Alternative Fuels for Vehicles Fleet Demonstration Program

Volume 2: Appendices

Final Report 97-4
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New York State
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ALTERNATIVE FUELS FOR VEHICLES FLEET DEMONSTRATION PROGRAM

Final Report

Volume 2: Appendices

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ABSTRACT

The Alternative Fuels for Vehicles Fleet Demonstration Program (AFV-FDP) was a multiyear effort to collect technical data for use in determining the costs and benefits of alternative-fuel vehicles (AFVs) in typical applications in New York State. This report, Volume 2, includes 13 appendices to Volume 1 that expand upon issues raised therein.

Volume 1 provides:

- Information about the purpose and scope of the AFV-FDP;
- A summary of AFV-FDP findings organized on the basis of vehicle type and fuel type;
- A short review of the status of AFV technology development, including examples of companies in the State that are active in developing AFVs and AFV components; and
- A brief overview of the status of AFV deployment in the State.

Volume 3 provides expanded reporting of AFV-FDP technical details, including the complete texts of the brochure *Garage Guidelines for Alternative Fuels* and the technical report *Fleet Experience Survey Report*, plus an extensive glossary of AFV terminology. The appendices cover a wide range of issues including: emissions regulations in New York State; production and health effects of ozone; vehicle emissions and control systems; emissions from heavy-duty engines; reformulated gasoline; greenhouse gases; production and characteristics of alternative fuels; the Energy Policy Act of 1992; the Clean Fuel Fleet Program; garage design guidelines for alternative fuels; surveys of fleet managers using alternative fuels; taxes on conventional and alternative fuels; and zero-emission vehicle technology.

Keywords: Alternative fuels, ozone, reformulated gasoline, greenhouse gases, EPACT, fuel taxes, zero-emission vehicles

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APPENDIX A
NYS EMISSIONS REGULATIONS

The air-quality problems in New York State are second only to those experienced in southern California. More than 17 million people live in the New York City-Northern New Jersey-Long Island metropolitan region, which is classified as a severe ozone nonattainment area and contains 42% of all the people in the U.S. living in severe ozone nonattainment areas. (By comparison, only 13 million people live in extreme ozone nonattainment areas, the worst possible classification). In addition, this area is also a moderate carbon monoxide nonattainment area [1].

Most of the major metropolitan areas of New York State are not in attainment with the Clean Air Act Amendments (CAAA; see Appendix I for more information), and further actions are necessary to bring these areas into compliance. (If New York State does not reach attainment with the CAAA, EPA can withhold federal funds for highway construction and other federally funded New York State construction activities, and place sanctions on business development activities within the nonattainment areas.) As in other areas in the U.S., transportation vehicles contribute a significant portion of the air-emissions inventory, and any plan for emissions reductions needs to take transportation vehicle emissions into account.

> 17 million New Yorkers are exposed to the second highest levels of ozone and carbon monoxide of any area in the nation.

Emissions standards are the cornerstone of New York State's effort to lower transportation vehicle emissions. New York State has proposed adopting the California vehicle emissions standards, but this has been challenged in court by the auto industry, which has argued that in order for its California vehicles to meet California emissions standards, the vehicles must use gasoline reformulated according to specifications set by California (i.e., CARB2 RFG, gasoline that has lower vapor pressure, sulfur, and aromatics than typical gasoline outside of California.) A New York State-funded study (see Appendix E) indicated that gasoline reformulated to new federal standards demonstrated better cost-effectiveness than California reformulated gasoline for meeting emissions goals. The California vehicle standards are in place for new 1996 vehicles and beyond sold in New York State, and fuel standards in New York State adhere to federal specifications.

Another controversial aspect of the California emissions standards is the requirement for zero-emission (i.e., electric) vehicles. The California regulations originally required that two percent of vehicles sold in 1998 be zero-emission vehicles. In 2001, the requirement rises to five percent, and in 2003 to 10%. California is now adjusting these sales mandates, but New York State is adhering to the original schedule.

New York City has the worst air-quality problems in New York State. In addition to the vehicle emissions regulations for the whole State, an Inspection/Maintenance (I/M) program has been instituted in New York City. The I/M program requires periodic emissions tests of all light-duty vehicles at an idle condition. While such tests identify many polluting vehicles, they are not foolproof. Various options are being weighed to enhance the New York City I/M program. One option being considered would require a check of gasoline filler caps during the State-required safety inspection. Improperly functioning gasoline caps result in greater emissions of gasoline vapor than occur otherwise, especially during warm weather. These emissions react and create ozone, and also contain hydrocarbons known to be toxic. Reducing gasoline-vapor emissions will help reduce ground-level ozone formation during the summer.

REFERENCES

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APPENDIX B

PRODUCTION AND HEALTH EFFECTS OF AMBIENT AIR OZONE

Ambient air ozone (O_3) is defined by the U.S. Environmental Protection Agency (EPA) as a criteria pollutant.[1] While scientific knowledge of the health effects associated with criteria pollutants is continually growing, much that is already known has been applied by EPA to the development of health-based regulatory standards for air emissions. Because the regulatory standards and their scientific underpinnings have been subjected to rigorous peer review in the public, private, and academic sectors, the process of establishing whether there may be a health risk at a particular location is a matter of identifying the standards and determining if the estimated ambient-air concentrations exceed them.

Ozone is formed as the result of atmospheric physical and chemical processes involving two classes of precursor pollutants: volatile organic compounds (VOCs) and nitrogen oxides (NO_x). Transportation vehicles are major contributors to emissions of VOCs and NO_x in urban areas. The formation of ozone from these precursors is complex and nonlinear, involving intensity and spectral distribution of sunlight, atmospheric mixing and related meteorological conditions, precursor concentrations in ambient air, the ratio of VOCs to NO_x, and the reactivity of organic precursors. Specifically, ozone formation begins with tropospheric photolysis of NO_2 to yield NO, which reacts with molecular oxygen (O_2) to form ozone. The presence of reactive VOCs leads to the conversion of NO to NO_2 without the intermediary of ozone, and the photolysis of NO_2 then leads to the formation of elevated levels of ozone.

The health-based National Ambient Air Quality Standards (NAAQS) are established by EPA. The short-term standards (1-hour, 8-hour, and 24-hour) are designed to protect people from short-term, reversible respiratory effects of acute exposure. The long-term (quarterly and annual) standards protect people from health effects associated with chronic exposure. Most of the standards are derived from epidemiological data or scientific studies on humans exposed to very low levels of a particular chemical in a human exposure chamber. In these instances, the threshold for a respiratory effect is the standard.

Extensive investigations of ambient-air ozone in humans and experimental animals have been described in several definitive scientific reviews [1,2,3]. Ozone in the ambient air, in sufficiently high concentrations, irritates the upper respiratory tract, causes measurable degradation of pulmonary function, enhances lung infectivity, and causes alterations in blood biochemistry related to immune response. Most of the reported effects were observed after administration of doses considerably higher than those to which humans are routinely exposed. Under these conditions, morphological effects of ozone in the respiratory tract include

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[1] Criteria pollutants are those determined by EPA to be hazardous to human health. There are six criteria air pollutants regulated by EPA: carbon monoxide, nitrogen oxides, lead, sulfur dioxides, ozone, and particulates.

damage to ciliated cells, proliferation of bronchiolar cells, cellular inflammation, and thickening of pulmonary arteriolar walls. Short-term exposure to ozone affects pulmonary function by increasing breathing frequency, airway resistance, and airway reactivity. Tidal volume, lung compliance, and diffusion capacity are decreased. Long-term exposure to ozone causes increased lung volume and airway resistance, and decreased lung compliance, respiratory flow, and lung function indicators. Biochemically, ozone causes increases in metabolic enzymes in the lungs and blood, permeability changes in the lungs, and increased oxygen consumption. Finally, ozone affects host defense mechanisms by delaying mucociliary clearance, accelerating alveolar clearance, inhibiting bacterial activity, altering lung macrophages causing a decrease in function, altering the number of defense cells, increasing susceptibility to bacterial infection, and altering immune activity.

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1. U.S. Environmental Protection Agency, "Air Quality Criteria for Ozone and Other Photochemical Oxidants, Volumes 4 and 5," Report No. EPA/600/8-84/0206F, 1986. U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, Research Triangle Park, NC.

2. Lippmann, M., "Health Effects of Ozone—A Critical Review," Journal of Air Pollution Control Association, 1989, 39:672-692.

3. National Research Council, "Ozone and Other Photochemical Oxidants," National Academy of Sciences, Washington, DC, 1977.

APPENDIX C

VEHICLE EMISSIONS, CONTROL SYSTEMS, AND CERTIFICATION

Vehicle emissions deteriorate air quality and directly affect the delicate balance of the earth's atmosphere. Emissions are either directly or indirectly responsible for posing several hazards to human health. The primary pollution problems from vehicles include carbon monoxide, air toxics, ground-level ozone, and particulates, all of which are harmful to human health, especially to the respiratory system.

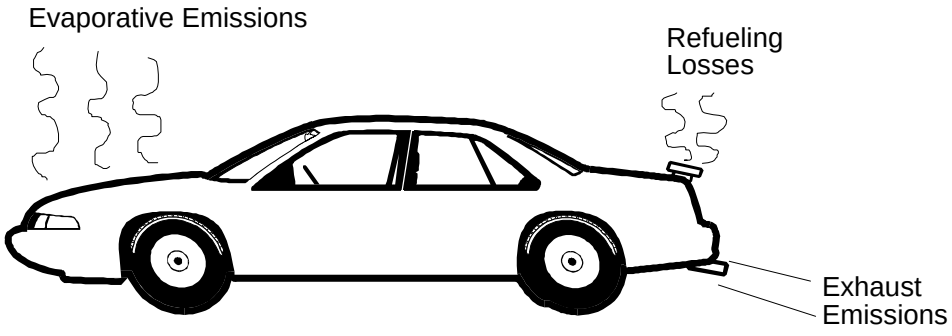
SOURCES OF VEHICLE EMISSIONS

The power to move a vehicle comes from burning fuel in an engine. Emissions from gasoline vehicles originate from combustion by-products (exhaust emissions), from evaporation of the fuel (evaporative emissions), and from fuel losses during refueling (refueling losses). In current automobiles, these three types of emissions are roughly equal in terms of their contribution to air-quality problems. Diesel vehicles, on the other hand, emit the large majority of their pollution in the form of engine exhaust.

The Combustion Process

Gasoline and diesel fuels are mixtures of hydrocarbons, compounds composed of hydrogen and carbon atoms. In an ideal engine, complete combustion of the fuel would occur, in which oxygen from air would combine with hydrogen and carbon from the fuel to form water and carbon dioxide. In reality, the combustion process is not perfect, resulting in emissions of several types of pollutants presented and explained as follows [1].

Aldehydes: These are toxic organic compounds resulting from incomplete combustion of alcohol-containing fuels such as methanol and ethanol and also, to a lesser degree, from combustion of gasoline



and diesel fuels. The predominant aldehyde produced by the combustion of methanol (CH_3OH) is formaldehyde (HCHO); for ethanol (C_2H_5OH), acetaldehyde (CH_3CHO) is the predominant aldehyde produced.

Carbon Monoxide (CO): This is a colorless, odorless gas produced by incomplete combustion of fuels, as may result from a limited oxygen supply in automobile engines. CO is poisonous if inhaled, entering the bloodstream through the lungs and forming carboxyhemoglobin, a compound that inhibits the blood's capacity to carry oxygen to organs and tissues. CO can impair exercise capacity, visual perception, manual dexterity, and learning functions. CO does not contribute to ozone formation, although it is a weak greenhouse gas. CO from vehicle exhaust is generally only a problem in urban areas during cold weather. CO emissions from vehicles are highest during vehicle warm-up in cold weather.

Hydrocarbons (HC): These are emissions of unburned or partially burned fuel. Hydrocarbon emissions are of three types: exhaust, evaporative, and refueling losses. Exhaust hydrocarbon emissions occur from incomplete fuel combustion in the engine. Some hydrocarbons are considered toxic (see below), while others are of concern because they help create ground-level ozone.

Non-Methane Hydrocarbons: Almost all unburned hydrocarbons contain a small fraction of methane, except for natural gas, where the vast majority of unburned hydrocarbons are methane. Because methane is nontoxic and has very low reactivity (i.e., has very little involvement in forming ozone or other pollutants) compared with most other typical hydrocarbons, some emissions regulations are written to include only non-methane hydrocarbons.

Oxides of Nitrogen (NO_x): Under the high-pressure and temperature conditions that occur during combustion in an engine, nitrogen and oxygen atoms in the air react to form various oxides of nitrogen. NO_x and hydrocarbons react in the presence of sunlight to form ozone. NO_x also contributes to the formation of acid rain.

Particulates: Particulates are the result of incomplete combustion of fuels. Diesel engines emit a much higher level of particulates than gasoline engines. Diesel engines also produce relatively large amounts, as compared to other particulate emitters, of the fine particulates that are of special concern to health researchers (see Appendix D).

Toxics: Air toxics are pollutants that cause cancer or are otherwise directly harmful to human health. EPA defines toxics from vehicles as benzene, formaldehyde, acetaldehyde and 1,3-butadiene. Some toxics, such as benzene, are present in gasoline fuel and are emitted as unburnt fuel or fuel vapors. Others, such as formaldehyde, are not present in the fuel but are by-products of incomplete combustion [2].

Volatile Organic Compounds (VOCs): VOCs are carbon-based compounds that participate in atmospheric photochemical reactions. Examples of VOCs in vehicle fuels include all the exhaust, evaporative, and refueling hydrocarbons from gasoline, methanol from M85, and ethanol from E85. VOCs also include partially combusted fuel constituents such as aldehydes and ketones.

Evaporative Emissions

Gasoline vaporizes at warm ambient temperatures, causing increased pressure inside a gasoline vehicle's fuel system. Carbon canisters are incorporated into gasoline-fuel systems to capture gasoline vapor, but the carbon canister cannot handle the large amount of vapor generated in some situations and the fuel system automatically vents excess vapor (e.g., through a valve built into the fuel cap) to prevent an unsafe pressure build-up. The following describes the different categories used by emissions specialists to classify evaporative emissions from gasoline vehicles. (Note: Diesel vehicles do not have significant evaporative emissions because diesel fuel vaporizes much less readily than gasoline.)

Diurnal: Evaporative emissions during a day in which a vehicle is not used, but where the temperature rises during the day, heating the fuel and causing vapor release.

Running Losses: Gasoline vapors released from the fuel system when the car is running. Most vehicles today have fuel-injection systems that recirculate large amounts of fuel from the engine compartment to the fuel tank to prevent heat build-up and associated problems in the underhood fuel system components. This causes the fuel tank to become heated, which generates vapor.

Hot Soak: Evaporative emissions during the period following vehicle operation, where the engine and fuel system are hot and gasoline evaporation continues when the car is parked.

Refueling Loss Emissions

Gasoline vapors are released to the atmosphere whenever a gasoline vehicle is refueled. Gasoline vapors are first released from the vehicle fuel tank (which is typically slightly pressurized) when the tank cap is removed. During refueling, gasoline vapors inside the tank are displaced out through the filler tube. These vapors are recovered if the gasoline dispenser has a Stage II refueling system (they are routed to the service-station gasoline tank); if not, they become additions to refueling loss emissions. Refueling emissions also occur when tanks are overfilled, when gasoline is spilled from the nozzle between the dispenser and the vehicle, and when gasoline evaporates from the wetted portions of the nozzle after refueling.

Reactivity of Vehicular Emissions

Emissions reactivity is the potential of emissions constituents to combine chemically with each other to form new compounds. The relative concentration of these emissions constituents is important in determining the rate and extent of the reaction. Some of the important consequences of reactivity include formation of ozone, smog, and acid rain.

Ozone (O_3): Ground-level ozone is formed by the reaction of VOCs and NO_x in the presence of sunlight and warm temperatures. Ozone in the upper atmosphere occurs naturally and protects life on earth by filtering out harmful ultraviolet radiation from the sun. Ground-level ozone is harmful to the human respiratory system (see Appendix B).

Smog: Smog is a brownish haze in the air that forms in highly polluted metropolitan areas. Its main unhealthy ingredient is ground-level ozone. Sunlight and warm temperatures are conducive to smog formation.

Acid Rain: Acid rain is rainwater, snow, fog, and other forms of precipitation that contain mild solutions of sulfuric and nitric acids. Burning fossil fuels produces pollutants that contribute to acid rain formation. Combustion emissions of note in this regard include sulfur dioxide (SO_2), the primary source of which is coal-fired power plants, and NO_x. Acid rain usually forms high in the clouds where SO_2 and NO_x react with water and oxidants, forming a mild solution of sulfuric and nitric acids. Sunlight increases the rate of these reactions. Acid rain causes damage to lake and forest habitats, as well as significant damage to building exteriors and other property.

VEHICLE EMISSION-CONTROL SYSTEMS

Exhaust Aftertreatment

Exhaust catalysts are incorporated in vehicle emissions-control systems to control HC, CO, and NO_x emissions. The active catalytic elements reside in a device called a catalytic converter that is installed in the engine exhaust system. Two types of exhaust catalysts are used for vehicles: oxidation and three-way (oxidation and reduction combined). Oxidation catalysts increase the rate of reaction between oxygen and unburned hydrocarbons and CO in the exhaust, thereby reducing CO and hydrocarbon emissions. A three-way catalyst is a combination of an oxidation and a reduction catalyst (reduces NO_x to nitrogen and oxygen). The three-way catalyst can simultaneously oxidize hydrocarbons and CO while reducing NO_x. Traditionally, diesel engines have not been equipped with catalysts except in special applications, but diesel-engine manufacturers are now offering catalysts as an option for reducing emissions, especially particulates, in vehicles such as transit and school buses.

Evaporative Emission-Control Systems

Gasoline vehicles use an evaporative emission-control system to reduce hydrocarbons emitted to the atmosphere from the fuel system. The fuel vapor from the fuel tank is fed into a canister containing activated carbon that traps and stores the vapor when the engine is not running. When the engine is running, the canister is purged by air drawn through the canister to the intake manifold on the engine. Diesel engines do not normally require an evaporative emission-control system.

EMISSION CERTIFICATION

EPA has developed several certification programs to control automotive emissions. EPA requires vehicles to have emissions levels meeting certain criteria, depending on the vehicle weight rating. Vehicles with curb weight not exceeding 6,000 pounds, and gross vehicle weight not exceeding 8,500 pounds are classified as light-duty vehicles. Light-duty vehicles are certified for emissions by testing them with the Federal Test Procedure (FTP) for HC, CO, and NO_x emissions. EPA also has set emission certification standards for gasoline and diesel-fueled engines used in heavy-duty vehicles (gross vehicle weight rating above 8,500 pounds) based on tests conducted with the engine mounted on a test stand.

Federal Test Procedure (FTP)

The FTP is the driving cycle used by EPA to certify light-duty vehicles for emissions. The FTP simulates on-road vehicle operation using a chassis dynamometer in a laboratory test cell held between 68° and 86°F. The test vehicle is first driven for 4,000 miles to allow the catalyst and other vehicle systems to be "broken in"; then the vehicle is driven on the dynamometer (the vehicle's drive wheels are placed on rollers that absorb the engine's power) over a driving cycle representative of city driving conditions. The method for measuring tailpipe emissions of HC, CO, and NO_x requires filling a bag with exhaust drawn from the tailpipe and diluted with air. The bagged sample is analyzed for the concentrations of exhaust constituents, which serve as inputs to subsequent emission calculations. Additional procedures apply to the sampling of particulate matter from diesel vehicles and organic materials from alternative-fuel vehicles.

Heavy-Duty Engine Transient Test

This transient engine test is administered after an engine is broken in and consists of a 1,060-second transient speed-versus-time cycle designed to simulate heavy-duty gasoline and diesel-vehicle engine operation in urban areas. For this test, the engine is mounted in a test cell and connected to an engine dynamometer, which absorbs the power from the engine's crankshaft. The test schedule includes 30% idle operation, and the engine is operated at speeds equivalent to a maximum road speed of 55 mph and an average road speed of 18.9 mph. The gaseous emissions measured from the engine dynamometer test are collected and analyzed for HC, CO, and NO_x emissions. In addition, particulates are measured for diesel engines.

Deterioration Factor

Deterioration factors are used to extrapolate (by multiplication) the 4,000-mile exhaust-emissions test results on new vehicles to determine emissions compliance over the statutory useful life of the vehicles [3]. The deterioration factors are used to account for the decrease in emissions-control system efficiency over the statutory useful life of the vehicle. Light-duty vehicles have a statutory useful life of 50,000 or 100,000 miles (depending on the emission standard) and the deterioration factors are determined by means of prototype durability-data vehicles that are driven for the useful life and tested at regular intervals. Some light-duty trucks have a statutory useful life of 120,000 miles. Heavy-duty vehicles have a statutory useful life of 290,000 miles.

For further discussion of vehicle emissions and emissions regulations, see Appendices A, B, D, E, and I.

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3. U.S. Environmental Protection Agency, "Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines—Federal Certification Test Results for 1989 Model Year," 1989.

APPENDIX D

EMISSIONS FROM HEAVY-DUTY DIESEL ENGINES
(The following is excerpted from EPA Environmental Fact Sheet EPA420-F-95-008, June 1995)

BACKGROUND

Heavy-duty engines (HDEs) are used in both highway vehicles, such as large trucks and buses, and nonroad equipment, including farm equipment and construction machinery. HDEs are an important source of oxides of nitrogen (NO_x), hydrocarbons (HC), and particulate matter (PM), contributing 60% of NO_x emissions, 17% of HC emissions, and 90% of PM emissions from mobile sources. Data for 1990 indicate that HDEs account for approximately 20-30% of the total NO_x inventory in the Northeast. This category is similar in proportion to the contribution from utility combustion.

Health and Environmental Concerns

NO_x is a major component of both smog and acid rain. In addition, NO_x and HC (specifically, volatile organic compounds) combine in the atmosphere to form ground-level ozone, the primary constituent of smog. Ozone is a highly reactive pollutant that inflames and damages lung tissue, causing congestion and reducing vital lung capacity. It is responsible for the shortness of breath and coughing sometimes associated with smog. In addition, ozone damages trees and vegetation, causing an estimated annual loss of several billion dollars in agricultural crop yields. Acid rain damages buildings, forests, and crops, and degrades lakes and streams.

PM-10 (i.e., particulate matter 10 microns and smaller), which includes dust and soot, also has significant health and environmental impacts. PM-10 causes headaches, eye and nasal irritation, chest pain, and lung inflammation. PM-10 also may contribute to significant increases in illness and death related to asthma, bronchitis, emphysema, and heart disease. Studies have shown that the fine (i.e., 2.5 microns and smaller) carbon-particulate portion of diesel emissions is a probable human carcinogen. Environmental impacts of PM-10 include reduced visibility and soiling and premature deterioration of buildings.

Air-Quality Trends

States are required to meet National Ambient Air Quality Standards (NAAQS) for both ozone and PM-10. Currently, however, 25 states have moderate to extreme ozone nonattainment areas, affecting about 111 million people. In addition, 25 states have areas of PM-10 nonattainment ranging from moderate to serious, which affects more than 30 million people.

Many states are limited in their ability to address their nonattainment problems due to “interstate transport” of air pollution, in which emissions from one area are carried downwind, resulting in an increase in the level of

pollution in another area. When air pollution crosses state lines, it results in more difficulty for states to achieve their air-quality goals without regional or national action. STAPPA/ALAPCO (State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials) point out that "it is becoming increasingly apparent that for many areas, lowering NO_x emissions outside the urban center will result in reduced peak ozone levels in downwind areas; reductions that occur through such a phenomenon will very likely assist many areas in attaining the ozone standard."

Given these trends, a national program to control NO_x, HC, and PM emissions from HDEs is critical to state and local efforts to attain the health-based air standards. States, cities, public health officials, and environmental and public interest groups have urged EPA to initiate national measures to lower these emissions from both highway and nonroad HDEs.

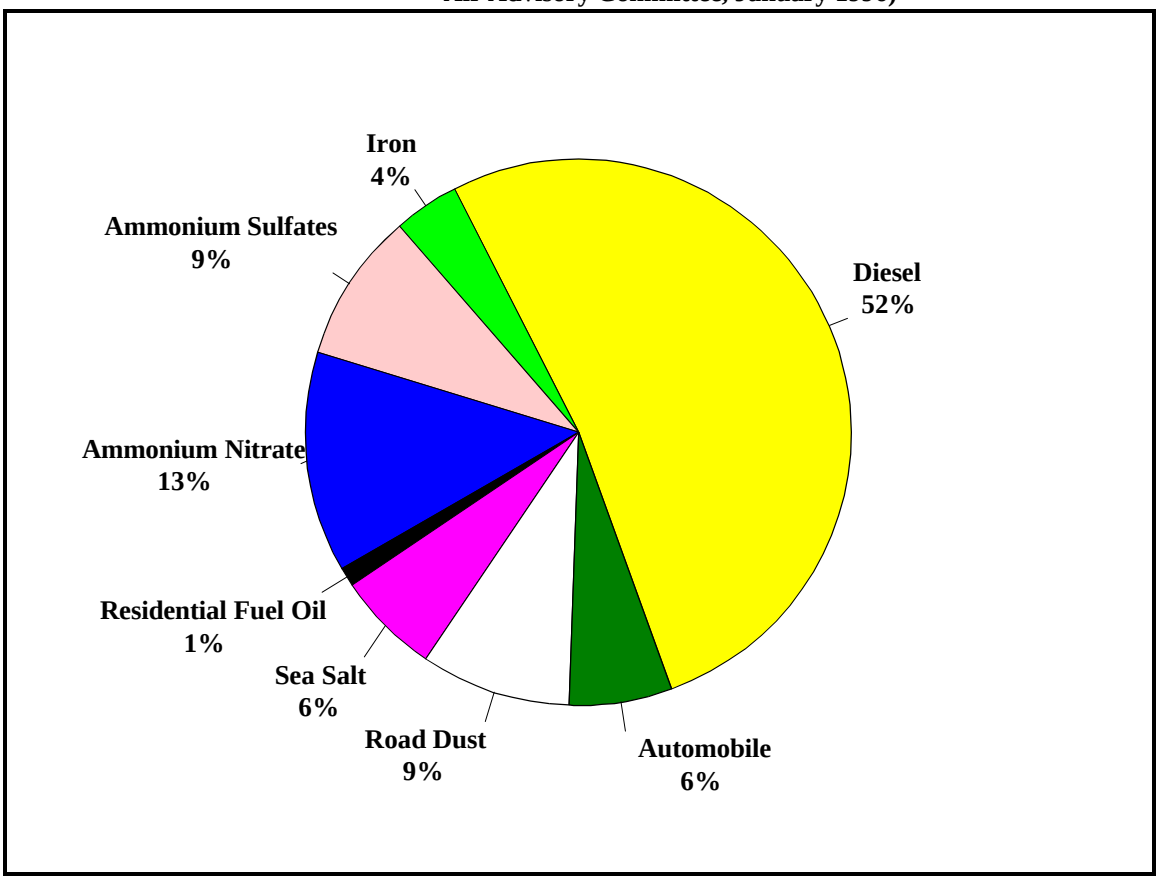
(end of excerpt)

PARTICULATE EMISSIONS IN NEW YORK CITY

Particulate emissions are a primary air-quality concern in New York City. Figure D.1 illustrates that 52% of all PM-10 emissions in Manhattan arise from diesel vehicles, primarily transit buses and heavy trucks. EPA is presently planning to revise the National Ambient Air Quality Standards (NAAQS) for particulate matter (PM); the regulatory emphasis will shift to smaller particles (i.e., PM-2.5, or diameters of 2.5 microns or less), because health studies are increasingly naming the smaller particles as the greater villains. EPA's move is bad news for diesels because they produce PM that is almost entirely within the new, narrowed range. Thus, diesels will presumably represent a proportionately larger part of the PM problem under the new definitions. The shift to a PM-2.5 standard will likely worsen Manhattan's chances for NAAQS attainment and simultaneously shift more of the blame to diesel vehicles.

Increasingly stringent HDE certification standards have been proposed in attempts to reduce the emissions impact of heavy-duty vehicles, especially transit buses and other diesel vehicles used in urban areas. Engine manufacturers report being hard pressed to meet the proposed standards, noting problems with building engines that simultaneously produce low NO_x and low PM-10 emissions. Current diesel technology is capable of meeting EPA's PM-10 engine-certification levels of 0.05 grams per brake-horsepower-hour (g/bhp-hr), measured with the engine on a test stand (i.e., not installed in a vehicle). Typically, this level of emissions performance requires that the engine be equipped with a catalytic converter. Diesel engine

Figure D.1 Sources of PM-10 in Manhattan
(Source: New York State Department of Environmental Conservation Air Advisory Committee, January 1996)



manufacturers are now selling catalyst-equipped engines to transit and other customers. Debate continues on the ability of diesel manufacturers to satisfy future HDE certification standards if NO_x and PM requirements are tightened further.

Transit officials in New York City have been acquiring increasing numbers of CNG buses, in part because CNG engines inherently produce less PM than diesels. Certification data for the latest diesel and CNG engines indicate CNG engines produce 60% less PM (0.02 g/bhp-hr, versus 0.05 g/bhp-hr). To achieve these low numbers, both types of engines require catalytic converters. These devices are expected to function more reliably on CNG engines because natural gas, as compared to diesel fuel, does not contain nearly as much of the substances (e.g., sulfur) known to disable catalysts. Thus the PM advantage of CNG may grow significantly as engines age.

APPENDIX E

REFORMULATED GASOLINE STUDY

Executive Summary

As directed by the New York State Clean Air Compliance Act, NYSERDA retained a contractor to study the use of reformulated gasoline (RFG) in New York State [1]. The study was to consider the impact of RFG on "the availability and distribution of motor fuels in the state, the costs to customers and to the economy of the state, and the air quality benefits…" Further, the study was to include an analysis of California RFG specifications and "any other specifications for gasoline which the Commissioner of Environmental Conservation recommends for inclusion in the study."

Following review of proposals submitted in response to a solicitation, NYSERDA selected a team of contractors led by Turner, Mason & Company (TM&C) of Dallas, Texas. DRI/McGraw-Hill of Washington, DC and Sierra Research of Sacramento, California were subcontractors to TM&C and performed economic impact and air quality analyses, respectively. TM&C was responsible for analyzing fuel production and distribution and for combining the results of the various analyses into a final report.

In addition to Federal RFG (EPA I and EPA II), California Air Resources Board RFG (CARB 2) and a modified Federal low sulfur RFG (LS-EPA II) were investigated. The effects of these alternative RFGs on petroleum refinery gasoline production costs, gasoline distribution costs, New York State air quality, and the New York State economy were considered.

New York State has already adopted the California low emission vehicle (LEV) and other emission control programs that will affect vehicles and maintenance. From 1998 to 2012 without the introduction of any type of RFG, these programs are estimated to reduce State mobile source summer emissions by 341 tons per day (or 40%) of non-methane hydrocarbons (NMHC) and by 292 tons per day (or 28%) of nitrogen oxides (NO_x), and to reduce winter emissions of carbon monoxide (CO) by 3,072 tons per day (or 39%). By 2012, the planned imposition of Federal RFG will produce further reductions (percent of 1998 levels) of 10%, 4%, and 11%, respectively, for NMHC, NO_x, and CO. If New York State goes beyond EPA II and adopts CARB 2 specifications, further reductions achieved in 2012 are estimated to be very small, equaling 2% or less of 1998 levels of NMHC and NO_x emissions, while CO emissions would actually <u>increase</u> by about 2%. When compared to EPA II over the same time frame, LS-EPA II would produce negligible (less than 1%) reductions in each of the above emissions categories.

The cost of CARB 2 gasoline would be high relative to EPA II. New York motorists could expect to pay about 30¢ per gallon (in 1992 dollars) more at the pump for CARB 2 gasoline than for conventional gasoline (about

18¢ per gallon more than for EPA II). NMHC and NO_x emissions reductions achieved with EPA II cost less than the EPA standards of $5,000 per incremental ton. CARB 2 emissions reductions are much more expensive at over $100,000 per incremental ton.

Adopting CARB 2 RFG would have a deleterious effect on the New York economy. Approximately 23,300 jobs would be lost in the year 2000 compared to continued use of conventional gasoline (14,300 more than for EPA II). Higher pump prices and poorer fuel economy for CARB 2 RFG would cause New York drivers to travel three billion (or 2.2%) fewer miles in 2004 than they would if they could continue to use conventional gasoline (1.8 billion, or 1.3% fewer miles than with EPA II).

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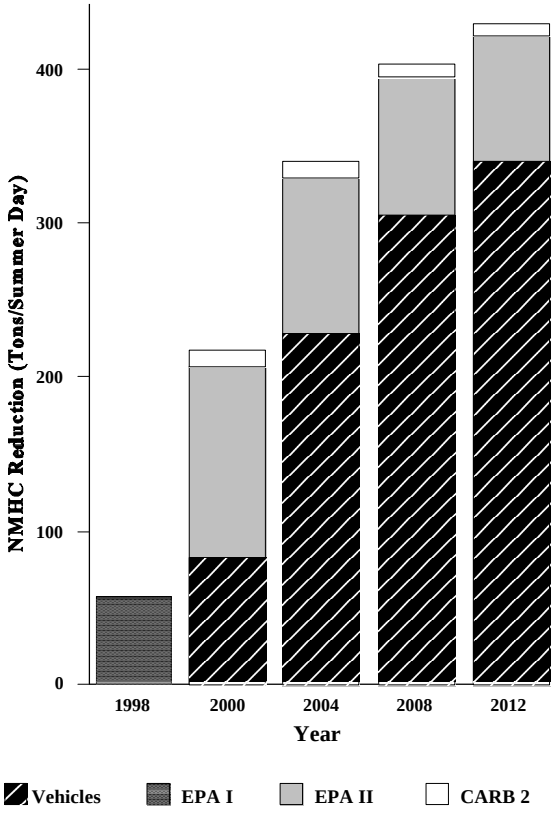
Summer Gasoline Specifications and Properties

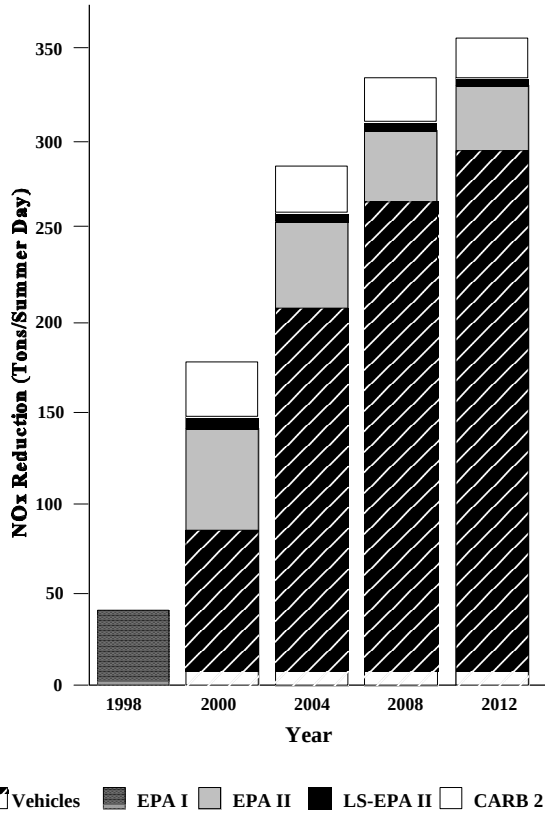
		RFG			
	Baseline CG	EPA I	EPA II	LS-EPA III	CARB 2
Octane, (R+M)/2	89.3#	89.3#	89.3#	89.3#	89.3#
Aromatics, Vol. %	31.9	26.2	27.6	27.0	22.0*
Oxygen, Wt. %	0.4	2.1#	2.1#	2.1#	2.0#
Olefins, Vol. %	15.8	12.5	11.6	13.1	4.0*
Benzene, Vol. %	1.69	0.95*	0.95*	0.95*	0.80*
Sulfur, wppm	449	240	124	75*	30*
RVP, psi	8.2*	8.0	6.7	6.8	6.6*
Distillation, °F					
50%	210	197	203	204	199*
90%	351	341	344	342	290*
% Reduction [(1)]					
VOC	7.0	15.7#	27.6#	27.6#	29.5
NO_x	(6.8)	1.7#	6.8#	8.2	14.9
TAP	(4.9)	24.3	26.6	27.7	34.5

* At maximum specification.
\# At minimum specification.
(1) From statutory, based on EPA Phase II complex model for comparability.

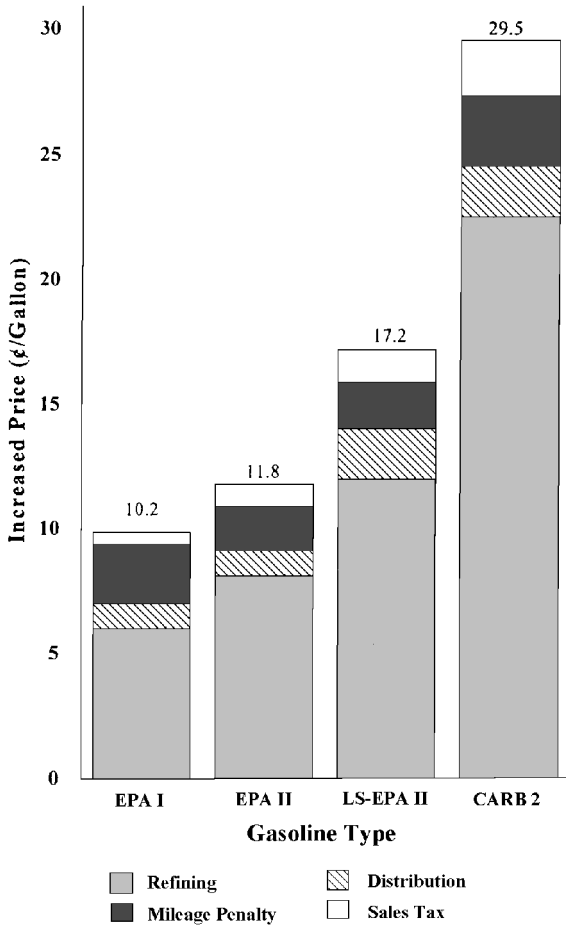
New York State Mobile Source NMHC Reduction
(compared to 1998 vehicles operating on CG)



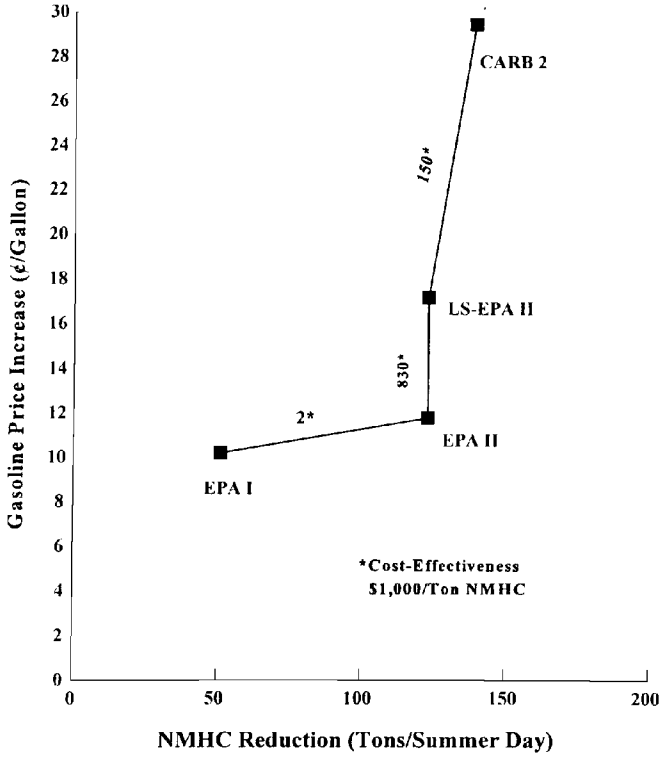
New York State Mobile Source NO_x Reduction
(compared to 1998 vehicles operating on CG)



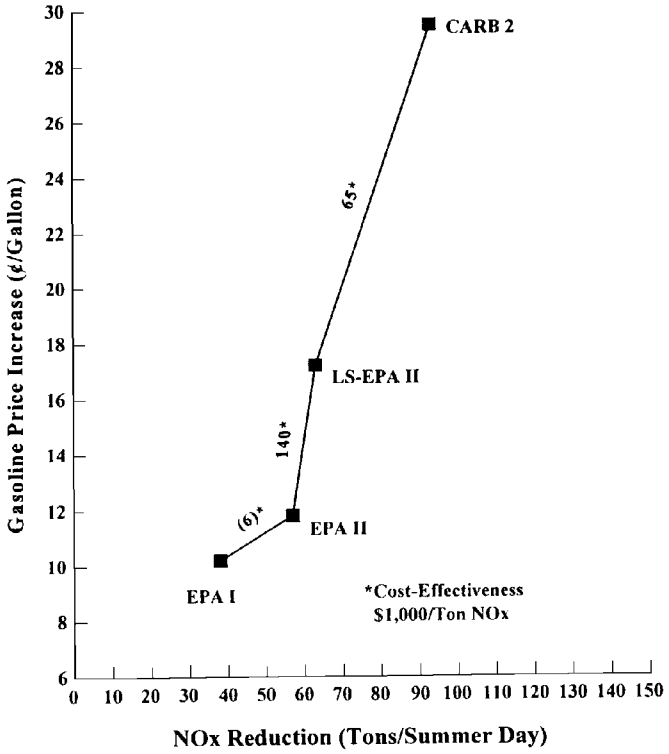
Summer Gasoline Price Increase over CG



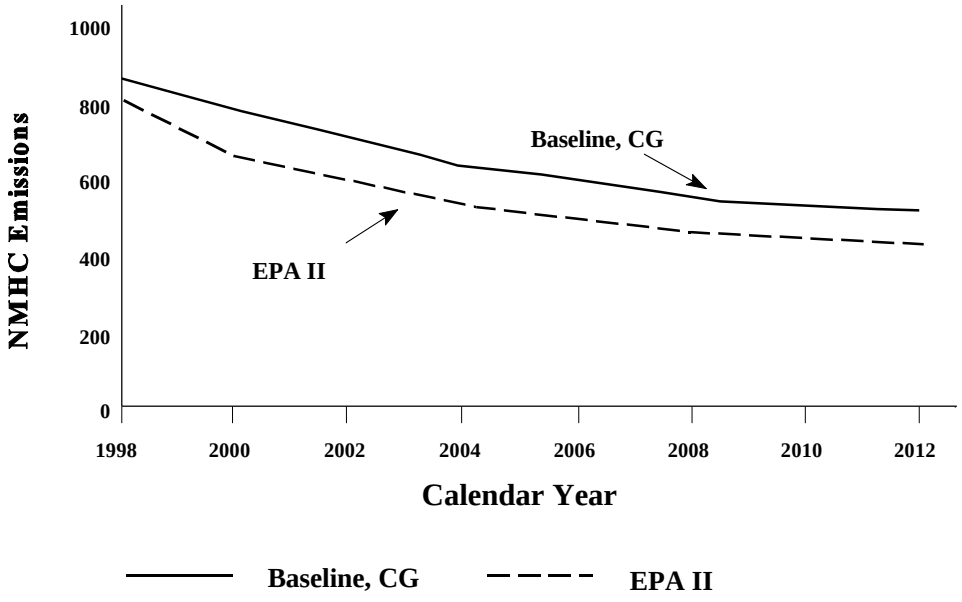
Cost-Effectiveness of NMHC Reduction
(2000 summer)



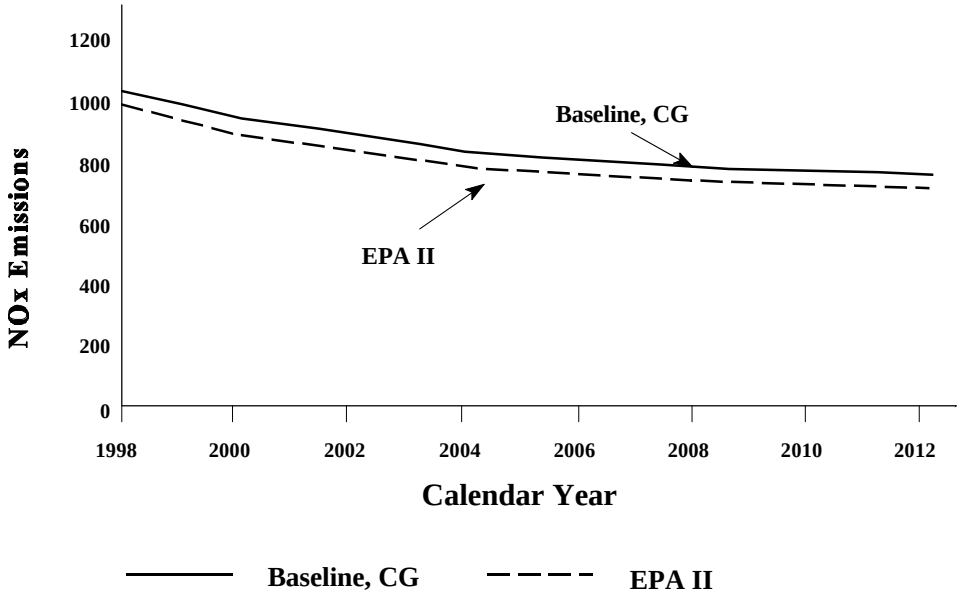
NO_x Reduction Cost-Effectiveness
(2000 summer)



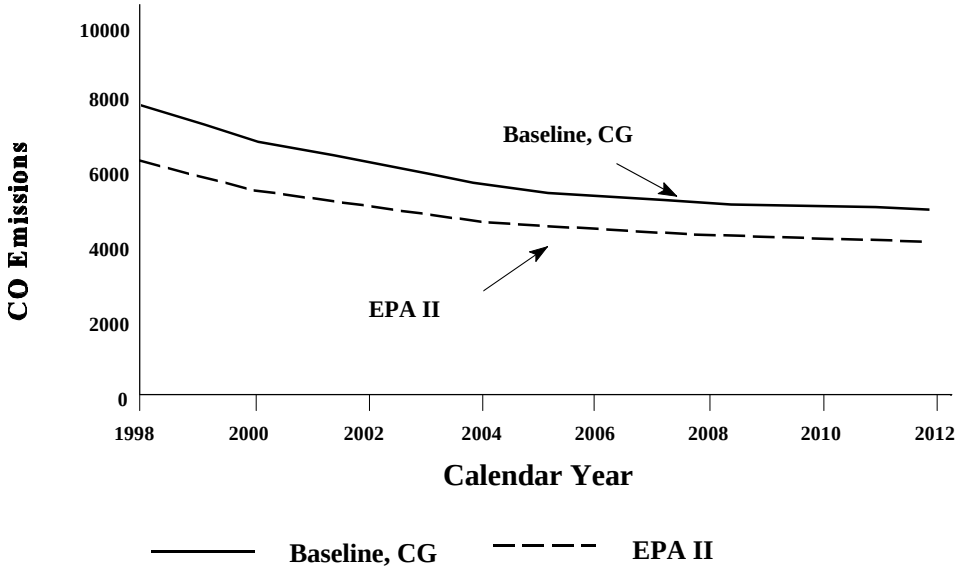
New York State Mobile Source NMHC Inventory
(tons/summer day)



New York State Mobile Source NO_x Inventory
(tons/summer day)



New York State Mobile Source CO Inventory
(tons/winter day)



Reductions in Criteria Pollutants Versus Baseline
(NMHC, NO_x - tons/summer day; CO - tons/winter day)

	Calendar Year				
	1998†	2000	2004	2008	2012
RFG					
EPA II					
NMHC	56	123	101	89	82
NO_x	41	57	47	40	37
CO	1,575	1,350	1,029	881	823
LS-EPA II					
NMHC	56	123	102	89	82
NO_x	41	63	52	45	40
CO	1,575	1,367	1,044	892	830
CARB 2 *					
NMHC	56	131	108	94	87
NO_x	41	72	60	50	45
CO	1,575	1,244	962	825	768
CARB 2					
NMHC	56	135	112	98	90
NO_x	41	93	80	68	62
CO	1,575	1,107	858	728	674

† All EPA I in 1998.
* In NYC-SMSA, EPA I and EPA II elsewhere.

APPENDIX F

GREENHOUSE GASES, GLOBAL WARMING, AND ALTERNATIVE FUELS

GREENHOUSE GASES AND GLOBAL WARMING

Greenhouse gases in the atmosphere are an important influence on the earth's climate. These gases allow solar radiation to penetrate the atmosphere more readily than they allow infrared radiation from the earth to escape into outer space, thus trapping energy in the atmosphere and causing a rise in temperature. Without any greenhouse gases, it is believed the average temperature on earth would be about -18°C (0°F) [1]. Growth in the concentration of greenhouse gases is believed to create a net increase in the earth's temperature, called "global warming." Given the current and projected growth in greenhouse gases, global warming may increase the global average temperature by 2°C (3.6°F) by the year 2030. Accompanying this level of global temperature change would be widespread change in weather patterns and corresponding changes in vegetation and agricultural productivity. Global warming also may cause net melting of polar ice caps, with the result that sea levels may rise 6 to 20 inches over current levels by 2050, accelerating coastal erosion, threatening wetlands, and exacerbating coastal flooding [2].

Sources of Greenhouse Gases

The major greenhouse gases are water vapor, carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs), hydrogenated chlorofluorocarbons (HCFCs), ozone (O_3), and nitrous oxide (N_2O). Table F.1 lists the various sources of greenhouse gases generated by human activity [3].

The net annual emissions of CO_2 from the biosphere,[1] such as volcanic emissions, are small compared to human-induced CO_2 emissions [4]. Human activities are estimated to have caused the atmospheric concentration of CO_2 to increase 25% during the last century and to be responsible for the currently estimated rate of increase of 0.5% a year. In the same period, human activity is estimated to have caused a doubling in the levels of atmospheric CH_4, which is currently increasing at a rate of 0.9% a year. CFCs and HCFCs are not naturally occurring greenhouse gases; their presence in the atmosphere is the result of human activity.

The estimated worldwide annual greenhouse-gas emissions from human activities are listed in Table F.2 [4]. Although CO_2 accounts for most of the greenhouse gases, its potency per ton is lower than that of other greenhouse gases. For example, CFCs are approximately 5,400 times more potent than CO_2 and despite their emissions being very minor compared to CO_2, their effect on the earth's climate is significant. While CO_2 emissions are 36,000 times greater than CFC emissions, their global warming impact is only seven times as

[1] The part of the earth where life exists.

great. Similarly, methane emissions are much smaller than CO_2 emissions, but their global-warming impact is significant.

Table F.1 Sources of Greenhouse Gases from Human Activities

Sectors	Activities	Greenhouse Gases
Energy	Fossil fuel combustion and industrial activities	CO_2, CH_4, N_2O, O_3
Forestry	Deforestation and harvesting	CO_2, CH_4, N_2O
Agriculture	Food production, animal husbandry, and fertilizer use	CO_2, CH_4, N_2O
Waste Management	Sanitary landfills, incineration, and decay	CO_2, CH_4, N_2O, O_3
Refrigeration and Air Conditioning	Leaks and losses due to maintenance activities	CFC
All	Miscellaneous	CO_2, N_2O

Table F.2 Greenhouse Gases from Human Activities (Worldwide)

Greenhouse Emission	Emissions (10^6 metric tons/year)	Relative Potency	Combined Relative Impact
Carbon Dioxide	21,800	1	1
CFCs	0.6	5,400	0.15
Methane	320	21	0.31
Nitrous Oxide	4	290	0.05

Global Warming

Although some amount of greenhouse gases are naturally occurring (e.g., from the natural carbon cycle) and are necessary to maintain the earth's normal temperature, human activity has contributed to increased atmospheric concentration of greenhouse gases. The burning of fossil fuels (i.e., coal, natural gas, and petroleum) for electricity generation and in transportation vehicles (petroleum) is a major contributor to greenhouse gases. The percentage contributions to the net global-warming phenomenon caused by various human activities, on a worldwide basis, are [2]:

1. Energy consumption, mostly from burning fossil fuels, approximately 50%
2. Production and use of chlorofluorocarbons, approximately 20%
3. Deforestation and agricultural activities, approximately 13-14%
4. Waste-management and other human activities, remaining 16-17%.

TRANSPORTATION EFFECTS ON GLOBAL WARMING

Transportation plays a major role in the emission of greenhouse gases. The transportation sector accounts for 31% of the fossil fuel and 69% of the petroleum consumed in the U.S. [5]. The effects of transportation vehicle emissions on greenhouse gases and global warming are as follows [2]:

Carbon Dioxide: Worldwide, carbon dioxide from human activities is estimated to be responsible for about half the annual increase in global warming. For every gallon of petroleum fuel consumed by a motor vehicle, nearly 20 pounds of carbon dioxide go directly into the atmosphere. In the U.S., motor vehicles are responsible for 25% of carbon dioxide emissions.

Chlorofluorocarbons: CFCs, estimated to be the second-largest contributors to global warming, account for 20% of the total. In addition to being potent greenhouse gases, CFCs also reduce the stratospheric ozone layer that protects the earth from harmful ultraviolet radiation. Motor vehicle air-conditioning systems contribute approximately 30% of the CFCs entering the atmosphere. Production of CFCs has been banned in the U.S. since 1992. Replacements for CFCs have been developed that have much smaller global-warming effects.

Methane: Methane from human activities is judged to be the third-largest contributor to global warming, accounting for 13-18%. Methane is a by-product of many natural biological processes, including the decomposition of organic waste from humans, animals, and flora, and is also the primary constituent of natural gas. The methane emissions attributable to transportation are relatively small and include methane released during petroleum and natural-gas exploration, processing, distribution, and combustion of fossil fuels in vehicles.

Ozone: Ozone in the lower atmosphere (the troposphere) is created in sunlight-driven reactions involving nitrogen oxides (NO_x) and volatile organic compounds. In the U.S., vehicles are the source of about 47% of NO_x emissions and about 44% of VOCs. Tropospheric ozone worldwide contributes an estimated 8% to global warming. Besides contributing to greenhouse-gas problems, tropospheric ozone pollution also directly degrades the health of humans and other living things.

Table F.3 lists the major transportation-related greenhouse gases, their estimated overall contribution to the global-warming effect, and the net transportation factor in global warming for each of the four greenhouse

Table F.3 Estimated Global-Warming Impact of Transportation

Type of Greenhouse Gas	Global-Warming Impact of Human Activity, Contribution by Major Types of Greenhouse Gases	
	All Human Activity	Transportation
Carbon Dioxide	50%	12.5%
CFCs	20%	6%
Methane	13-18%	< 1%
Ozone	8%	3%

gases. This factor is calculated by taking the product of the total worldwide contribution of global warming for a particular greenhouse gas and the percent contribution to that greenhouse gas from transportation.

IMPACT OF ALTERNATIVE FUELS

Alternative fuels can reduce transportation-generated greenhouse gases in three ways:

1. Inherently lower CO_2 production
2. Potentially less CO_2 because of greater efficiency
3. Reduced emissions of ozone precursors.

Since CO_2 emissions are the largest contributors to global warming, strategies for reductions in CO_2 emissions can potentially play the largest role in slowing the rate of global warming. A comparison of the CO_2 emissions, in grams (g), from the combustion of 100,000 British thermal units (100 kBtu) of gasoline and various alternative fuels is shown in Table F.4. Complete combustion of the fuel is assumed.

Table F.4 shows that alternative fuels generally result in lower CO_2 emissions compared to gasoline. Among carbon-based fuels, natural gas offers the most significant reduction in CO_2 emissions. The combustion of hydrogen fuel involves its reaction with oxygen to form water vapor, and therefore does not result in any CO_2 emissions. The numbers in Table F.4 do not represent a complete analysis of the relative CO_2 emissions that would result from using these fuels in a vehicle. Factors such as powertrain efficiency, energy losses in fuel production, and others need to be included to compare the on-road CO_2 emissions performance of each fuel. For example, methanol engines can be made more efficient than gasoline engines, and thus reduce methanol's

relative CO_2 emissions. If methanol is used in fuel-cell-powered vehicles, significant improvements in the drivetrain efficiency can be achieved, further reducing the relative CO_2 emissions from methanol. CO_2 emissions in the electricity-generation process from coal

Table F.4 CO_2 Emissions Comparison

Fuel	CO_2 Emissions g/100 kBtu	Relative CO_2 Emissions
Gasoline	4,967	1.000
Methanol	4,652	0.937
Ethanol	4,824	0.971
Natural gas	3,886	0.782
Propane	4,387	0.883
Electricity from coal	6,708	1.35
Hydrogen	0	0

are highest in the comparison shown in Table F.4. However, the powertrain efficiency of an electric vehicle can be twice that of gasoline engines, thus reducing the relative CO_2 emissions for an electric vehicle.

As is the case with methanol, it is possible to reduce greenhouse gases by designing engines dedicated to and optimized for the use of other alternative fuels. Like methanol, ethanol and methane (the major component of natural gas) have higher octane ratings than gasoline. Therefore, it is possible to design dedicated alternative-fuel engines with higher compression ratios, which would result in more energy-efficient engine operation, in turn leading to lower fuel consumption and CO_2 production [6][7].

Electric vehicles (EVs) have the potential to reduce greenhouse-gas emissions in geographical areas where the contribution of fossil fuels for generating electric power is relatively low. Depending on the efficiency and fuel source of the EV, its impact can range from moderate reduction to nearly complete elimination of greenhouse gases compared to gasoline vehicles. Hydrogen (H_2), too, is a potential candidate alternative fuel for achieving significant reductions in greenhouse-gas emissions. (The only emissions from a H_2-powered internal combustion engine are nitrogen oxides, which can be controlled to low levels, and water vapor.) H_2 also can be used in fuel-cell vehicles that do not have NO_x emissions. If H_2 is produced from renewable sources, and then used in fuel-cell-powered vehicles, its use can reduce greenhouse-gas emissions to essentially zero.

RESOURCE-THROUGH-END-USE ESTIMATES

The overall greenhouse-gas impact of using alternative fuels, including emissions resulting from fuel extraction, processing, and distribution, for compressed natural gas, methanol from natural gas, ethanol fermented from corn, and propane is illustrated in Table F.5 [1][8]. The overall greenhouse-gas impact using compressed natural gas is less than that of gasoline because combustion of natural gas causes less CO_2 emissions and natural gas needs very little processing energy except for pipeline transport and compression energy. Methanol from natural gas has a similar greenhouse-gas impact as gasoline. Ethanol made from the fermentation of corn has a similar greenhouse-gas impact as gasoline, even though CO_2 produced from combustion of ethanol is recycled by the crops used to make the ethanol. This is because ethanol production makes much more greenhouse-gases than gasoline production. Propane is estimated to have potentially the lowest greenhouse-gas impact because it produces less CO_2 when combusted, and has lower processing needs than even compressed natural gas. It should be noted that these estimates assume current alternative-fuel production and vehicle technology. For example, ethanol from biomass should have a lower overall greenhouse-gas impact than ethanol made via fermentation. Also, the more efficient vehicles possible with alternative fuels would decrease their overall greenhouse-gas impact in proportion to their increase in relative efficiency compared to gasoline vehicles.

Table F.5 Resource-Through-End-Use Greenhouse Gas Emissions Impact Comparison

Fuel	Relative Impact
Gasoline	100
Compressed Natural Gas	85
Methanol from natural gas	95 to 105
Ethanol fermented from corn	80 to 100
Propane	80 to 90

SUMMARY

Greenhouse gases in the earth's atmosphere act as heat traps, and their increasing concentrations due to human activities could result in a net global-warming effect that could have a significant influence on the earth's environment. The transportation sector is responsible for sizable proportions of these greenhouse-gas emissions.

Alternative fuels offer benefits including lower CO_2 and other greenhouse gas emissions, and increased fuel efficiency. Alternative fuels such as hydrogen for fuel-cell-powered vehicles and electricity from non-fossil fuels for battery-operated electric vehicles have the potential to eliminate transportation-generated greenhouse gases. Others, such as ethanol from biomass, have the potential to reduce the overall greenhouse-gas impact compared to gasoline. Although alternative fuels can be used to achieve significant reductions in greenhouse-gas emissions compared to gasoline, production and distribution methods play a significant role in the extent to which they can be effective in reducing these emissions.

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APPENDIX G
MAJOR TYPES OF ALTERNATIVE FUELS

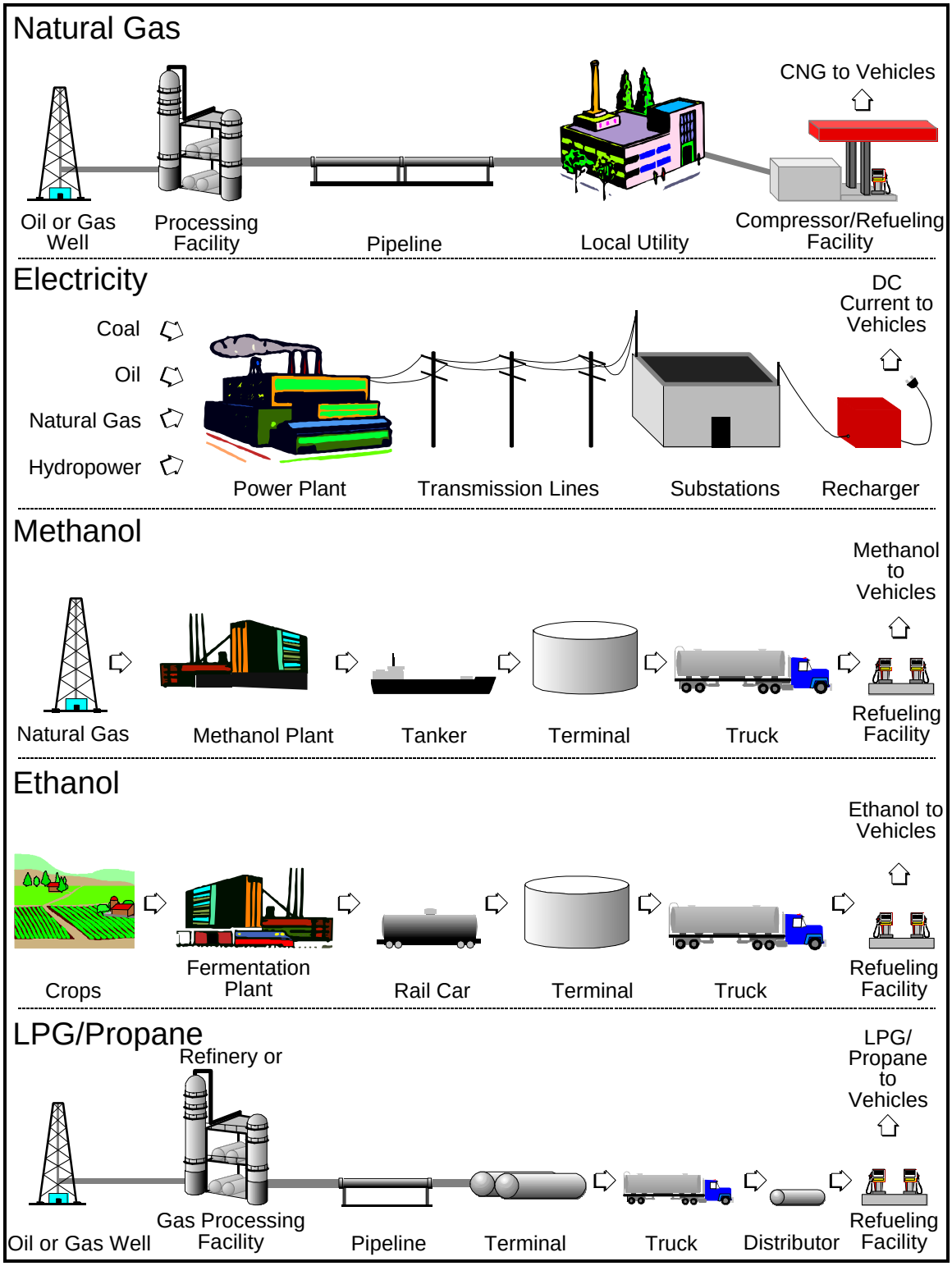
Alternative transportation fuels have been studied for a long time and each is at a unique stage of development. Of the alternative fuels, natural gas, electricity, methanol, ethanol, and LPG/propane are currently the predominant ones of interest in the near term in New York State. Figure G.1 identifies the basic resources and conversion processes typically used to produce these alternative fuels. Reformulated gasoline and so-called clean diesel are generally not classified as alternative fuels because they are made predominantly from petroleum and do not require significant changes to vehicles or the fuel-distribution infrastructure. (For more information on reformulated gasoline, see Appendix E.) Other fuels, such as hydrogen, are considered long-range options requiring significant research to overcome technical and economic hurdles.

NATURAL GAS

In recent years, natural gas has become a popular alternative fuel and is now in use in many states in a wide range of vehicles. The most common form of this fuel in vehicles is compressed natural gas (CNG). Liquefied natural gas (LNG), which is generated and stored at extremely low temperatures (-259°F), is almost pure methane (the primary constituent of natural gas) and also can be used as a vehicle fuel, but CNG has proven to be more popular because of technical and economic issues surrounding LNG. To enable vehicles to carry adequate amounts of the fuel, CNG is typically compressed to pressures of 3000 pounds per square inch (psi) or greater. Increased pressure reduces volume but requires larger amounts of energy for compression and stronger, heavier storage tanks. Because of these trade-offs, CNG vehicles are usually equipped with less fuel capacity, and consequently have reduced driving range, than vehicles using conventional fuels. Another drawback is that CNG equipment, including fueling stations and hardware onboard the vehicle, tends to be significantly more expensive than conventional fuels.

On the plus side, research efforts and increased production volumes may bring equipment prices down, and the basic resource (natural gas) is an inexpensive, abundant domestic resource with a widespread distribution system, and can be burned very cleanly in vehicle engines. CNG cars, trucks, and buses were operated by more than a dozen fleet operators in the AFV-FDP, and CNG vehicles comprised the largest contingent of vehicles, by fuel type, in the overall project. Also, numerous NYSERDA-funded efforts seek to improve the performance and cost-effectiveness of CNG vehicle hardware and fueling equipment.

Figure G.1 Typical Resource-Through-End-Use Paths for Alternative Fuels
(Source: EA Engineering, Science, and Technology, Inc.)



ELECTRICITY

Electric vehicles store energy in onboard batteries that supply power to electric propulsion motors, and the batteries are recharged by connection to an electric outlet. Electric vehicles are of interest because electricity can be generated from a wide assortment of nonpetroleum sources and, by eliminating the internal combustion engine and its tailpipe exhaust, electric vehicles have been defined as zero-emission vehicles (ZEVs). Although fuel is burned by utility companies to make much of the electricity used by ZEVs, these vehicles are thought to be capable of helping many states achieve their air-quality improvement goals.

New York State, California, and Massachusetts each have passed laws intended to establish a large market for ZEVs, starting in 1998. Unfortunately, due to present limitations on battery performance, electric vehicles suffer severe restrictions on range and other performance factors, especially in cold weather. Also, production volumes of electric vehicles are presently very low and, for this and other reasons, vehicle prices are very high. NYSERDA purchased a single ZEV for evaluation in the AFV-FDP. Because of the generally limited availability of ZEVs, NYSERDA has focused its efforts on developing improved vehicle technology. (For more information on ZEVs, see Appendix M.)

METHANOL/ETHANOL

Methanol and ethanol are alcohol fuels and in many states have been the subject of large demonstration and research projects for application to the vehicle fuels market. Both are colorless, odorless liquids with good performance and emissions properties when used in internal combustion engines. U.S. industry produces ethanol at a rate of about two million gallons per day, mostly from corn. Aside from being an alternative to petroleum, ethanol has been promoted as a "renewable" fuel, but it is very expensive to produce, even in large, optimized production plants. Ethanol is presently used as an additive in reformulated gasoline, an application that has been stimulated by provisions of the federal tax code. In the AFV-FDP, NYSERDA limited its evaluation of ethanol vehicles to a single vehicle operated by the City of White Plains, but has supported research into more cost-effective ways of making ethanol, including production from biomass resources prevalent in New York State, such as from wood and the cellulosic (paper and wood) components of municipal solid waste.

Methanol is made primarily from natural gas, but also can be made from coal, biomass, and other abundant domestic resources. Studies indicate that methanol potentially could be produced in large volumes at a price competitive with conventional fuels, but recent price fluctuations have dampened enthusiasm for methanol. Much of the price swing was caused by the rising demand for methanol as an additive for conventional and reformulated gasoline. U.S. industry produces methanol at a rate of more than three million gallons per day

and almost half is used for transportation fuel. NYSERDA has evaluated use of methanol in transit bus applications and also has evaluated, in cooperation with the City of New York, the City of White Plains, the New York State Thruway Authority, and Monroe County, a large number of passenger cars specifically built by Ford Motor Company to run on M85, a mixture of 85-volume-percent methanol and 15-volume-percent gasoline, with the gasoline added to improve engine starting.

LPG/PROPANE

Liquefied petroleum gas (LPG), often referred to as propane (the primary constituent of LPG sold in New York State), has been a popular alternative fuel for decades, especially in rural areas, where this fuel is used for many applications, including home and commercial heating and as an engine fuel for both highway and off-highway vehicles. LPG/propane is easily liquefied by applying moderate pressure, typically less than 200 psi, and this allows a relatively large mass of the fuel to be stored in liquid form on vehicles, yielding a driving range close to that of conventional fuels.

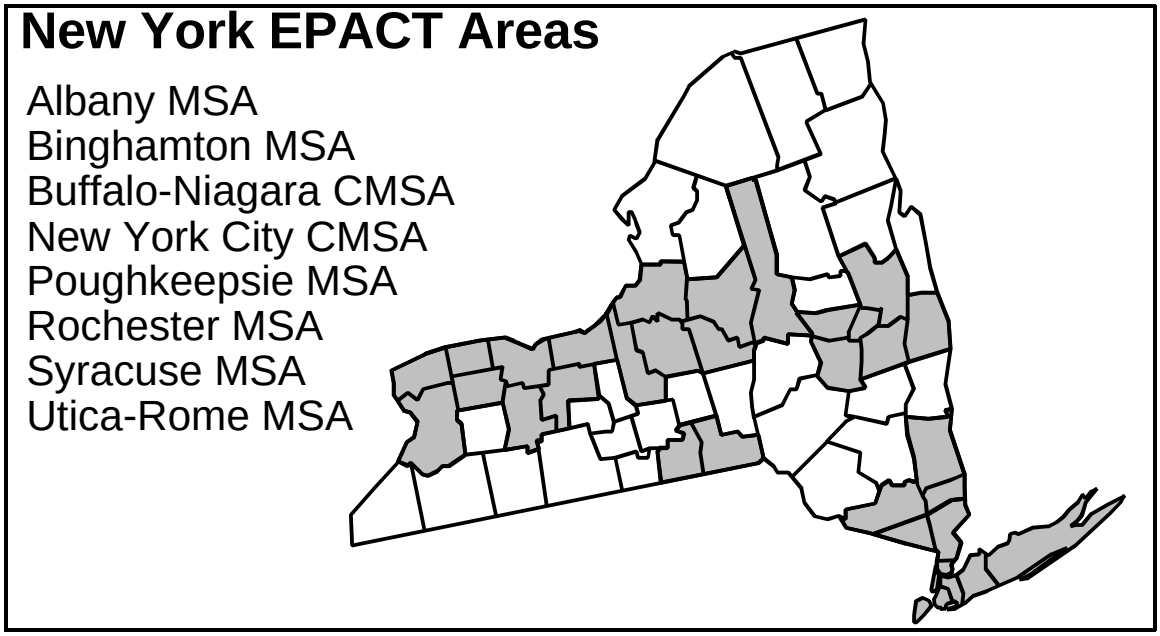
The primary drawback is the tendency of LPG vapors to stay close to the ground, increasing the risk of explosions when leaks occur (unlike natural gas, which is lighter than air and tends to dissipate quickly when leaks occur), which has given rise to restrictions on LPG/propane use in urban areas. Also, some policy makers question its status as an alternative fuel because about half of the LPG/propane used in the U.S. is a by-product of petroleum refinery operations. On the plus side, the rest of the supply comes primarily from natural gas wells. Also, LPG/propane has a well-established distribution system, a price close to that of conventional fuels, and the potential to be a very clean-burning engine fuel. NYSERDA has worked cooperatively with the New York Propane Gas Association and the New York State Office of Parks, Recreation and Historic Preservation to demonstrate and evaluate LPG/propane use in trucks operated at State parks.

APPENDIX H

THE ENERGY POLICY ACT OF 1992 (EPACT)

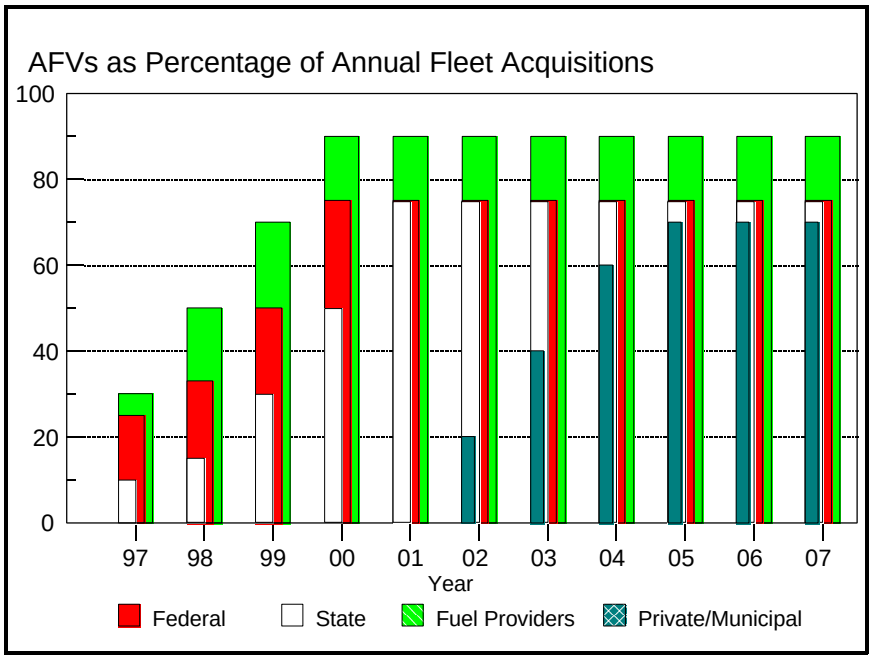
Among its many aspects EPACT is designed to reduce light-duty vehicles' dependence on imported petroleum fuel. This is especially pertinent to New York State as, in 1992, 73% of the petroleum used in the State was imported from foreign sources. For the U.S. overall in 1992, 48% of petroleum was imported. Interruption of the supply of imported fuel, or increases in the price of imported fuel, would have a greater negative impact on New York State (and other similar import-dependent states) than the nation as a whole. Fleets covered by EPACT are those with at least 50 vehicles (on a national basis), with 20 or more vehicles operating in areas with population exceeding 250,000 according to the 1980 Census, that are capable of being centrally fueled. In New York State, many counties are in Metropolitan Statistical Areas (MSAs) or Consolidated MSAs (CMSAs) that fall within EPACT's geographic definitions, as illustrated in Figure H.1.

Figure H.1 Areas in New York State Subject to EPACT



EPACT greatly expanded on earlier federal AFV initiatives[1,2] by specifying AFV purchase quotas for the federal vehicle fleet and fleets operated by state and local governments, alternative-fuel providers, and other parties. Alternative fuels in EPACT are defined as compressed natural gas (CNG), liquefied natural gas (LNG), LPG/propane, electricity, hydrogen, coal-derived liquid fuels, and gasoline blends containing at least 85% methanol or ethanol. State and fuel-provider fleets will have to start purchasing AFVs in 1997. Unlike the CAAA (see Appendix I), EPACT vehicle purchase requirements are satisfied only through acquisition of alternative-fuel vehicles (i.e., those vehicles capable of using non-petroleum fuels designated as alternative fuels by DOE). Federal fleets have been required to buy thousands of AFVs since 1993 and some of these are already operating in New York State. As shown in Figure H.2, 30% of new vehicles purchased by fuel providers in 1997 are required to be AFVs. By 2000, this requirement grows to 90%. State fleet AFV acquisitions must equal at least 10% of new vehicle purchases in 1997, a requirement that increases to 75% in the year 2001. These requirements mean that fleet operators must not only plan to meet the 1997 requirements but also prepare for a larger and continuing use of alternative fuels. Analyses of the need to include private fleets within EPACT are being conducted by DOE.

Figure H.2 Schedule of AFV Acquisitions Under EPACT



[1] In 1988, the U.S. government passed the Alternative Motor Fuels Act (AMFA). AMFA required the federal government to: acquire vehicles that were fueled by alcohol (methanol or ethanol) or natural gas, study the use of alcohols and natural gas in heavy-duty trucks and buses, and provide fuel-economy credits to AFV manufacturers for use in meeting corporate average fuel economy (CAFE) standards.

[2] In 1990, the CAAA provided additional impetus for AFVs beyond AMFA.

EPACT provides incentives in the form of tax deductions (or a tax credit in the case of purchasing electric vehicles) to offset the incremental cost of AFVs and alternative-fuel storage and dispensing systems. Table H.1 summarizes the incentives and penalties for EPACT. For all covered fleets, EPACT allows for the trading of vehicle credits. Fleet operators that implement AFVs sooner or in greater quantities than required will create vehicle credits that can be marketed anywhere in the country to other covered fleets because EPACT is designed to meet a national goal reducing imported petroleum.

Fleets in the New York City CMSA will have to meet the combined requirements of both EPACT and the CAAA. This will create opportunities to maximize the benefits of a planned transition to alternative fuels. The same vehicle can create emission reduction credits (ERCs) as well as EPACT vehicle credits and tax deductions (depending on the tax status of the vehicle owner). The high concentration of covered fleets may spur investment in alternative-fuel refueling infrastructure and increase the local availability of AFV service and support functions.

The experience gained by NYSERDA's AFV-FDP, begun before passage of both CAAA and EPACT, has helped build the initial educational and infrastructure foundation for the changes in fleet operation these laws will require. State, county, municipal, transit, and school district fleets throughout the State have had opportunities to participate in the AFV-FDP and have been exposed to various types of AFVs, while mechanics and drivers have become accustomed to the differences between conventional and alternative-fuel vehicle operating characteristics. Fuel providers have worked in tandem with the AFV-FDP to expand their own AFV programs and to enlarge the pool of knowledge available to potential AFV buyers.

Table H.1 EPACT Incentives and Penalties

Tax Deduction for Buying an AFV	
Vehicles up to 10,000 lbs GVW	$2,000
Vehicles 10,001 to 26,000 lbs GVW	$5,000
Truck or van over 26,000 lbs GVW	$50,000
Bus seating 20 or more adults	$50,000
Alternative-fuel refueling facility	$100,000
Electric vehicles: 10% tax credit, up to $4,000 per vehicle	
Penalties	
First occurrence	$5,000
Multiple occurrences	$50,000

Further, DOE has developed the Clean Cities Program, a formalized system of combining local government and business efforts to introduce AFVs and to provide necessary refueling and maintenance facilities. NYSERDA has been active in organizing Clean Cities in New York State. Fleet operators are encouraged to contact NYSERDA and their local elected officials (e.g., mayors and county executives) to determine the status of local Clean Cities activities.

APPENDIX I

THE CLEAN AIR ACT AMENDMENTS OF 1990 (CAAA)

CAAA designated 22 urban areas of the U.S. as non-attainment areas, i.e., they fail to comply with National Ambient Air Quality Standards (NAAQS). The New York City Consolidated Metropolitan Statistical Area (NYC-CMSA) is one of the listed areas. It includes portions of three states—New York, New Jersey, and Connecticut—and has the largest population of any of the non-attainment areas, with more than 18 million people. Because the NYC-CMSA is classified as a severe ozone non-attainment area, CAAA requires that all fleets of more than 10 vehicles within the non-attainment area, and capable of being centrally refueled, purchase clean-fuel vehicles (i.e., vehicles that use reformulated gasoline, clean diesel, or alternative fuels to reduce vehicle emissions). None of the other ozone non-attainment areas in New York State (see Figure I.1) are classified as being severe or worse, either of which would invoke the clean-fuel vehicle (CFV) requirements of CAAA. Figure I.2 illustrates the current schedule for implementing the Clean Fuel Fleet Program (CFFP) of CAAA in the NYC-CMSA, as agreed between the New York State Department of Environmental Conservation (DEC) and the U.S. Environmental Protection Agency (EPA).

Figure I.1 Ozone Non-Attainment Areas in New York State

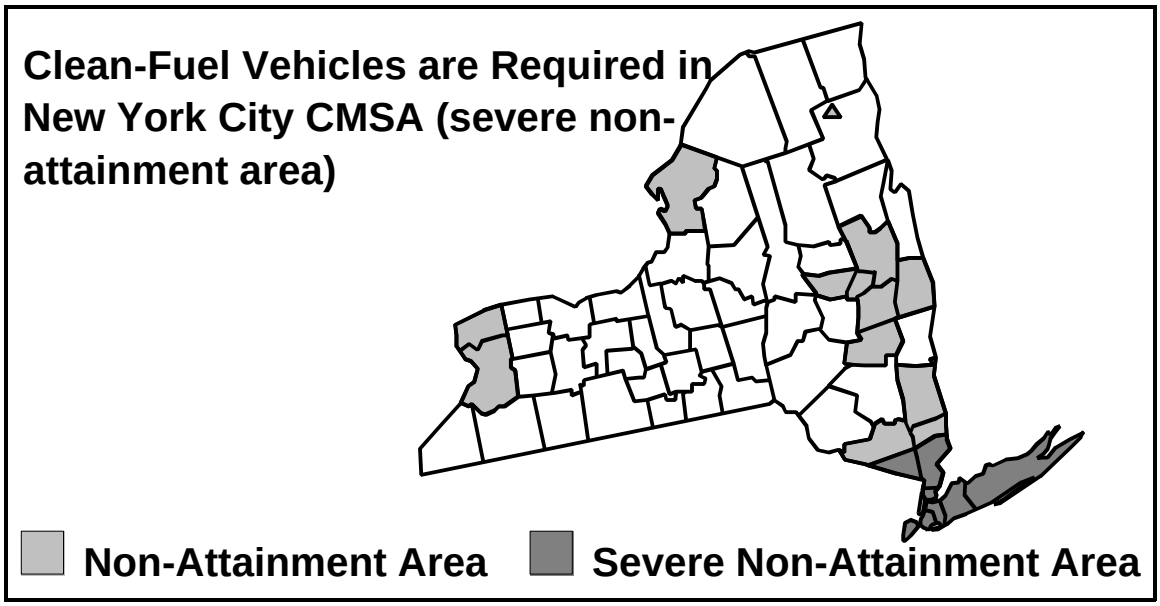
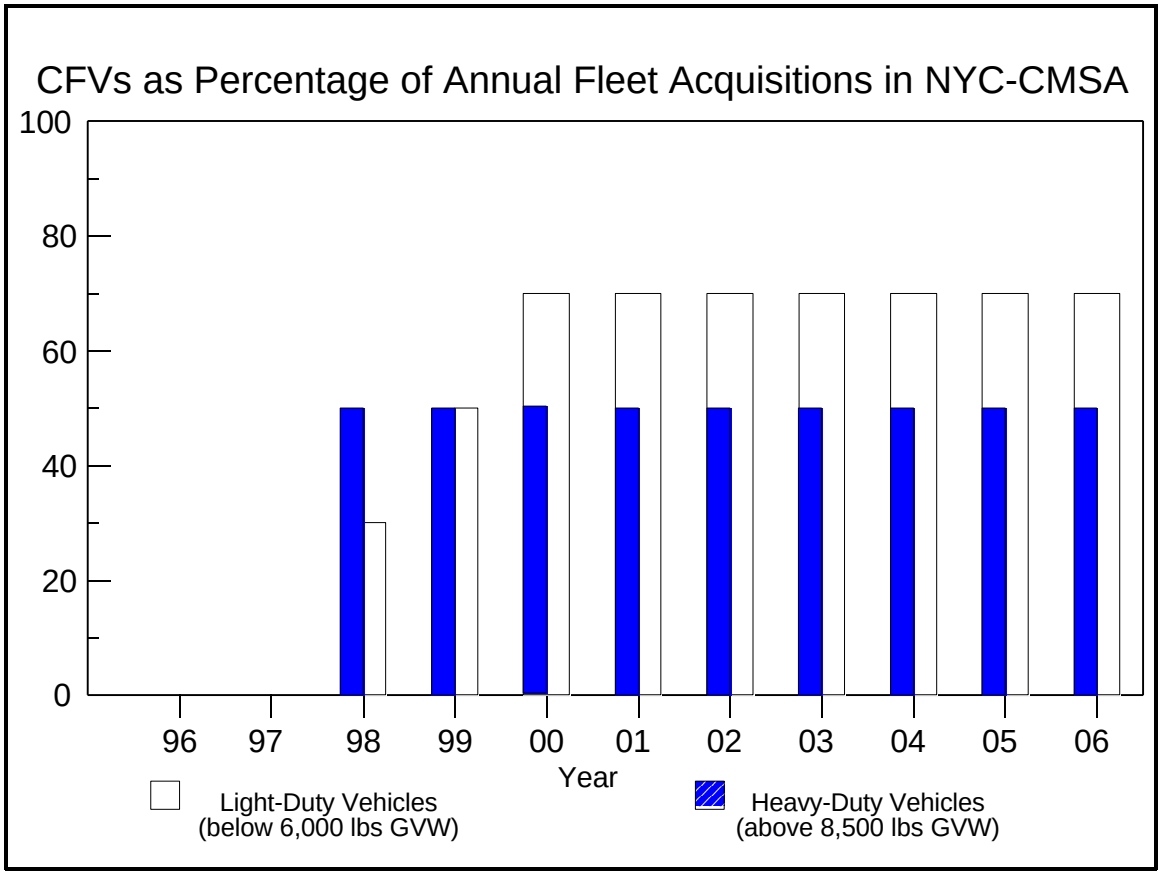


Figure I.2 New York State Clean-Fuel Fleet Implementation Schedule



Within the boundaries of the non-attainment area, CAAA provides both incentives and penalties for fleet operators. Incentives exist for using clean-fuel vehicles earlier than required by CAAA, using clean-fuel vehicles in excess of those required by CAAA, and using vehicles cleaner than required by CAAA. Such operation generates emission reduction credits (ERCs) that can be traded or sold within the non-attainment area to offset other emission-producing operations (either stationary or mobile), or to offset clean-fuel vehicle-purchase requirements in the future.

ERCs are assets that can be sold in an open market or used internally to allow flexibility in fleet planning. This allows emissions-reduction efforts within a non-attainment area to be optimized to achieve an overall emissions-reduction goal in an economically efficient way. For instance, a specialized vehicle fleet or a geographically isolated fleet may not be able to acquire clean- or alternative-fuel supplies without economic hardship. In such cases, the fleet operator could buy ERCs from another fleet instead. This procedure may be less expensive for the buyer, compared to achieving compliance by implementing clean-fuel vehicles, and it

would compensate the "selling" fleet for purchasing/operating clean-fuel vehicles in excess of CAAA provisions. Income from the sale of ERCs may become a significant source of funds to offset the investment in clean-fuel vehicles. There are also penalties for covered fleets that do not comply with CAAA. In New York State, DEC is responsible for administrating compliance with CAAA. Lack of regional compliance with CAAA by a state means the potential loss of significant federal funds for infrastructure development in the state. To prevent this, the state will monitor fleet compliance with CAAA and set penalties to enforce compliance.

EMISSIONS-REDUCTION CREDITS

Many AFVs have lower emissions than their petroleum-fueled counterparts. Where emissions reduction is a goal to improve air quality, those technologies that achieve emissions reductions beyond those required by regulation are valuable. EPA has long recognized the value of this and has instituted rules and regulations for stationary sources that allow discrete emission reduction (DER) credits for those emissions that have been avoided. EPA also permitted an open market for trading DERs (with certain restrictions) among regulated entities. The regulations for open-market trading of DERs generated by vehicles are being developed and could be in place in 1997. The mobile-source DERs would be issued for VOCs and NO_x that are precursors to ground-level ozone. DERs created by mobile stationary sources would be traded internally in the local air-quality region.

The open-market trading program creates incentives for businesses to achieve more emissions reductions than required by regulation. By exceeding emissions reductions called for by the regulations, DERs can be created. The generator of DERs can sell them in the open market or use them to meet future emissions-reduction requirements. Some entities will be able to exceed regulated emissions reductions less expensively than others and will generate DERs. Entities for which it would be costly to achieve required emissions reductions will most likely find it less expensive to purchase DERs. On average, achieving total emissions reductions is less expensive than if every entity had to demonstrate individual emissions reductions. To ensure a net emissions benefit accrues from an open-market trading program, EPA is requiring that 10% of all DERs generated be set aside for the benefit of the environment (i.e., one out of every 10 DERs must be retired and cannot be used or sold).

The mobile-source open-market trading program would be administered by each state through its State Implementation Plan (SIP). EPA will provide standard protocols for calculating DERs, but states may

Fleets of AFVs could produce valuable emission-reduction credits.

propose alternative protocols, subject to approval as part of their SIP approval. Entities that generate DERs must notify their state when they have excess DERs for future use or sale, but it will be the responsibility of the buyer of any such DERs to verify the authenticity of the DERs. DER restrictions include limiting their use to the same non-attainment area in which they were generated, forbidding the use of DERs for satisfying other emissions regulations, and limiting the use of DERs in an ozone season that were generated in a non-ozone season. For mobile sources, it is unclear whether vehicles that must participate in EPA's Clean Fuel Fleet Program will be allowed to generate DERs.

While certain AFVs will be in a position to generate DERs, it is uncertain whether they will be able to generate DERs in attainment areas, or in non-attainment areas that overlap with EPA's CFFP. It is also uncertain whether the mobile-source open-market trading program will represent a significant economic incentive for AFV fleets to generate DERs. (An individual AFV probably will not be able to generate a significant portion of a DER, but large fleets of AFVs might be able to do so.) Most of these uncertainties should be resolved as the mobile-source open-market trading program is implemented and states develop protocols for generating DERs. If structured in a way acceptable to EPA, states could use DERs to promote use of AFVs within their borders.

APPENDIX J
GARAGE GUIDELINES FOR ALTERNATIVE FUELS

GENERAL RECOMMENDATIONS

(The following summarizes a NYSERDA brochure that was compiled based on experience gained in the AFV-FDP. The entire brochure, intended for distribution to fleet operators, is included in Volume 3. Table J.1 lists the key safety features that are recommended to be followed for the most common alternative fuels. A case study of garage modifications to accommodate CNG vehicles follows Table J.1 and is based on work performed as part of the AFV-FDP.)

Many of the garage requirements for alternative fuels are already included in normal good shop safety practices (such as using protective eyewear when handling fuels or working in an engine compartment, etc.) or are logical extensions of existing shop safety practices. Just as good ventilation and an absence of ignition sources are needed near the floor for gasoline, alcohol and LPG vapors, similar measures are needed overhead for natural gas or hydrogen releases.

If a facility needs to be upgraded significantly for alternative fuels, it might be wise to combine fuel safety improvements with general upgrading, energy reduction or other facility safety projects. For instance, Class 1 Division 2 lighting (proper for use with CNG) might fit in with an energy reduction or lighting improvement project. Installing heating systems that comply with Class 1 Division 2 in the areas where alternative fuels may travel also offers the potential of choosing a system with reduced energy costs. A new eyewash will protect against eye damage from all liquid fuels—not just alternative liquid fuels.

National Electrical Code (NEC), Building Officials and Code Administrators (BOCA), and National Fire Protection Association (NFPA) codes and standards are being prepared specifically for alternative fuels. These new rulings will contain the most recent consensus on facility safety procedures. These sources should be consulted before going ahead with facility upgrades. Material Safety Data Sheets are additional sources of safety information and are available from suppliers of alternative fuels.

Local fire-fighting staff should be informed of the types of alternative fuels being used so they can obtain proper training and suitable equipment, such as alcohol-compatible extinguishers (NFPA Class 1B fire).

Certified technician training courses have been developed for CNG in New York State by the Automotive Technician Training Program (ATTP) and an Automotive Service Excellence (ASE) Certification program is now available. Such training should pay off in faster service times and fewer fuel releases. When the proper

precautions are taken (proper equipment and proper training), alternative fuels can be handled just as safely as conventional fuels.

Table J.1 Summary of Alternative Fuel Hazards and Typical Garage Modifications

Fuel	Key Fuel Characteristic for Identifying Hazards	Typical Garage Modifications and Hazard Mitigation Actions
CNG	Natural gas is comprised mostly of methane, which is flammable and lighter than air, and rises to the highest point within a facility	• Addition of methane detectors • Elimination of ignition sources in ceiling area • Enhanced ventilation to remove released natural gas • Safety training of vehicle maintenance staff
Methanol or Ethanol	Similar flammability characteristics as gasoline; methanol is toxic and ethanol is denatured to make it toxic	• Same precautions as for gasoline • Good floor-level ventilation • Explosion-proof wiring in pits • Provide eye wash stations and protective gear (goggles, gloves, etc.) • Safety training of vehicle maintenance staff
LPG/Propane	LPG/Propane is heavier than air and when released presents similar flammability hazards as spilled gasoline	• Similar precautions as for gasoline • Good floor-level ventilation • Explosion-proof wiring in pits • Safety training of vehicle maintenance staff
Electricity	Electric vehicles have batteries that present significant shock and chemical hazards; when being recharged, some batteries may release hydrogen, which is flammable, lighter than air, and rises to the highest point within a facility	• Good ceiling-level ventilation if batteries release hydrogen • Elimination of ignition sources in the recharging area • Provide specified test and repair equipment and appropriate protective gear (goggles, gloves, etc.) • Safety training of vehicle maintenance staff

CASE STUDY: INTRODUCING CNG VEHICLES TO AN EXISTING FACILITY

INTRODUCTION

A fleet operator is planning to acquire several compressed natural gas (CNG) light-duty vehicles. Physical properties of CNG differ from those of conventional fuels and these differences affect the safety procedures needed to maintain and service CNG vehicles. Facility designs need to take these property differences into account in order to maintain or improve facility safety.

The fleet operator's CNG vehicles will use a maintenance facility originally designed to meet building and fire codes written to address the hazards presented by conventional (gasoline and diesel) liquid fuels. The current national code organizations including the National Fire Protection Association (NFPA), National Electric Code (NEC) and the Building Officials and Code Administrators (BOCA), have not issued extensive guidelines on the mechanical and electrical requirements for facilities servicing CNG vehicles. However, by comparing the hazardous properties of conventional fuels with those of CNG, existing codes can be used as a guide for identifying possible electrical and mechanical modifications. These recommendations for garage modifications are based on technical data, engineering judgement, historical information and a review of current national mechanical and electric codes. The relative risks presented by servicing and storing CNG vehicles in current vehicle maintenance facilities and the methods of reducing these risks are discussed.

CNG AS A VEHICLE FUEL

All vehicle fuels raise safety concerns mainly with the physiological properties of the fuel, e.g. toxicity, and with its flammable properties. These risks are primarily controlled by preventing the release of fuel from vehicles. During the vehicle repair process as well as due to component failures, there may be times when fuel releases will occur. The hazards presented by these fuel releases can be controlled by:

- limiting workers' exposure to released fuels (if the fuels present a physiological hazard),
- keeping released fuel vapor concentrations outside of their limits of flammability,
- isolating ignition sources from locations where ignitable fuel mixtures may exist.

Methods used to accomplish these goals are in a large part dependent on the physical properties of the fuel in use.

Physical Properties of Natural Gas

Natural gas is a mixture of several gases (methane, propane, ethane, butane, carbon dioxide, nitrogen, etc.) with methane as the primary (>90 percent) constituent. The natural gas used as a vehicle fuel is the same gas supplied to other customers for cooking, heating etc., and is odorized so fuel leaks are readily detectable. Natural gas is generally considered nontoxic and methane, its primary constituent, is a simple asphyxiant. Coal miners inhale concentrations of up to 9 percent methane in air without any apparent ill effects. (1)* Concentrations of natural gas that present an asphyxiant hazard are above the lower flammability limit. Hence, as long as ventilation systems can keep gas concentrations below the lower flammability limit, the asphyxiant hazard is avoided.

Fuel release prevention is controlled primarily by proper vehicle design and by establishing safe rules for vehicle storage and repair. Keeping released fuel vapor concentrations outside flammability limits and isolating fuel vapors from ignition sources is controlled by building design, vehicle design and good work procedures.

Current facility and safety codes are designed to help keep liquid fuel vapors outside their flammability limits and isolated from ignition sources. The code requirements for facilities use the properties of conventional fuels and their vapors to help determine locations where upgraded electrical and ventilation systems are needed. Some relevant fuel properties are listed in Table 1.

Table 1. Properties of Different Vehicle Fuels (2)

Property	Methane	Diesel	Gasoline
Gas (Vapor) Density Relative to Air	0.555 (lighter-than-air)	N/A*	>4.0 (heavier-than-air)
Vapor Pressure (psia)	N/A**	7.35×10^{-3}	7-15***
Diffusion Coefficient (ft^2/hr)	0.62	N/A*	0.19
Flammability limits, vol% in air	5.3-15.0	0.5-4.1	1.0-7.6
Autoignition temp °F	1004	500	442-880***

* Not applicable, diesel does not readily form vapors
** Methane is a gas at normal temperatures and pressures
*** Dependent on composition and age

*Numbers in parentheses refer to references listed at the end of this case study.

Both diesel and gasoline vapors are heavier than air, filling depressions and low lying areas. Current garage design standards increase safety by minimizing areas near the floor where vapors can accumulate, and by removing sources of ignition from low lying areas.

Since gasoline and diesel fuel vapors are heavier than air and tend to sink, there is little need for measures to increase vapor dissipation or limit ignition sources in the space above vehicles. For example, in vehicle repair facilities, electrical equipment that may produce electrical arcs may be installed less than 12 feet above the floor as long as the equipment is enclosed to prevent sparks from dropping to the floor (3).

Methane is lighter than air and will rise when released. Introduction of CNG vehicles into an existing repair facility will require examination and possible changes to ventilation and ignition sources located above vehicles (where methane will travel when released) or near a building's ceiling (where released methane will tend to accumulate if a building is inadequately ventilated).

The diffusion coefficient of methane is higher than that of gasoline. This indicates that methane will dissipate more quickly in air than gasoline vapors will. This fact, combined with the higher concentrations of methane needed to be within the flammability range (5.3% by volume compared to 1.0% by volume for gasoline), suggests that a larger volume of methane can be released than gasoline vapor before a flammable mixture is produced.

The physical state of a fuel (solid, liquid or vapor) and its readiness to form vapors will help determine the quantity of vapors formed during a fuel release. Since methane is a gas, all of the fuel released from a vehicle is released as a vapor. The quantity of flammable mixture present will be greatest during and immediately (several minutes) following a fuel release and is dependent on the quantity of fuel released. In general, after a natural gas fuel release has ended, the volume of gas within the flammability limits around and above the release point will quickly decrease until the only remaining flammable mixtures will be pockets of gas trapped in the vehicle or near the roof of a facility.

CNG Fuel System General Description

Although natural gas is commonly used as a fuel for stationary internal combustion engines, its use as a vehicle fuel presents unique problems. In order to carry enough fuel to provide an adequate range, natural gas is stored on the vehicle at a high pressure, usually 3,000 psi, in cylinders approved by the U.S. Department of Transportation (USDOT) or most recently, certified as meeting the requirements of the AGA/ANSI NGV-2 standard.

The pressure of the gas in the fuel tanks is reduced through a series of pressure regulators, as shown in Figure 1, to a lower pressure (slightly above the manifold pressure) for use by the engine. Two methods are commonly used to mix fuel with air for use by the engine. Older style systems use a fuel mixer (in principle similar to a gasoline carburetor), newer systems use a computer controlled fuel injection system. Aside from the fuel system, other components of a CNG engine are similar to those used in gasoline vehicles.

CNG Vehicle Safety Systems

CNG vehicle fuel systems have been designed to prevent the unintended release of fuel, and to limit the volume of fuel should a release occur. While there are several areas of the fuel system that are susceptible to leaking, features have been incorporated into CNG vehicles that decrease the probability of an accidental fuel release. CNG fuel systems are equipped with several safety related valves as shown in Figure 1. These valves include:

- Safety Relief Valve(s). These valves—also known as Pressure Relief Devices or PRDs—are designed to prevent catastrophic cylinder failure due to either cylinder over-pressure or over-temperature. The relief valves are designed to release the pressurized gas in a controlled manner. Filled fuel cylinders require several minutes to completely vent fuel through the Safety Relief Valve.

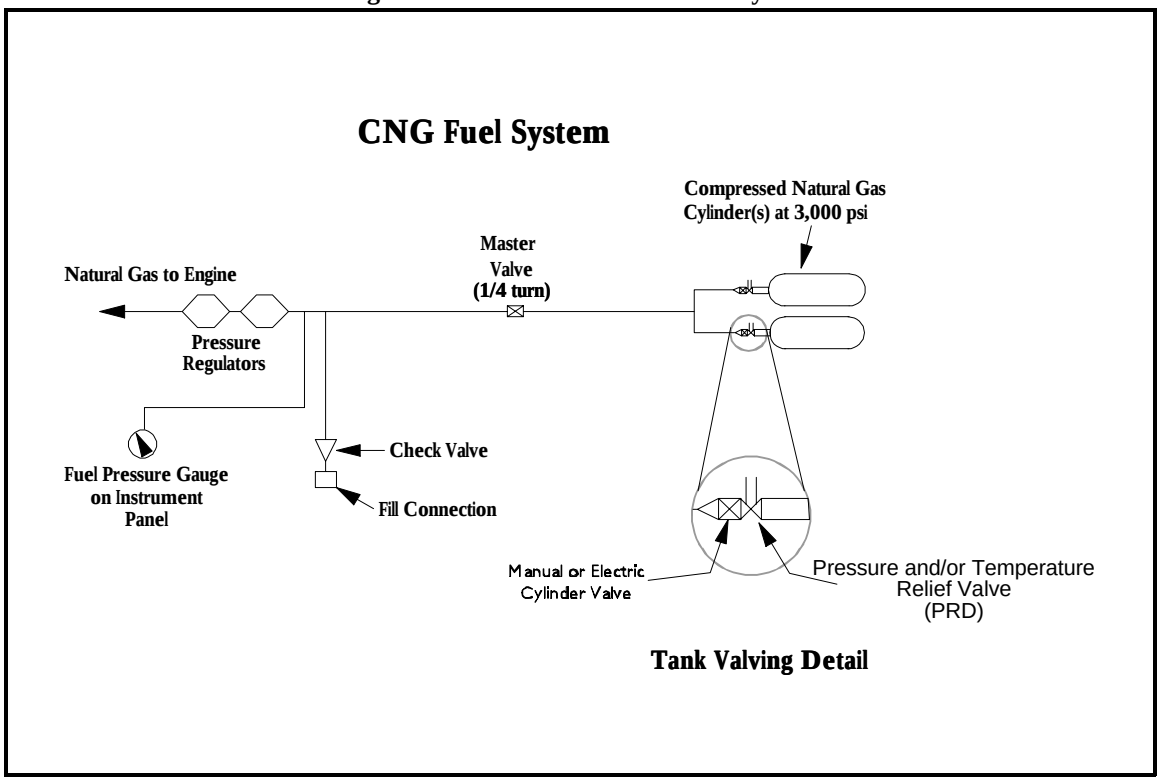
- Manual Cylinder Valves. These valves isolate the gas stored in the cylinder from the rest of the fuel system (except for the Safety Relief Valves). These valves should be closed whenever a vehicle's fuel cylinders are being serviced.

- Master Valve. The main fuel line contains a main fuel shut-off (quarter-turn) valve. Before servicing a vehicle fuel system (other than those with electric cylinder valves) this valve should be closed by repair personnel. Closing this valve prevents flow of fuel from the cylinders and allows servicing of the fuel system between the engine and this valve.

- Electric Cylinder Valve. On some OEM vehicles solenoid valves are installed on the vehicle fuel cylinders. These valves isolate the gas stored in the cylinders from the rest of the fuel system. These valves are usually controlled in the same manner as electric fuel pumps on conventional vehicles and would normally be closed except when a vehicle's engine is running.

The high pressure fuel lines on the vehicle are made of stainless steel tubing to limit corrosion. Ferrule-type fittings are used to attach the fuel lines to valves, regulators or pressure transducers. This allows lines to be easily repaired or serviced by qualified mechanics.

Figure 1. Schematic of CNG Fuel System



TYPICAL HAZARDS AND PREVENTIVE MEASURES

Maintaining a safe environment in a vehicle repair facility is helped by:

- taking proper precautions when working on CNG vehicles in a facility
- using facility designs that minimize locations where rising natural gas can be trapped
- eliminating sources of ignition from areas where natural gas may be present or travel through if released from vehicles
- controlling ventilation rates to limit volumes of combustible mixtures present in a facility after a fuel release

Safety Practices and Worker Training

Worker training and implementation of safe work procedures are one method of decreasing the hazard presented by bringing CNG vehicles into a facility. Training should emphasize methods of:

- minimizing the possibility of a fuel release
- limiting the volume of fuel released should a leak occur

- limiting worker related sources of ignition in locations where released fuel may be present
- proper response to hazardous conditions

Preventing and Limiting Fuel Releases. There are several practices that should be observed to prevent fuel releases when working on CNG vehicles. The following describes some of them.

During Maintenance. Natural gas releases can occur from any component of the fuel system that is pressurized. The higher the pressure, the greater the risk of a spontaneous release (a release occurring due to a fuel system failure and not due to damage caused by accidents or improper repair practices). The simplest way of accomplishing this is to not refuel the vehicles, if possible, before scheduled repairs. This is not to say fully fueled vehicles cannot be brought in for repair, but it is a practice that is discouraged.

Proper use of fuel system control valves can limit the volume of natural gas released by a leak. If a PRD actuates, it will release all of the fuel stored in the cylinders, since the cylinders are manifolded together. To limit this type of release, the manual cylinder valves should be closed whenever repairs involving the vehicle fuel system are performed or when repairs require several days to complete. By closing each individual manual cylinder valve, the fuel released by any single PRD will be limited to the fuel stored in the cylinder to which it is attached. On vehicles with electric tank valves the valves are automatically closed whenever the engine is not running. Fuel releases downstream of the cylinder valves will be limited to the volume of pressurized fuel in the fuel lines and regulators (equivalent of less than one cup of gasoline for a typical light-duty vehicle**). To eliminate even this small amount of fuel, it is possible to depressurize the fuel system downstream of the fuel storage cylinders by operating the engine with the individual fuel cylinder valves closed. The engine will operate until the natural gas in the fuel system (lines and regulators) is consumed. Depressurizing the fuel system by running the engine with the manual cylinder valves closed will limit the potential fuel release locations to only the PRDs and cylinder valves.

Besides spontaneous fuel releases, vehicles may release fuel due to improper worker actions. These releases can be limited by proper worker training. Non-mechanics should not attempt vehicle fuel system repairs or adjustments no matter how insignificant they may appear.
Mechanics should follow procedures set forth in the chassis, fuel system, and engine manufacturers' repair manuals. Whenever fuel valves are closed for vehicle repair, they should be safety wired shut with warning tags to prevent inadvertent opening before repairs are completed. After performing fuel

** Based on 15 feet of 0.250 inch fuel line, two regulators with 5 inch diameter diaphragms pressurized to 3,600 psi.

system repairs, new components should be checked for leaks when exposed to gas pressure both before the vehicle has been refueled and after, when the fuel system has been fully pressurized.

Venting. Some maintenance procedures will require venting the vehicle cylinders, e.g., replacing the fuel cylinder, changing the PRD, changing the cylinder valve, etc. Precautions need to be taken whenever a cylinder is vented. Before venting the vehicle should be moved to an outdoor location away from sources of ignition.

During venting the released fuel undergoes a rapid decrease in pressure causing a drop in temperature. Under some release conditions the temperature reduction may be great enough to cause the released fuel to lose its buoyancy. During these times the released fuel will be heavier than air until it is warmed sufficiently by the surroundings to become buoyant. Ignition sources located below the vehicle can cause ignition. Releasing the fuel slowly will help to prevent this from occurring.

The high speed jet formed during the venting process may also create static charges on the cylinder and objects the released fuel strikes at high speed. Static electric sparks caused by these charges can ignite the released fuel. The generation of the charges can be controlled by grounding the cylinder and nearby objects. In order to prevent other objects from becoming charged the release should be controlled by slowing the release rate and aiming the released fuel away from other objects.

During Storage. When vehicles are stored in a maintenance facility it is preferable not to refuel them until they are ready for use. Workers should not bring any vehicle they suspect of releasing fuel into a maintenance facility. If gas odors are noticed or if fuel can be heard escaping, the vehicle should be left outdoors until a mechanic can check the integrity of the fuel system and take corrective action. Likewise if, at the beginning of a shift, gas odors are noticed, vehicles should not be started nor should electrical equipment be switched on or off until the source of the odor and the extent of the fuel release is known. In addition to identifying the extent of the fuel release, proper operation of the facility exhaust system should be checked.

Worker Related Sources of Ignition. A flammable mixture will always be present in the vicinity of a leaking fuel system component. Because of this, sources of ignition in the immediate vicinity of a fuel leak have a high probability of igniting the leaking fuel. Sources of ignition in the vicinity of a vehicle fuel leak are mostly worker related. These include static discharges, electrical shorts, open flames from torches used to repair vehicles, electrical tools, drop lights, cigarettes, chisels or grinders which generate sparks, etc. A program of worker training along with an evaluation of worker practices and equipment should be implemented before CNG vehicles are placed in service.

Hazardous Fuel Releases. Even with good vehicle design and proper worker training some failures which cause fuel to be released from vehicles will occur. Safety can be maintained by preventing ignition or accumulation of the released fuel. The ignition of the releasing or released fuel presents several hazardous scenarios.

Early Ignition Scenario. Ignition of the leaking fuel near the source of the release will produce a flame similar to a burner or torch flame. If ignition occurs soon after the leak has begun, the initial volume of flammable mixture will be small and so will the danger presented by the scenario. Once ignited the main safety concern is the overheating of fuel system components or ignition of other nearby combustible materials causing the fire to spread.

Ignited fuel releases should be extinguished by interrupting the flow of fuel to the fire, e.g., closing the master shut-off valve or the cylinder valves. Once the fuel release is stopped and the fuel fed portion of the fire goes out, the other non-fuel related combustion can be extinguished in a normal manner. Extinguishing the fire before the flow of fuel is stopped increases the risk of a flashover, when the continuing flow of releasing fuel is reignited.

Rapid Fuel Release Scenario. Far more hazardous are incidents involving ignition of accumulated quantities of flammable fuel air mixtures. There are several ways large quantities of flammable fuel/air mixtures can be generated before ignition. Fuel leaks which release fuel at a high rate, e.g., actuation of a PRD or rupture of a main fuel line (if the cylinder valves are open), will generate a large cloud of flammable mixture (up to the equivalent of several gallons of fully vaporized gasoline) above the site of the fuel release in a short period of time. If unconfined and no sources of ignition are present the cloud will dissipate harmlessly. If a vehicle is inside a building when a rapid fuel release occurs, the released fuel would have to be vented out of the building (by either forced or natural ventilation removing air from above the vehicle) while at the same time being kept isolated from ignition sources. Without proper ventilation, a flammable mixture will rise and form a layer under the ceiling inside the building. Ignition of such a mixture would rapidly release large amounts of energy and likely cause extensive damage from over-pressure and fire. Although leaks with high rates of fuel release should be a rare occurrence, facility designs need to incorporate ventilation and other features to ensure safety during these types of releases.

Accumulated Slow Fuel Release Scenario. Another scenario where large quantities of flammable mixtures may be generated involves slow fuel leaks without ignition in locations where adequate ventilation is not provided. Slow leaks can occur at any of the fittings in the fuel system (from vibration, accident damage, improper installation or repair), from defective regulators, or faulty valves. Low rate fuel releases may be difficult to locate, depending on the rate of fuel release. Their existence will be

readily known from the telltale odor, but maintenance personnel may not (if the leak is slow enough) be immediately aware of the location of the fuel leak. A small fuel leak may, over a period of time, release a large volume of natural gas. The main dangers presented by these types of leaks are associated with gas accumulation. If there is inadequate ventilation, flammable mixtures of gas can become trapped in parts of the vehicle or in the building. If the fuel continues to accumulate for a long period of time, it is possible that a large quantity of ignitable mixture may be present.

FACILITY MECHANICAL AND ELECTRICAL SYSTEMS

The current national mechanical and electrical codes were examined to see what impact they would have on CNG facility safety. These mechanical and electrical codes are designed to prevent accumulation and/or ignition of vapors generated from unplanned releases of conventional fuels. These conventional code requirements are used to make general design recommendations for facilities where CNG vehicles are repaired.

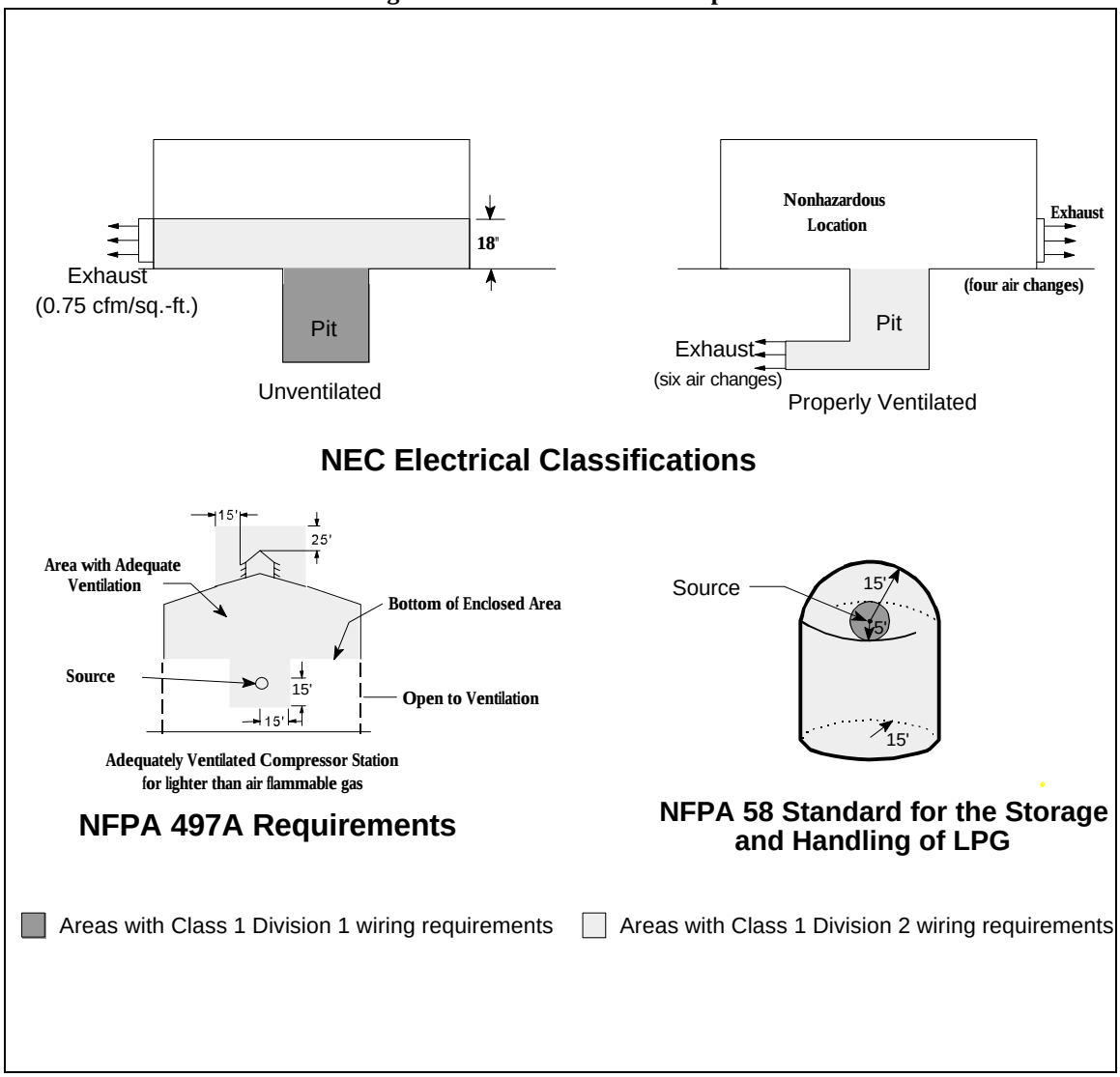
Current Code Recommendations

Repair areas where CNG vehicle conversions and repairs are to be performed should have provisions for either natural or forced ventilation. Current codes only describe ventilation requirements for facilities servicing conventional liquid fuel vehicles, however, these codes can be used as a basis to determine the needs of facilities servicing CNG vehicles.

Both the NFPA and the NEC provide ventilation and electrical requirements for garages where gasoline and diesel vehicles are repaired. These standards are designed to prevent the accumulation of vapors inside the garage and limit sources of ignition in locations released fuel vapors are likely to be found. These NFPA and NEC requirements are illustrated in Figure 2.

NFPA 88B - "Standard for Repair Garages" requires that areas below grade used for repair vehicles have forced ventilation systems capable of continuously removing at least 0.75 cubic feet of air per minute for each square foot (cfm/sq.-ft.) of floor space (4). This ventilation requirement helps prevent accumulation of heavier-than-air fuel vapors which could accumulate in below grade areas.

Figure 2. Current NEC and NFPA Mechanical and Electrical Requirements for Both Heavier and Lighter than Air Flammable Vapors



NFPA 88B removes potential sources of ignition from areas where fuels may accumulate by requiring suspended unit heaters be located at least 8 feet above the floor (5). In addition, other heaters with glowing elements must be located at least 18 inches above the floor and the garage must have continuous forced ventilation at the rate of 0.75 cfm/sq.-ft. (6).

All electrical equipment installed less than 18 inches above the ground must comply with NEC's Class I Division 2 wiring requirements to limit the probability of ignition occurring in hazardous environments (7). All electrical equipment installed in unventilated pits must comply with NEC's Class I Division 1 wiring requirements.

NFPA 497A Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, contains recommendations for wiring requirements in an enclosed area where lighter-than-air flammable gases may be released. While these recommendations are for chemical processing areas, the releases are similar in the hazard they present to what would be found for natural gas released in repair garages. These recommendations are illustrated in Figure 2.

NFPA 58 Standards for Handling and Storage of Liquid Petroleum Gases, contains recommendations for areas were LPGs are handled. Included are recommendations for wiring requirements, illustrated in Figure 2. While LPGs are heavier than air, the release hazards presented at ground level would be analogous to those found near the ceiling during a CNG fuel release.

Several studies have been done on the risks presented by CNG vehicles. These studies are useful in helping to determine safety changes in the absence of clear code requirements. A recent study modeling probable fuel releases from CNG transit buses has shown that flammable mixtures <u>may</u> extend more than 18 inches down from the ceiling but that horizontal displacement of released fuel rarely exceeds three to four feet from the release site (8). Caution should be used before extrapolating the results of this study. These are results of a single study, modeling various sized fuel releases from transit buses, stored in a modern (conventional fuel designed) transit bus garage. The buses modeled (Flxible with fuel tanks mounted under the chassis) had the outlets of all the PRDs routed to the roof of the vehicle through a single manifolded line. The PRDs on the fleet operator’s vehicles will most likely release fuel under the vehicle. A PRD releases fuel quickly and with great velocity. When released under a vehicle, this high velocity fuel release may be deflected by the ground or vehicle components and travel greater distances than if it were released above a vehicle.

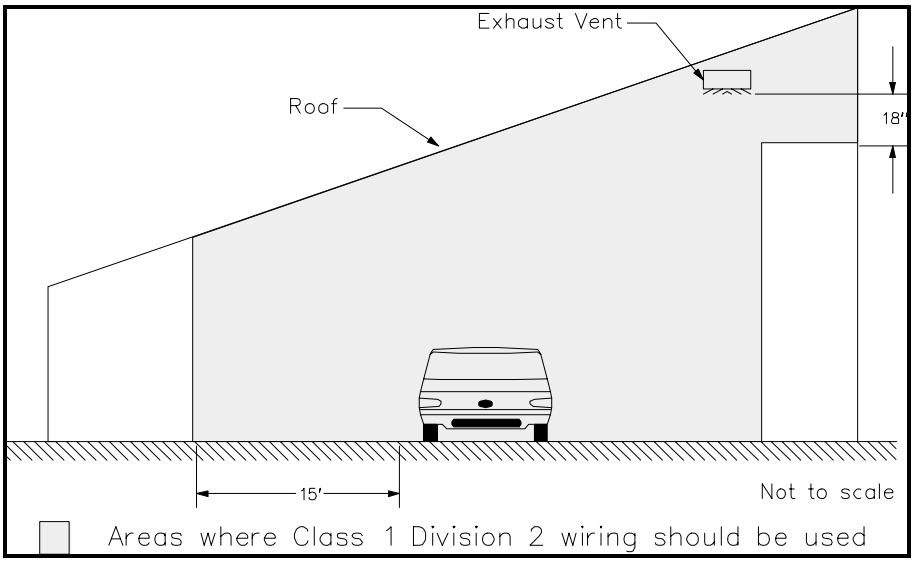
Fuel can accumulate to depths (distances directly below the ceiling) greater than 18 inches during periods of large scale fuel releases. The rate at which fuel is released due to a major component failure, e.g., release by a

PRD, can be quite large. One study has calculated an initial fuel release rate of 932 scfm when a typical vehicle PRD has activated (9). A garage ventilation system removing 0.75 cfm/sq.ft. from above a vehicle could still allow fuel to accumulate if the overall ventilation rate is insufficient to handle a 932 scfm release. Increasing the background ventilation rate, to account for the maximum rate of fuel release may cause problems if no fuel were being released, e.g., annoying drafts in the repair bay, need for additional heating, etc. For this reason it is recommended that gas detectors be installed at strategic locations. These gas detectors would be used to increase the ventilation rate - increasing the exhaust fan speed or activating additional exhaust fans. In addition to increasing the ventilation rate, the gas detectors should be wired into an alarm system to warn personnel of elevated methane concentrations above the vehicles.

General Mechanical and Electric Recommendations

Based solely on the national code requirements, a generalized work area for CNG vehicles can be developed. This generalized work area, shown in Figure 3, is used to develop more specific repair area recommendations for the fleet operator's garage.

Figure 3. General Electrical Requirements for CNG Repair Areas Based on Modification of National Codes



The shaded areas in Figure 3 are based on the properties of natural gas, a review of the current garage related national codes, and other studies of gas releases in repair facilities. The codes where these recommendations appear include:

- NFPA 497A - all electrical systems within 15 feet of the vehicle (when in the repair bay) should be rated for use in Class 1 Division 2 locations.

- NFPA 88B - the garage ventilation system should remove at least 0.75 cfm/sq. ft. of floor space. The pick-up points for the air removal system should be located above the vehicles near the ceiling in areas where CNG vehicles will be serviced. Additional ventilation, controlled by a methane detection system, may be needed to safely handle large fuel releases.

- Based on NEC requirements for conventional fuels, all electrical systems both above and within 18 inches below the ventilation systems air inlet should meet NEC's Class 1 Division 2 rating.

- No heating unit, with open flames or surface temperatures at or above the ignition point of natural gas (~1000° F), should be installed in any area where the electrical recommendations require Division 2 wiring.

The code's recommended distance requirements (15 feet and 18 inches) are based on the diffusion properties of lighter than air flammable gases (similar to natural gas) and the properties of conventional fuel vapors and may need to be modified based on vehicle and building specifics.

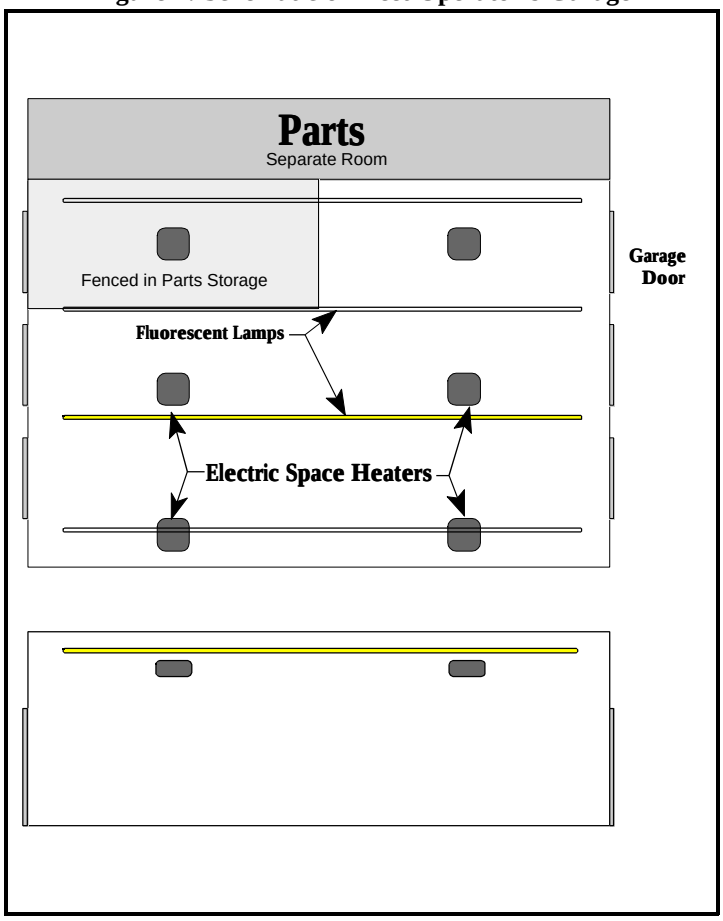
Fleet Operator Facility Description and Recommendations

A sketch of the fleet operator's garage is shown in Figure 4. Figure 5 shows the same area with shading to indicate areas where upgraded electrical equipment should be used.

The garage consists of five repair bays, a screened in parts storage area and a separate parts storage room. The ceiling is the underside of the flat roof. Heating is provided by several electrical unit heaters suspended approximately 30 inches below the ceiling. Several rows of fluorescent lights installed approximately 18 inches below the ceiling illuminate the work area.

General Recommendations. Since the planned number of CNG vehicles will constitute only part of the fleet (approximately 5% to 10%), CNG vehicle repairs can be limited to a single repair bay. By limiting CNG vehicle repair to a single bay, required building modifications can be minimized. With proper ventilation, it will be possible to limit lighting and heating changes to equipment located near the designated repair space. Some electrical equipment located elsewhere may require some modification.

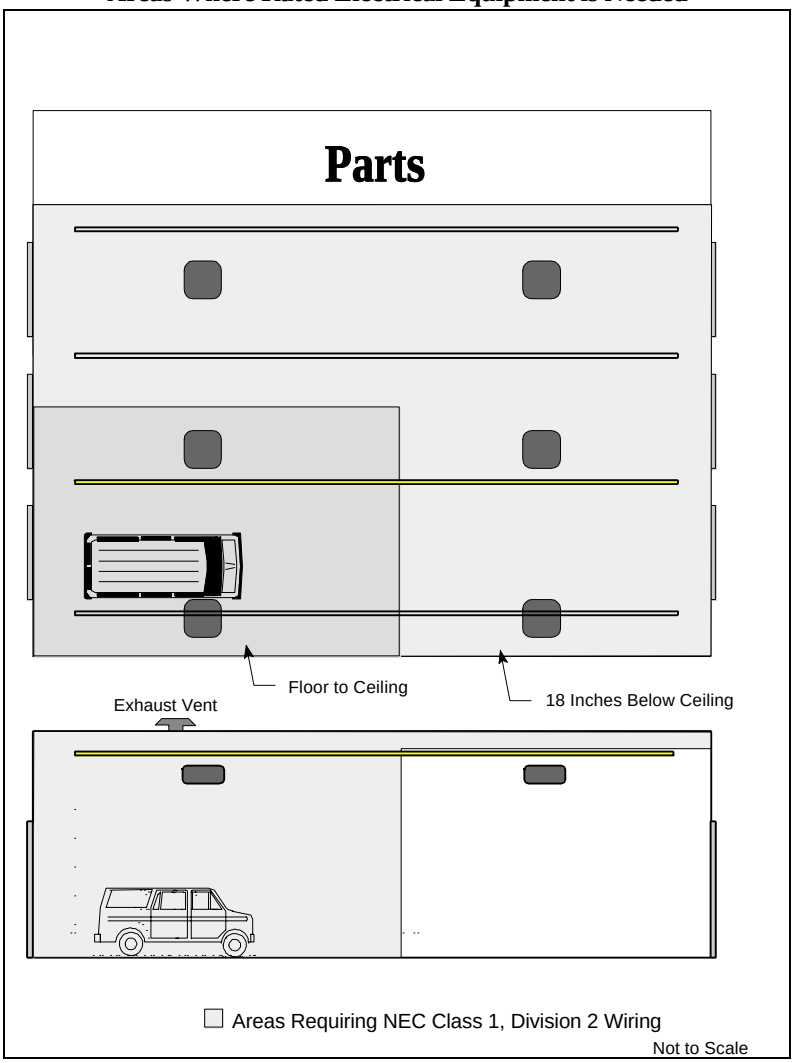
Figure 4. Schematic of Fleet Operator's Garage



<u>Electrical Recommendations</u>. Fuel released from a vehicle undergoing repair will travel up from the release site. Sources of ignition directly above the designated CNG vehicle repair area (the bay itself plus a 15 foot wide border around the bay) need to be eliminated. These include the fluorescent lights, the electric heater and any electric equipment not rated for Class 1 Division 2 area. In addition, all non-rated equipment located within 18 inches of the ceiling will need to be modified.

New lighting fixtures meeting Class 1 Division 2 requirements should be installed over the CNG repair bay. Many types of lighting (including fluorescent fixtures) are available that meet these requirements. The only other equipment that appears to cause a problem is the heater units. These are discussed in the heating section. Some conduit is located near the ceiling. This should not cause any problems as long as there are no junction boxes near the ceiling. Junction boxes within 18 inches of the ceiling will need to be sealed.

Figure 5. Fleet Operator's Garage Showing CNG Repair Bay and Areas Where Rated Electrical Equipment is Needed



Heating Recommendations. The heating equipment directly over the CNG repair bay will need to be changed. Electric heaters for use in hazardous areas are available. The existing heater(s) could be changed to one of these. Alternatively, a new building-wide heating system could be installed, using either a remote boiler with unit heaters that are rated for use in Class 1 Division 2 areas, direct catalytic infrared heaters, or any other heating system designed for use in Class 1 Division 2 Areas.

Ventilation Recommendations. An exhaust system will need to be installed above the CNG repair area to keep any released natural gas from accumulating in and/or traveling to other areas of the garage. The exhaust system should provide, at a minimum, the NFPA-required ventilation for the CNG repair bay. It is possible, e.g., after actuation of a PRD, that a vehicle may be releasing fuel faster than the exhaust fan (sized to provide 0.75 cfm of exhaust for every square foot of floor area in the CNG repair bay) is able to remove it. At these

times the exhaust system will need to be able to operate at a higher capacity. The exhaust system can either be sized to provide this higher ventilation rate at all times (increasing the building's heating requirements) or controlled to automatically provide the higher ventilation rate at times when released fuel is accumulating above the CNG vehicle. By using a methane detection system, the exhaust system can automatically increase ventilation whenever fuel starts to accumulate. Since the exhaust system is needed to maintain safety in the repair facility, it should be rated for Class 1 Division 1 operations.

Methane Detection System. A methane detection system should consist of one or more methane detectors installed above the CNG repair area. In addition to increasing the rate of ventilation, the methane detection system could control other safety-related items including disabling non-rated (not meeting NEC Class 1 Division 2 standards) electrical equipment that is located in areas where released fuel may travel and/or activating an operator warning system to warn garage personnel that methane is accumulating above the work area. The ventilation system and the methane detectors are used to maintain a safe environment in the facility. Ideally these systems should be connected to the garage's emergency generator system (if available) so that they will continue to operate in the event of a power failure.

SUMMARY OF RECOMMENDATIONS

In summary, the fleet operator's garage modifications should include:

Electrical

- Changing light fixtures above (as illustrated in Figure 5) a designated CNG repair area to fixtures of similar style meeting NEC's requirements for use in Class 1 Division 2 environments.
- Sealing electrical conduit passing above the repair area or located close to the ceiling so it meets NEC's Class 1 Division 2 requirements.
- Installing a methane detection and alarm system to warn of fuel accumulations above the repair area.
- Upgrading electrical equipment that is located where released fuel may travel, e.g., the shaded area of Figure 5 to meet Class 1 Division 2 standards or having the electric circuits serving the equipment automatically disabled and locked off when methane is detected above the repair area.

Training

- Train workers to: provide proper maintenance of CNG vehicles; be aware of the hazards presented by CNG and proper safety related procedures to use when working on CNG vehicles; and to avoid operating electrical equipment if there is a possibility of natural gas being present.

Heating and Ventilation

- Installing a two speed exhaust fan (rated for Class 1 Division 1 locations), above the repair area. The fan should operate on low speed whenever a CNG vehicle is in the facility. High speed should be controlled by the methane detection system.

- Replacing the electric unit heaters above the CNG repair area (or changing the facility heating system) so that ignition sources are removed from the space above the CNG repair area.

REFERENCES

1. Compressed Gas Association, Handbook of Compressed Gases, Second Edition 1981.

2. Ebasco Services Inc., Safety Analysis of Natural Gas Vehicles Transiting Highway Tunnels, New York State Energy Research and Development Authority Report 90-2, August 1989.

3. National Electric Code, Article 511-7a.

4. National Fire Protection Association, NFPA 88B Standard for Repair Garages 1985 Edition, Section 3-3.3.

5. Ibid, Section 3-2.3.1.

6. Ibid, Section 3-2.2.2.

7. National Electric Code, Article 511-3a.

8. Murphy, M., et. al., "Extent of Indoor Flammable Plumes Resulting from CNG Bus Fuel Leaks," SAE Paper No. 922486, SAE International, 400 Commonwealth Drive, Warrendale, PA, 15096-0001.

9. Grant, T., et. al., "Hazard Assessment of Natural Gas Vehicles in Public Parking Garages," Ebasco Services Incorporated, July 1991.

APPENDIX K
FLEET EXPERIENCE SURVEY REPORT

(The following summarizes a survey of fleet managers in New York State who operate AFVs. The objective of the survey was to elicit opinions of non-quantitative AFV operating characteristics not otherwise collected as part of the AFV-FDP. The entire text of the Fleet Experience Survey Report is included in Volume 3.)

SUMMARY

Fleet operator surveys revealed and confirmed some of the key areas where AFVs and their supporting infrastructure must improve. Fleet operators expressed informed opinions about their fleets providing useful information pertinent to the development of AFV technology.

Perceived Advantages of AFVs

By operating AFVs, fleets are gaining the knowledge they need to make informed decisions on how to meet future AFV requirements. Fleet operation of AFVs is a good method of gauging some factors that make AFVs desirable for expanded fleet operation. The only area where fleet administrators feel AFVs offer a significant advantage over conventional-fuel vehicles is in emissions. Emission improvements, however, are difficult for a fleet administrator to judge based solely on vehicle fleet operation.

Perceived Disadvantages of AFVs

There are four areas where fleet administrators felt AFV performance was significantly below conventional-fuel vehicle performance. These deficient areas were surprisingly consistent across vehicle and fuel types. In order of increasing negative impact these were:

- drivers' acceptance
- operating range
- refueling procedure
- purchase price

Drivers' Acceptance. Drivers' acceptance can be improved by addressing areas where drivers rated AFV performance lower than conventional-fuel vehicles. The survey indicated two areas where drivers rated AFV performance below that of conventional vehicles: engine stalling and low power. Further vehicle development, particularly increased OEM AFV availability, should help to eliminate or decrease these performance weaknesses.

Operating Range. Limited operating range is due to the lower energy densities of most of the alternative fuels which make it difficult to duplicate the range of conventional-fuel vehicles. Increased operating ranges can be designed into the vehicles, but trade-offs in other vehicle attributes (e.g., cargo-carrying capacity, acceleration, vehicle weight, etc.) may have to be made. New technology in lightweight CNG cylinders and higher-capacity batteries may help to narrow the operating-range gap.

Refueling Procedures. Complaints related to refueling procedures were mostly attributable to the non-liquid alternative fuels. Fleet administrators saw no real difference between conventional-vehicle and methanol-vehicle refueling. Fleet administrators felt the other refueling facilities (CNG and LPG) were inferior because they were not available on site, were unreliable, had an initial cost that was too high, and were time-consuming and inconvenient. Some of these items could probably be addressed through improved facility design (e.g., reliability and location). Other refueling items could be improved, but are not likely to exceed the performance of current conventional refueling facilities.

Purchase Price. The premium paid for AFVs would likely decrease if production of the vehicles increases. For methanol vehicles, the vehicle purchase-price premium could be eliminated. For the other fuels, it would be difficult for the premium to be totally eliminated.

APPENDIX L

TAXES ON HIGHWAY FUELS

Taxes on conventional and alternative fuels vary significantly at both the federal and state levels. Alternative-fuel engine and vehicle technology has advanced to the point where there is often little difference in energy efficiency among engines and fuels, with the result that a similar amount of work is accomplished with a similar amount of fuel *energy* regardless of the fuel used. The road-use tax codes were developed with just gasoline and diesel fuel in mind, without consideration for differences in fuel-energy content. This approach is reasonable in the U.S. because these two fuels tend to serve separate markets; that is, there is little direct competition between gasoline and diesel, so differences in taxation have little impact on consumer choices. Table L.1 presents the current tax rates at the federal and New York State level in both gallon and equal-energy (gasoline-gallon-equivalent) terms.

As Table L.1 shows, the federal taxes for methanol, ethanol, LNG, and propane are all higher than for gasoline when adjusted for energy content. The federal tax on CNG is only 30.4% of the tax assessed on gasoline, and CNG is the only alternative fuel to receive road-use tax preference at the federal level.[*] At the New York State level, all alternative fuels are taxed at a higher rate than gasoline on an energy basis, except for propane, which is taxed at only 71.1% of the rate for gasoline because propane is exempt from the New York State petroleum business tax of 14.35 cents per gallon equivalent.[**] Table L.2 shows the total per-gallon and gasoline-equivalent taxes for highway fuels in New York State. Figure L.1 illustrates federal, New York State, and combined taxes on highway fuels, expressed on an energy basis in percentages compared to the taxes on gasoline. Taxes for methanol and ethanol are higher at both the federal and State levels. Federal taxes for CNG are lower, while the State taxes are higher, but the overall combined taxes are lower. Both federal and State taxes are higher for LNG. For propane, the federal tax is higher, the State tax is lower, and the combined tax is just one percent less than for gasoline.

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[*] Ethanol also receives a federal blender tax credit of 54 cents per gallon. The ethanol blender tax credit is not a road-use tax and is separate from this discussion.

[**] Highway fuel taxes in New York State include a petroleum business tax, an excise tax, State sales tax (4.0%), and local sales tax (0 to 4.2%). The petroleum business and excise taxes are assessed on a per-gallon basis, while the sales taxes are assessed on the total of fuel cost plus the petroleum business and the State excise taxes. The data of Table L.1 assume a maximum local sales tax of 4.2% and typical wholesale fuel prices in New York State.

In addition, natural gas is subject to section 186 and 186a taxes of 0.75 and 3.5% of the selling price of the natural gas (without other federal or state taxes). In NYC a 17% MTA surcharge is levied on the 186 and 186a taxes (17% surcharge on the 4.25% tax, raising the total to 4.9725%). In addition, NYC adds its own 186 style tax of 2.35%. Sales taxes are charged on the all the 186 style taxes. The pricing in this section assumes all sales are occurring in NYC, where all of the above described surcharges are added.

Table L.1 Federal, State, and Local Taxes on Highway Fuels in New York State

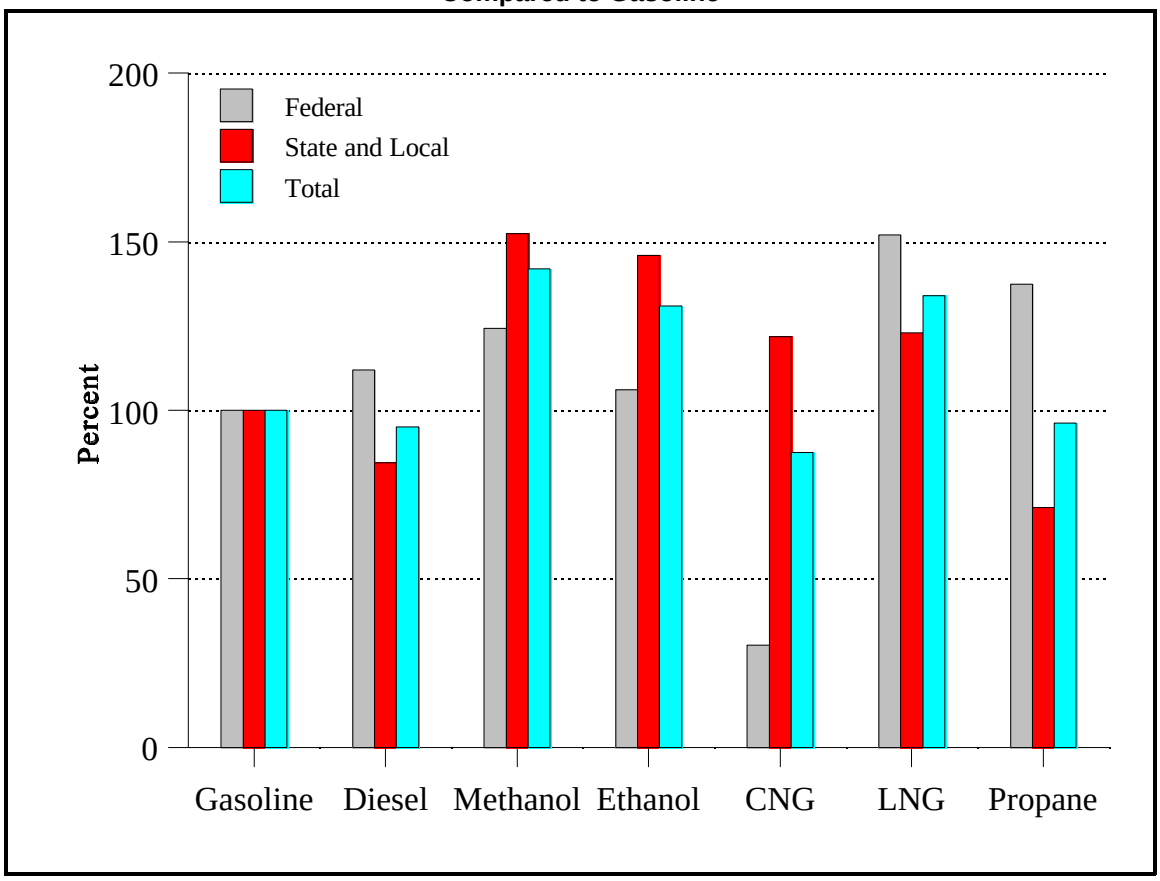
	Federal Taxes			State and Local Taxes		
		Per Gasoline-Equivalent Gallon[1]			Per Gasoline-Equivalent Gallon[1]	
	Cents Per Gallon	Cents Per Gallon	% of Gasoline	Cents Per Gallon	Cents Per Gallon	% of Gasoline
Gasoline	18.4	18.4	100.0	30.1	30.1	100.0
Diesel Fuel	24.4	20.6	112.0	30.1	25.5	84.4
Methanol	11.4	22.9	124.3	22.9	45.9	152.4
Ethanol	13.0	19.5	106.0	29.3	44.0	146.0
CNG	5.6	5.6[2]	30.4	36.8	36.8	121.9
LNG	18.4	28.0	152.0	24.4	37.1	122.9
Propane	18.3	25.3	137.4	15.5	21.4	71.1

[1] Calculations based on lower heating value (LHV) of each fuel.
[2] Because CNG is not a liquid, the gallon-equivalency of CNG was defined by legislation for taxing purposes.

Table L.2 Total Taxes on Highway Fuels in New York State (cents per gallon)

Fuel	Per Gallon			Gasoline Gallon-Equivalent		
	Federal	State and Local	Total	Federal	State and Local	Total
Gasoline	18.4	30.1	48.5	18.4	30.1	48.5
Diesel Fuel	24.4	30.1	54.5	20.6	25.5	46.1
Methanol	11.4	22.9	34.3	22.9	45.9	68.8
Ethanol	13.0	29.3	42.3	19.5	44.0	63.5
CNG	5.6	36.8	42.4	5.6	36.8	42.4
LNG	18.4	24.4	42.8	28.0	37.0	65.0
Propane	18.3	15.5	33.8	25.3	21.4	46.7

Figure L.1 Highway Fuel Taxes in New York State, on an Energy Basis Compared to Gasoline



APPENDIX M

ZERO-EMISSION VEHICLE TECHNOLOGY ASSESSMENT

New York State adopted the California Low Emission Vehicle (LEV) program that includes a sales mandate for ZEVs starting in 1998. The New York State Department of Environmental Conservation (DEC) was required to perform a technology review of zero-emission vehicles (ZEVs) by the amendments to 6NYCRR Part 218, February 1992. NYSERDA entered into a cooperative agreement (Contract 2000-ERER-ER-93) with DEC on September 3, 1992, to carry out this study. Following a review of proposals submitted in response to a solicitation, Booz•Allen & Hamilton was selected to perform the study.

The Final Report [1] presents an overview of technology as of the spring of 1995, and a projection of technology status over the next 10 years. Booz•Allen wrote the final report, and performed the following tasks as part of the assessment: assembled a database of key ZEV organizations, their products or services, and plans; described the current state of ZEV technologies; identified barriers to widespread ZEV deployment and projected future ZEV technical capabilities; and estimated the cost of ZEVs from 1998 to 2004.

Data for the ZEV Technology Assessment were obtained from several sources, including the following: existing ZEV industry publications and Booz•Allen files; major automotive original equipment manufacturers; independent electric vehicle manufacturers; battery developers and manufacturers; infrastructure and component developers and manufacturers; the U.S. Department of Energy, the California Air Resources Board, and other concerned government agencies; trade associations such as the Electric Power Research Institute and the Electric Transportation Coalition; and public and private consortia. These sources were contacted by phone, mail, or in person. Some site visits of manufacturers were also conducted. Where possible, raw data were analyzed by Booz•Allen staff and/or verified by independent sources. Performance data from standardized test cycles were used as much as possible.

Findings and conclusions are summarized as follows:

- Vehicle range and cost, associated primarily with battery performance, will most likely continue to be an impediment to EV competitiveness with gasoline-powered vehicles through the study period (1994-2004). Although incremental improvements in battery performance are occurring, significant breakthroughs will be required to fully mitigate the cost and range issues.

- Cold-weather effects on vehicle performance can likely be minimized through appropriate design using existing technologies. However, such measures will require that EVs operated in New York be different than those operated in California.

- Infrastructure to support EV use in New York State is currently inadequate. Infrastructure issues include recharging facilities, standards for plugs and cords,

public education, battery recycling, safety training, vehicle registration, insurance coverage, and the cost of infrastructure development and implementation.

- Adequate lead time is required to provide the necessary infrastructure and vehicle production volume. Major vehicle manufacturers, small vehicle conversion facilities, and motor/controller manufacturers must quickly establish or expand production facilities to meet production volume goals for 1998.

REFERENCES:

1. Booz•Allen & Hamilton Inc., "Zero-Emission Vehicle Technology Assessment - Final Report," prepared for the New York State Energy Research and Development Authority, Report No. 95-11, August 1995.

ADDENDUM: DIRECTORY OF ALTERNATIVE FUEL INFORMATION SOURCES

The following directory is excerpted from **Alternative Fuel Sources**, published for the United States Department of Energy (U.S. DOE) by Argonne National Laboratory, and has been supplemented by NYSERDA to include additional listings that provide a sharper focus on New York State. For additional information about the U.S. DOE source document, call the U.S. DOE Alternative Fuels Hotline: 800-423-1363.

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ORGANIZATIONS

AUTOMOTIVE

American Automobile Association
1000 AAA Drive, Heathrow, FL 32746-5063 407-444-7000

American Automobile Manufacturers Association
1401 H St., N.W., Suite 900, Washington, DC 20005 202-326-5500

American Trucking Associations
2200 Mill Road, Alexandria, VA 22314-4677 703-838-1966

Association of International Automobile Manufacturers, Inc.
1001 19th St., North, Suite 1200, Arlington, VA 22209 703-525-7788

Chrysler Corporation
800 Chrysler Drive East, Auburn Hills, MI 48326-2757
Alternative Fuel Hotline 800-255-2616

Ford Motor Company
The American Road, Dearborn, MI 48121-1899
Alternative Fuel Hotline 1-800-ALT-FUEL

General Motors Corporation
3044 West Grand Blvd., Detroit, MI 48202
General Information Hotline 1-888-GM-CFT-4U, 1-800-CHEV-USA

Motor & Equipment Manufacturers Association
P.O. Box 13966, Research Triangle Park, NC 27709 919-549-4800

National Association of Fleet Administrators
100 Wood Ave., South Suite 310, Iselin, NJ 08830 732-494-8100

National Automobile Dealers Association
8400 Westpark Drive, McLean, VA 22102-3591 703-821-7000

Society of Automotive Engineers
400 Commonwealth Drive, Warrendale, PA 15096-0001
Publications Department 412-776-4970

BIODIESEL and OTHER BIO-OILS

American Biofuels Association
1925 N. Lynn St., Suite 1050, Arlington, VA 22209 703-522-3392

Biofuels America
26 Lorin Dee Drive, Westerlo, NY 12193-9801 518-797-3377

National Renewable Energy Laboratory
1617 Cole Blvd., Golden, CO 80401-3393 . . . . . 303-275-4347/4481

National Biodiesel Board
P.O. Box 104898, Jefferson City, MO 65110 . . . . . 800-841-5849, 573-635-3893

New York State Department of Environmental Conservation
Division of Air Resources, 50 Wolf Road, Albany, NY 12233-3250
Mobile Sources 518-485-8913

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399
Energy Resources Program . . . . . 518-862-1090, ext. 3288
Transportation Program . . . . . 518-862-1090, ext. 3258

Oak Ridge National Laboratory
P.O. Box 2008, Oak Ridge, TN 37831 423-574-7818

State University of New York — College of Environmental Science & Forestry
Bray Hall, Syracuse, NY 13210
Dean of Research 315-470-6606

U.S. Department of Agriculture – Office of Energy and New Uses
1301 New York Ave., N.W., Room 1212, Washington, DC 20005-4788 202-219-1941

U.S. Department of Energy – Office of Fuels Development
1000 Independence Ave., S.W., Washington, DC 20585
Biodiesel Program 202-586-4898
Biofuels Systems Integration 202-586-4898
Biochemical Conversion 202-586-5618

U.S. Environmental Protection Agency
National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
Fuels Regulatory Issues 313-668-4432
Biodiesel 202-233-9034

CERTIFICATION and TRAINING PROGRAMS

Automotive Training Managers Council
13505 Dulles Technology Drive, Herndon, VA 22071 703-713-1113

National Automotive Technicians Education Foundation
13505 Dulles Technology Drive, Herndon, VA 22071 703-713-0100

National Institute for Automotive Service Excellence
13505 Dulles Technology Drive, Herndon, VA 22171
Certification Registration Information 703-713-3800

North American Council of Automotive Teachers
11956 Bernardo Plaza Drive, Dept. 436, San Diego, CA 92128 619-487-8126

U.S. Department of Energy
1000 Independence Ave., S.W., Washington, DC 20585
Training Programs 202-586-7694

CLEAN DIESEL

American Petroleum Institute
1220 L St., N.W., Ninth Floor, Washington, DC 20005 202-682-8000

American Trucking Associations – Trucking Research Institute
2200 Mill Road, Alexandria, VA 22314-4677 703-838-1966

California Air Resources Board
P.O. Box 2815, Sacramento, CA 95812 916-322-6019

New York State Department of Environmental Conservation
Division of Air Resources, 50 Wolf Road, Albany, NY 12233-3250
Mobile Sources 518-485-8913

U.S. Environmental Protection Agency
National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
Fuels Regulatory Issues 313-668-4432

ELECTRIC and HYBRID-ELECTRIC

CALSTART
3601 Empire Ave., Burbank, CA 91505 818-565-5600

Electric Auto Association
2710 St. Giles Lane, Mountainview, CA 94040 800-537-2882

Electric Power Research Institute
3412 Hillview Avenue, P.O. Box 10412, Palo Alto, CA 94303
General 415-855-2000
Electric Vehicles 415-855-2644

Electric Transportation Coalition
701 Pennsylvania Ave., N.W., Fourth Floor, Washington, DC 20004 202-508-5995

Electric Vehicle Association of the Americas
601 California St., Suite 502, San Francisco, CA 94108 415-249-2690

Electric Vehicle Association
9140 Centerway Drive, Gaithersburg, MD 20879 301-869-4954

Empire State Electric Energy Research Corporation
1515 Broadway, 43rd Floor, New York, NY 10036 212-302-1212

The Energy Association of New York State
111 Washington Avenue, Suite 601, Albany, NY 12210 518-449-3440

Federal Transit Administration
400 7th Street, SW, Washington, DC 20590
Office of Technology 202-366-0212

General Motors Corporation
3044 West Grand Blvd., Detroit, MI 48202 . . . . . 1-800-25-ELECTRIC, 1-800-222-1020

National Renewable Energy Laboratory
1617 Cole Blvd., Golden, CO, 80401-3393
Renewable Systems Applications & Analysis 303-384-7331
Transportation Systems 303-275-4434

New York State Department of Environmental Conservation
Division of Air Resources, 50 Wolf Road, Albany, NY 12233-3250
Mobile Sources 518-485-8913

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399
Transportation Program . . . . . 518-862-1090, ext. 3258

New York State Technology Enterprise Corporation
75 Electronic Parkway, Suite 2, Rome, NY 13441-4505
Alternative Fuel Technology Center 315-338-5818

Northeast Sustainable Energy Association
50 Miles St., Greenfield, MA 01301
Director, Tour de Sol 413-774-6051

Partnership for a New Generation of Vehicles
U.S. Department of Commerce
14th Street & Constitution Avenue, N.W., Room 4845, Washington, DC 20230
PNGV Government Technical Task Force 202-482-6260

U.S. Advanced Battery Consortium 810-680-5536
External Affairs Officer 313-390-5589

U.S. Department of Defense – Advanced Research Projects Agency
3701 N. Fairfax Drive, Arlington, VA 22203-1714 703-351-8470

U.S. Department of Energy
1000 Independence Ave., S.W., Washington, DC 20585
Office of Advanced Automotive Technologies 202-586-3388

EMISSIONS

American Lung Association
1640 Broadway, New York, NY 10019-4374 212-315-8700

California Air Resources Board
9528 Telstar Ave., El Monte, CA 97131
Mobile Source Division 818-575-6845

Colorado Department of Public Health & Environment
Air Pollution Control Division
15608 East 18th Ave., Aurora, CO 80011
Emission Technical Center 303-364-4135

Environmental Advocates
353 Hamilton Street, Albany, NY 12210 518-462-5526

Environmental Business Association of New York
1223 Peoples Avenue, Troy, NY 12180 518-276-2164

Environmental Defense Fund, Inc.
275 Park Avenue South, New York, NY 10010-7304 212-505-2100
1875 Connecticut Avenue, NW, Washington, DC 20009 202-387-3500

Natural Resources Defense Council
40 West 20th Street, New York, NY 10011 212-727-4454
1350 New York Avenue, N.W., Washington, D.C. 20005 202-783-7800

New York City Department of Environmental Protection
59-17 Junction Boulevard, Elmhurst, NY 11373-5107 718-595-6579
Office of Air Policy 718-595-3627
Mobile Systems (emissions lab, 75 Frost St., Brooklyn) 718-388-4994

New York City Department of Transportation
40 Worth Street, New York, NY 10013
Alternative Fuel Programs 212-442-0543

New York State Department of Environmental Conservation
Division of Air Resources, 50 Wolf Road, Albany, NY 12233-3250
Mobile Sources 518-485-8913

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399
Environmental Research . . . . . 518-862-1090, ext. 3205

Northeast States for Coordinated Air Use Management
129 Portland Street, Boston, MA 02114 617-367-8540

Ozone Transport Assessment Group
c/o Maine Department of Environmental Protection 207-287-2812

Ozone Transport Commission
444 N. Capital Street NW, Suite 638, Washington, D.C. 20001 202-508-3840

Sierra Club
85 Second Street., Second Floor, San Francisco, CA 94105-3441 415-977-5500

South Coast Air Quality Management District
21865 East Copley Drive, Diamond Bar, CA 91765-4182
Technology Advancement Office General Line 909-396-3300

U.S. Environmental Protection Agency
National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
General 313-668-4333
Methanol 313-668-4296
Electric Vehicles 313-668-4310
Ethanol 313-668-4432
CNG 313-668-4275
RFG 313-668-4432
Propane 313-741-7826
Emissions reports 313-668-4516
Health Effects 313-741-7827
Clean Fuel Vehicle Standards 313-668-4310

West Virginia University Mechanical & Aerospace Engineering Department – Mobile Emissions Lab
P.O. Box 6106, Morgantown, WV 26506-6106 . . . . . 304-293-3111 (ext. 313)

ETHANOL

American Biofuels Association
1925 N. Lynn St., Suite 1050, Arlington, VA 22209 703-522-3392

Biofuels America
26 Lorin Dee Drive, Westerlo, NY 12193-9801 518-797-3377

Bureau of Alcohol, Tobacco and Firearms
650 Massachusetts Ave., N.W., Washington, DC 20226
Alcohol and Tobacco Programs Division 202-927-8476

Clean Fuels Development Coalition
1925 N. Lynn St., Suite 725, Arlington, VA 22209 703-276-2332

Governors' Ethanol Coalition
Nebraska State Energy Office
P.O. Box 95085, Lincoln, NE 68509 402-471-2867

National Corn Growers Association
1000 Executive Parkway, Suite 105, St. Louis, MO 63141 314-275-9915

National Renewable Energy Laboratory
1617 Cole Blvd., Golden, CO 80401-3393 . . . . . 303-275-3803, 303-384-6820

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399
Energy Resources Program . . . . . 518-862-1090, ext. 3288
Transportation Program . . . . . 518-862-1090, ext. 3258

Northeast Regional Biomass Energy Program
CONEG Policy Research Center Inc., 400 N. Capitol St., N.W.
Suite 382, Washington, DC 20001 202-624-8450

Oak Ridge National Laboratory
P.O. Box 2008, Oak Ridge, TN 37831
Biofuels 423-574-7818

Renewable Fuels Association
One Massachusetts Ave., N.W., Suite 820, Washington, DC 20001 202-289-3835

U.S. Department of Agriculture – Office of Energy and New Uses
1301 New York Ave., N.W., Room 1212, Washington, DC 20005-4788 202-219-1941

U.S. Department of Energy – Office of Fuels Development
1000 Independence Ave., S.W., Washington, DC 20585
Ethanol Program 202-586-1707
Regional Biomass Energy Program 202-586-1480

U.S. Environmental Protection Agency
National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105 313-668-4332

FEDERAL PROGRAMS

Alternative Fuels Utilization Program
U.S. Department of Energy, Office of Technology Utilization
1000 Independence Ave., S.W., Washington, DC 20585 202-586-7182

Clean Cities Program
U.S. Department of Energy, Office of Technology Utilization
1000 Independence Ave., S.W., Washington, DC 20585
Program Coordinator 202-586-1885

National Clean Cities Hotline
P.O. Box 12316, Arlington, VA 22209 . . . . . 703-528-1222, 800-224-8437

Clean Cities Contacts in New York State

New York State Energy Research and Development Authority
Ruth M. Horton, Program Manager . . . . . 518-862-1090, ext. 3306
NYSERDA, Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399

Coordinators in Areas Officially Designated by DOE

City of White Plains
Joseph Nicoletti Jr., Coordinator 914-422-1210
Department of Public Works, 255 Main Street, White Plains, NY 10601

Clean Communities of Central New York
Joe Barry, Coordinator 315-422-5716
c/o Syracuse Metropolitan Transportation Commission
100 Clinton Square, 126 North Salina Street, Syracuse, NY 13202

Clean Communities of Western New York
William A. Pauly, Coordinator 716-836-0198
3131 Sheridan Drive, Amherst, NY 14226

Greater Long Island Clean Cities Coalition
Mark Noonan, Coordinator 516-853-6007
Long Island Regional Planning Board, 220 Rabro Drive, Happauge, NY 11788-4253

Coordinators in Areas Awaiting Designation or in Planning Stages

Capital Region Clean Communities
Tom Paolicelli, Coordinator 518-388-4355
Schenectady County Manager's Office, 620 State Street, Schenectady, NY 12305

Genesee Region Clean Communities
Paul Heaney, Coordinator 716-889-9516
6 Gateway Circle, Rochester, NY 14624-4415

New York City
Mark Simon, Director of Alternative Fuel Programs 212-442-0543
New York City Department of Transportation
40 Worth Street, Room 1002, New York, NY 10013

National Alternative Fuels Hotline
P.O. Box 12316, Arlington, VA 22209 . . . . . 800-423-1DOE, 703-528-3500

National Technical Information Service
5285 Port Royal Road, Springfield, VA 22161
Document Orders 703-487-4650
Document Research 703-487-4780

Partnership for a New Generation of Vehicles
U.S. Department of Commerce
14th Street & Constitution Avenue, N.W., Room 4845, Washington, DC 20230
PNGV Government Technical Task Force 202-482-6260

U.S. Department of Agriculture – Office of Energy and New Uses
1301 New York Ave., N.W., Room 1212, Washington, DC 20005-4788 202-219-1941

U.S. Department of Defense – Advanced Research Projects Agency
3701 N. Fairfax Drive, Arlington, VA 22203-1714 703-351-8470

U.S. Department of Energy – Office of Fuels Development
1000 Independence Ave., S.W., Washington, DC 20585
Alternative Fuel Engine Systems 202-586-8044
Biodiesel Program 202-586-4898
Ethanol Program 202-586-1707
National Energy Information Center 202-586-8800
Office of Advanced Automotive Technologies 202-586-8055
Regional Biomass Energy Program 202-586-1480
Training Programs 202-586-7694
Transit Bus Program 202-586-8031

U.S. Environmental Protection Agency
401 M St., S.W., FE (6406J), Washington, DC 20460
Oxy-Fuel Program 202-233-9036
Oxygenated Gasoline 202-233-9004

U.S. Environmental Protection Agency National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
RFG/Renewable Oxygenates 313-668-4432
Simple/Complex Models 313-668-4507

U.S. Department of Transportation – Federal Highway Administration
400 Seventh St., S.W., Washington, DC 20590
Intermodal Surface Transportation Efficiency Act 202-366-2311
Congestion Mitigation & Air Quality Improvement Program Funds 202-366-2080
Local Transit Authorities, Alternative Fuels Initiative Program (TR-20) 202-366-0241

U.S. Environmental Protection Agency National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
Clean Fuel Fleet Program 313-668-4310

U.S. Library of Congress
Congressional Research Service, Washington, DC 20540
Environmental Policy 202-707-7228

FLEETS

National Association of Fleet Administrators
100 Wood Ave., South Suite 310, Iselin, NJ 08830-2709 732-494-8100

U.S. Environmental Protection Agency National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
Clean Fuel Fleet Program 313-668-4310

U.S. General Services Administration
1941 Jefferson Davis Highway, Arlington, VA 22202 703-308-1457

U.S. Postal Service, Engineering Support Center
8403 Lee Highway, Merrifield, VA 22082
Alternative Fuel Vehicles 703-280-7138

FUEL CELLS

Fuel Cell Institute
P.O. Box 65481, Washington, DC 20035-5482 301-681-3532

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399
Transportation Program . . . . . 518-862-1090, ext. 3258

U.S. Department of Energy
1000 Independence Ave., S.W., Washington, DC 20585
Office of Advanced Automotive Technologies 202-586-3388

GENERAL

Brookhaven National Laboratory
Upton, NY 11973
Energy Applications Group 516-344-7917

Bureau of Internal Revenue Service
1111 Constitution Ave., N.W., Washington, DC 20224
Alternative Fuel Taxes 202-622-3110
Alcohol Fuel Taxes 202-622-3130
Toll-Free Order Desk – Publication #535 —
Alternative Fuel Vehicle Tax Deduction Booklet 800-829-3676

California Air Resources Board
Innovative Clean Air Technologies Program
P.O. Box 2851, Sacramento, CA 95812
Research Division 916-323-1511

California Energy Commission
1516 Ninth St., MS-41, Sacramento, CA 95814
Transportation and Fuels 916-654-4638

Clean Fuels Development Coalition
7315 Wisconsin Ave., East Tower – Suite 515, Bethesda, MD 20814 301-913-9636

Coalition of Northeastern Governors
400 North Capital Street, NW, Suite 382, Washington, DC 20001
Policy Research Center 202-624-8450

The Energy Association of New York State
111 Washington Avenue, Suite 601, Albany, NY 12210 518-449-3440

Energy Efficiency & Renewable Energy Clearinghouse
P.O. Box 3048, Merrifield, VA 22116 . . . . . 800-DOE-EREC

Federal Transit Administration
400 7th Street, SW, Washington, DC 20590
Office of Technology 202-366-0212

INFORM, Inc.
120 Wall Street, 16th Floor, New York, NY 10005-4001 212-361-2400

National Alternative Fuels Hotline
P.O. Box 12316, Arlington, VA 22209 . . . . . 800-423-1DOE, 703-528-3500

National Fire Protection Association
1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101 617-770-3000

National Renewable Energy Laboratory
1617 Cole Blvd., Golden, CO 80401-3393 303-275-3000

National Technical Information Service
5285 Port Royal Road, Springfield, VA 22161
Document Orders 703-487-4650
Document Research 703-487-4780

New York City Department of Transportation
40 Worth Street, New York, NY 10013
Alternative Fuel Programs 212-442-0543

New York State Department of Environmental Conservation
Division of Air Resources, 50 Wolf Road, Albany, NY 12233-3250
Mobile Sources 518-485-8913

New York State Department of Motor Vehicles
Swan Street Building, Empire State Plaza, Albany, NY 12228
Technical Services 518-474-4279

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Extension, Albany, NY 12203-6399
General 518-862-1090
Publications . . . . . 518-862-1090, ext. 3241
Transportation Program . . . . . 518-862-1090, ext. 3258
Energy Resources Program . . . . . 518-862-1090, ext. 3288

Clean Cities Program . . . . . 518-862-1090, ext. 3306

New York State Technology Enterprise Corporation
75 Electronic Parkway, Suite 2, Rome, NY 13441-4505
Alternative Fuel Technology Center 315-338-5818

Office of Scientific & Technical Information
P.O. Box 62, Oak Ridge, TN 37831 423-576-8401

Society of Automotive Engineers
400 Commonwealth Drive, Warrendale, PA 15096-0001
Publications Department 412-776-4970

South Coast Air Quality Management District
21865 East Copley Drive, Diamond Bar, CA 91765-4182
Technology Advancement Office General Line 909-396-3300

U.S. Department of Energy
1000 Independence Ave., S.W., Washington, DC 20585
National Energy Information Center 202-586-8800

U.S. Department of Transportation – Federal Highway Administration
400 Seventh St., S.W., Washington, DC 20590
Intermodal Surface Transportation Efficiency Act 202-366-2311
Congestion Mitigation & Air Quality Improvement Program Funds 202-366-2080
Local Transit Authorities, Alternative Fuels Initiative Program (TR-20) 202-366-0241

U.S. Library of Congress
Congressional Research Service, Washington, DC 20540
Environmental Policy 202-707-7228

HEAVY-DUTY ENGINES

American Bus Association
1100 New York Ave., N.W., Suite 1050, Washington, DC 20005-3945 202-842-1645

American Trucking Associations – Trucking Research Institute
2200 Mill Road, Alexandria, VA 22314-4677 703-838-1966

Engine Manufacturers Association
401 N. Michigan Ave., Chicago, IL 60611 312-644-6610

Heavy-Duty Manufacturers Association
P.O. Box 13966, Research Triangle Park, NC 27709-3966 919-549-4800

New York State Department of Environmental Conservation
Division of Air Resources, 50 Wolf Road, Albany, NY 12233-3250
Mobile Sources 518-485-8913

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399
Transportation Program . . . . . 518-862-1090, ext. 3258

U.S. Department of Energy – Office of Heavy Vehicle Technologies
1000 Independence Ave., S.W., Washington, DC 20585
Alternative Fuel Engine Systems 202-586-8044

U.S. Department of Transportation – Federal Highway Administration
400 Seventh St., S.W., Washington, DC 20590
Intermodal Surface Transportation Efficiency Act 202-366-2311
Local Transit Authorities, Alternative Fuel Initiatives Program (TR-20) 202-366-0241

U.S. Environmental Protection Agency National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
General 313-668-4333
Standards (Non-Road Vehicles) 202-233-9276
Buses 313-668-4270

HYDROGEN

American Hydrogen Association
216 S. Clark Drive, MS 103, Tempe, AZ 85281 602-921-0433

National Hydrogen Association
1800 M St., N.W., Washington, DC 20036-5802 202-223-5547

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399
Transportation Program . . . . . 518-862-1090, ext. 3258

U.S. Department of Energy – Heavy Vehicle Technologies
1000 Independence Ave., S.W., Washington, DC 20585
Atmospheric Reactions 202-586-6745

LPG/PROPANE

National Propane Gas Association (IL)
1600 Eisenhower Lane, Lisle, IL 60532 630-515-0600

National Propane Gas Association (DC)
1101 17th St., N.W., Suite 1004, Washington, DC 20036 202-466-7200

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399
Transportation Program . . . . . 518-862-1090, ext. 3258

New York Propane Gas Association
P.O. Box 5006, Albany, NY 12205 518-478-7227

Propane Vehicle Council
1101 17th St., N.W., Suite 1004, Washington, DC 20036 202-530-0479

U.S. Environmental Protection Agency National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
Propane 313-741-7826

Western Propane Gas Association
Sunrise Professional Center, 7844 Madison Ave., Suite 150, Fair Oaks, CA 95628 916-962-2280

METHANOL

American Methanol Institute
800 Connecticut Ave., N.W., Suite 620, Washington, DC 20006 202-467-5050

Canadian Oxygenated Fuels Association
55 Metcalfe St., Suite 800, Ottawa, Ontario, CANADA K1P 6L5 613-596-2846

New York City Department of Transportation
40 Worth Street, New York, NY 10013
Alternative Fuel Programs 212-442-0543

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399
Energy Resources Program . . . . . 518-862-1090, ext. 3288
Transportation Program . . . . . 518-862-1090, ext. 3258

U.S. Environmental Protection Agency National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
Methanol 313-668-4296

NATURAL GAS VEHICLES (CNG and LNG)

American Gas Association
1515 Wilson Blvd., Arlington, VA 22209 703-841-8660

Brookhaven National Laboratory
Upton, NY 11973
Energy Applications Group 516-344-7917

Brooklyn Union
One MetroTech Center, Brooklyn, NY 11201-3850
Information 718-403-3240

Canadian Gas Association
243 Consumers Road, Suite 1200, North York, Ontario, CANADA M2J 5E3
Canadian Natural Gas Vehicle Alliance, NGV Development 416-498-1994

Canadian Gas Research Institute
55 Scarsdale Road, Don Mills, Ontario, CANADA M3B 2R3
Senior Engineer 416-447-6661

Compressed Gas Association, Inc.
Crystal Square 2, Suite 1004
1725 Jefferson Davis Highway, Arlington, VA 22202-4102 . . . . . 703-412-0900 (ext. 712)

European Natural Gas Vehicle Association
Spaklerweg 28, 1096 BA Amsterdam, The Netherlands 31-20-597-3100
(e-mail: engva@euronet.nl)

Federal Transit Administration
400 7th Street, SW, Washington, DC 20590
Office of Technology 202-366-0212

Gas Research Institute
8600 W. Bryn Mawr Ave., Chicago, IL 60631
NGV Business Unit 773-399-8235

Institute of Gas Technology
1700 S. Mount Prospect Road, Des Plaines, IL 60018 . . . . . 847-768-0500, 847-768-0501

International Association for Natural Gas Vehicles
PO Box 28-590, Auckland, New Zealand 64-9-523-3567
(e-mail: iangv@iangv.org.nz)

National Renewable Energy Laboratory
1617 Cole Blvd., Golden, CO 80401-3393
Transportation Technology 303-275-4468

Natural Gas Vehicle Coalition
1515 Wilson Blvd., Suite 1030, Arlington, VA 22209 703-527-3022

Natural Gas Vehicle Producers Association
113 S. West St., 4th Floor, Alexandria, VA 22314 703-838-2941

New York City Department of Transportation
40 Worth Street, New York, NY 10013
Alternative Fuel Programs 212-442-0543

New York Gas Group
500 Fifth Avenue, Suite 1650, New York, NY 10110 212-354-4790

New York State Energy Research and Development Authority
Corporate Plaza West, 286 Washington Avenue Ext., Albany, NY 12203-6399
Energy Resources Program . . . . . 518-862-1090, ext. 3288
Transportation Program . . . . . 518-862-1090, ext. 3258

New York State Technology Enterprise Corporation
75 Electronic Parkway, Suite 2, Rome, NY 13441-4505
Alternative Fuel Technology Center 315-338-5818

Society of Automotive Engineers
400 Commonwealth Drive, Warrendale, PA 15096-0001
Staff Engineer 412-772-7159

U.S. Department of Energy – Office of Heavy Vehicle Technologies
1000 Independence Ave., S.W., Washington, DC 20585
Transit Bus Program 202-586-8031

U.S. Environmental Protection Agency National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
CNG 313-668-4275

REFORMULATED GASOLINE

American Automobile Manufacturers Association
1401 H St., N.W., Suite 900, Washington, DC 20005 202-326-5500

American Methanol Institute
800 Connecticut Ave. N.W., Suite 620, Washington, DC 20006 202-467-5050

American Petroleum Institute
1220 L St., N.W., Ninth Floor, Washington, DC 20005 202-682-8000

Canadian Oxygenated Fuels Association
55 Metcalfe St., Suite 800, Ottawa, Ontario, CANADA K1P 6L5 613-596-2846

Coordinating Research Council
219 Perimeter Center Parkway, Suite 400, Atlanta, GA 30346 770-396-3400

National Petroleum Council
1625 K St., N.W., Suite 600, Washington, DC 20006 202-393-6100

National Petroleum Refiners Association
1899 L St., N.W., Suite 1000, Washington, DC 20036
Technical Department 202-457-0480

National Reformulated Gasoline Hotline
1925 N. Lynn St., Suite 1090, Arlington, VA 22209 . . . . . 703-841-9674, 1-800-GO-TO-RFG

New York State Department of Environmental Conservation
Division of Air Resources, 50 Wolf Road, Albany, NY 12233-3250
Mobile Sources 518-485-8913

Oxygenated Fuels Association
1300 N. 17th St., Suite 1850, Arlington, VA 22209 703-841-7100

U.S. Environmental Protection Agency
401 M St., S.W., FE (6406J), Washington, DC 20460
Oxy-Fuel Program 202-233-9036
Oxygenated Gasoline 202-233-9004

U.S. Environmental Protection Agency National Vehicle & Fuel Emissions Laboratory
2565 Plymouth Road, Ann Arbor, MI 48105
RFG/Renewable Oxygenates 313-668-4432
Simple/Complex Models 313-668-4507

PERIODICALS

AFDC Update (quarterly newsletter)
National Alternative Fuels Hotline, 1925 N. Lynn St., Suite 1080, Arlington, VA 22209
Toll-Free 800-423-1353
Local 703-528-3500

Alternative Fuels Today (newsletter)
Environmental Information Networks, Inc., 119 S. Fairfax St., Alexandria, VA 22314
Circulation 703-683-0774

Alternative Fuels in Trucking
Trucking Research Institute, 2200 Mill Road, Alexandria, VA 22314-4677
Circulation 703-838-1966

Automotive Engineering
SAE International, 400 Commonwealth Drive, Warrendale, PA 15096 412-776-4841

Biodiesel Alert (monthly newsletter)
American Biofuels Association, 1925 N. Lynn St., Suite 1050, Arlington, VA 22209
Circulation 703-522-3392

BPN's Weekly Propane Newsletter
Butane-Propane News, 338 E. Foothill Blvd., Arcadia, CA 91006
P.O. Box 660698, Arcadia, CA 91066
Circulation 818-357-2168

Butane-Propane News (monthly magazine)
BPN, Inc., 338 E. Foothill Blvd., Arcadia, CA 91006
Circulation 818-357-2168

Clean Fuels Report (5/yr. magazine)
J.E. Sinor Consultants, Inc., P.O. Box 649, Niwot, CO 80544
Circulation 303-652-2632

Clean Fuel Vehicle Week
Energy West, 1709 Avenue Salvador, San Clemente, CA 92672
Circulation 714-492-1340

Coal & Synfuels News
Pasha Publications, 1616 N. Ft. Myer Drive, Suite 1000, Arlington, VA 22209
Circulation 800-424-2908, 703-528-1244

Diesel Progress North American Edition
Diesel & Gas Turbine Publications, 13555 Bishop's Court, Brookfield, WI 53005-6286
Publication Headquarters 414-784-9177

Electric Vehicles Today (newsletter)
Environmental Information Networks, Inc., 119 S. Fairfax St., Alexandria, VA 22314
Circulation 703-683-0774

Electrifying Times
ET, 63600 Deschutes Market Road, Bend, OR 97701
Circulation 541-388-1908

ETVI Current
Electric Transit Vehicle Institute, 1617-B Wilcox Blvd., Chattanooga, TN 37406
Circulation 423-622-3884

Fast Tracks
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