.2 g/mi of nitrogen oxides. Emissions from 50,000 to 100,000 miles may be slightly higher (SeeTable in Chapter 2.)

WARRANTY - seller's guarantee to purchaser that product is what it is represented to be and, if it is not, that it will be repaired or replaced. Within the context of vehicles, refers to an engine manufacturers guarantee that the engine will meet "certified" engine standards at 50,000 miles or the engine will be replaced. Retrofits will generally void an engine warranty.

ZEV (ZERO EMISSION VEHICLE) - any vehicle that is certified by the ARB to have zero tailpipe emissions. The only vehicles that currently qualify as ZEVs are electric vehicles (EVs).

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