CleanFleet
FINAL REPORT

December 1995

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Glossary

ACGIH	=	American Conference of Government and Industrial Hygienists
ADP	=	Adaptive digital processing
AFE	=	Advanced fuel electronics
AFV	=	Alternative fuel vehicle
ARB	=	California Air Resources Board
CAAA	=	Clean Air Act Amendments
CNG	=	Compressed natural gas
EV	=	Electric vehicle
NGV	=	Natural gas vehicle
NiCd	=	Nickel cadmium
NMOG	=	Nonmethane organic gases
OEM	=	Original equipment manufacturer
OFP	=	Ozone forming potential
OSHA	=	Occupational Safety and Health Administration
PbA	=	Lead acid
RFG	=	California Phase 2 reformulated gasoline
SMPI	=	Sequential multiport fuel injection
UNL	=	Unleaded gasoline (used in control vans)

EXECUTIVE SUMMARY

Introduction

CleanFleet, formally known as the South Coast Alternative Fuels Demonstration, was a comprehensive demonstration of alternative fuel vehicles (AFVs) in daily commercial service. The project was sponsored by a group of major public-private sector organizations (Table 1). Between April 1992 and September 1994, five alternative fuels were tested in 84 panel vans: compressed natural gas (CNG), propane gas, methanol as M-85, California Phase 2 reformulated gasoline (RFG), and electricity. The AFVs were used in normal FedEx package delivery service in the Los Angeles basin (Figure 1) alongside 27 “control” vans operating on regular gasoline.

The liquid and gaseous fuel vans were model year 1992 vans from Ford, Chevrolet, and Dodge. The two electric vehicles (EVs) were on loan to FedEx from Southern California Edison. The AFVs represented a snapshot in time of 1992 technologies that (1) could be used reliably in daily FedEx operations and (2) were supported by the original equipment manufacturers (OEMs). A typical van is shown in Figure 2.

The objective of the project was to demonstrate and document the operational, emissions, and economic status of alternative fuel, commercial fleet delivery vans in the early 1990s for meeting air quality regulations in the mid to late 1990s.

During the two-year demonstration, CleanFleet’s 111 vehicles travelled more than three million miles and provided comprehensive data on three major topics (Table 2): fleet operations, emissions, and fleet economics. Fleet operations were examined in detail to uncover and resolve problems with the use of the fuels and vehicles in daily delivery service. Exhaust and evaporative emissions were measured on a subset of vans as they accumulated mileage. The California Air Resources Board (ARB) measured emissions to document the environmental benefits of these AFVs. At the same time, CleanFleet experience was used to estimate the costs to a fleet operator using AFVs to achieve the environmental benefits of reduced emissions.

Table 1. CleanFleet Sponsors

Organization	Role
South Coast Air Quality Management District	Host, Project Oversight
U.S. DOE/National Renewable Energy Laboratory	Federal Demonstration Oversight
U.S. Environmental Protection Agency	Technical Oversight — Emissions
California Energy Commission	Vehicle Financial Support
California Air Resources Board	Vehicle Emission Measurements
California Mobile Source Air Pollution Reduction Review Committee	Emissions
FedEx	Fleet Operator
Chevrolet Motor Division	Vehicles
Chrysler Corporation	Vehicles
Ford Motor Company	Vehicles
American Methanol Institute	Methanol
ARCO Products Company Chevron U.S.A. Products, Inc.	Reformulated Gasoline
LP Gas Clean Fuels Coalition Gas Processors Association National Propane Gas Association Western Liquid Gas Association	Propane Gas
Southern California Gas Company	Compressed Natural Gas
Southern California Edison	Electric Vehicles

This executive summary presents the major findings from the project on a fuel-by-fuel basis (see Table 3). For each fuel, major findings are summarized; the vehicle technologies used in the project are highlighted; and information on emissions, operations, and economics is provided. Detailed findings have been documented in the eight-volume CleanFleet Final Report, which can be accessed electronically from the National Renewable Energy Laboratory's Alternative Fuels Data Center (1-800-423-1363) at www.afdc.doe.gov. A paper copy of the report can be obtained through the U.S. Department of Energy's Office of Scientific and Technical Information (1-615-576-1301). Questions concerning the project may be addressed to the technical contractor, Battelle, at 1-614-424-4062.

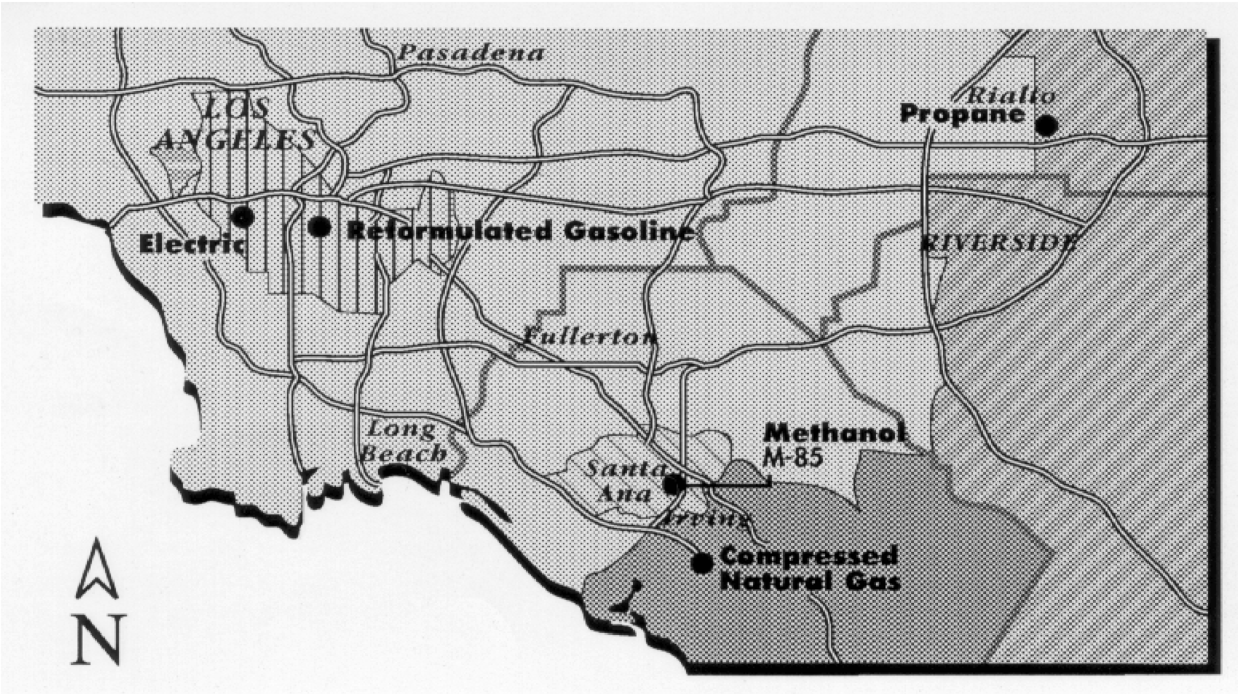

Figure 1. CleanFleet vehicles operated in the South Coast Air Quality Management District.

Figure 2. CleanFleet vans were full-size panel vans outfitted for FedEx operations.

Table 2. Topics Addressed in the CleanFleet Project

Fleet Operations	Vehicle Emissions	Fleet Economics
Vehicle	Regulated Emissions	Infrastructure Costs
Maintenance	Ozone Precursors	Personnel Training
Reliability	Air Toxics	Fueling Facility
Fuel Economy	Greenhouse Gases	Inside Vehicle Storage
Durability		Maintenance Facility
Safety		Mixed Fleet Complexity
Facilities		Owning Costs
Fueling		Base Vehicle Price
Vehicle Housing		Modification Cost
Employee Attitudes		Residual Value
Training		Operating Costs
Occupational Hygiene and Safety		Fuel Cost
Operational Impacts		Refueling Labor
		Maintenance
		Insurance
		Cost Incentives

Table 3. Summary of CleanFleet Findings

Fuel	Operations	Emissions	Fleet Economics
All AFVs	All AFVs delivered in routine operations. All AFVs (except RFGs) had tradeoffs. Variables included fuel availability, fleet needs, driving range, costs, local regulations. Production model AFVs were more reliable than after-market modified vans. AFVs must be rugged enough for commercial service.	All AFVs reduced emissions compared to control fuel.	Costs can vary considerably (except for RFG), depending on fleet owner's decisions. Costs in flux due to technology development for vehicles, fueling facilities.
CNG	Reliability, maintenance, and energy use efficiency reflected existing technology. Heavy onboard fuel tanks with limited capacity made driving range only marginally acceptable.	Exhaust emissions of most pollutants were lower than from any other AFVs. Ozone-forming potential was 90% less than from gasoline, steady with mileage.	Installation of needed infra-structure can entail significant capital and operating costs. If vans brought into buildings, officials may require significant changes to heating and ventila-tion systems and installation of flammable gas detectors.
Propane Gas	Energy use efficiency less than control vans, reflecting developmental status. Reliable, optimized AFV fuel system would increase efficiency.	Ozone-forming potential was 70% less than from gasoline, steady with mileage. Optimized AFV fuel system would further reduce emissions.	If vans brought into buildings, officials may require heating and ventilation system changes and installation of flammable gas detectors. 1996 projections: cost of using propane gas vans more than gasoline but less than other alternative fuels.
RFG	All infrastructure same as for gasoline. RFG sold commercially beginning in 1996. Energy efficiency same, fuel economy about 2% less compared to gasoline. Safety, maintenance, reliability, durability same as for gasoline.	Emission levels moderately less than gasoline. Ozone-forming potential was 17 to 29% less than from gasoline, increased with mileage.	No infrastructure changes required. Fuel cost slightly higher than standard gasoline (estimated +10 to 17¢ per gallon).
M-85	All fuel storage, dispensing equipment must be compatible with M-85. Energy efficiency same as for gasoline. Driving range about 57% of gasoline, consistent with fuel's energy content, adequate for urban fleet operations.	Ozone-forming potential was about 59% less than from gasoline, increased slightly with mileage.	No infrastructure changes or building modifications required. May need on-site M-85 storage tank to ensure supply. Fuel price varied substantially in 1994 and 1995 and is the main uncertainty in total costs for an M-85 fleet.
Electric	EVs usable in city on routes matching driving range. Battery technology critical to performance. Charger must be optimized for type of battery, both part of EV system.	No exhaust emissions—EVs defined as zero emission vehicles.	Major cost factors were cost of EV itself, battery price, life of battery pack, EV efficiency.

Compressed Natural Gas

The principal CleanFleet findings concerning the use of CNG were that:

1. Exhaust emission levels of most pollutants from the natural gas vans (NGVs) were lower than from vans using any of the other fuels that were demonstrated. The potential of the nonmethane organic gases in the NGV exhaust to generate ozone in the atmosphere was 90 to 95 percent less than the ozone-forming potential (OFP) of gasoline exhaust. The OFP of the NGV exhaust did not degrade significantly over mileage during the two-year demonstration.

2. Infrastructure is a key factor in gaining sufficient penetration of NGVs into fleet use to realize the low emissions level benefits of NGVs for an urban area. Capital and operating costs to install and operate CNG compressors, cascade storage, and dispensers can be significant. If NGVs are brought into buildings, the local fire marshall and code officials may require extensive changes to the heating and ventilation system and installation of flammable gas detectors. To optimize the economics of using NGVs, a fleet operator may need to modify the operating practices it is accustomed to using for gasoline or diesel vehicles.

   Infrastructure was a key factor in estimating the cost for a fleet operator to introduce and use CNG in 50 vans in Los Angeles in 1996. The estimated costs ranged from 40.4 to 45.9 cents per mile of vehicle travel (assuming 20,000 miles per year per van) if the fleet operator owns the natural gas compressor. Then the gas is bought from the utility at low pressure. If the compressor station is owned by a fuel provider and the fleet operator purchases compressed gas, the cost may range from 40.1 to 41.5 cents per mile. In both cases, the range of costs reflects the effects of different fleet operating practices.

3. The reliability and required maintenance of NGVs reflected the state of development of the technology demonstrated. The NGVs that were production vans required less maintenance than the NGVs that were after-market modifications of gasoline vans. Fleet operators need to examine closely the reliability of after-market NGVs before committing to their purchase and use.

4. The efficiency of NGVs in using the energy content of CNG was less than the efficiency of their gasoline controls, and this too reflected the state of technology development. This, coupled with the use of relatively heavy fuel storage tanks of limited capacity, gave the NGVs a driving range that was only marginally acceptable for urban fleet operations. Optimizing NGVs for fuel efficiency and using lighter tanks with more storage volume can ameliorate this concern.

Vehicle Technology

The CleanFleet NGVs represented a range of technologies. The Dodge vans were among the first production NGVs offered by Chrysler Corporation. They featured a 5.2-liter V8 engine, sequential multiport electronic fuel injection (SMPI), and a catalyst system designed for natural gas exhaust. The Dodge control vans used 5.2-liter gasoline engines. The Ford vans were modified by Ford to operate on CNG. They featured 4.9-liter, inline engines, limited calibration of a SMPI system, a compression ratio of 11:1 (compared to the Ford gasoline engine compression ration of 8.8:1), and a standard catalyst system for gasoline exhaust. The Ford control vans used 4.9-liter engines as well. The Chevrolet NGVs were gasoline vans with natural gas compatible engines (5.7-liter V8) that were modified to operate on CNG with an IMPCO Technologies fuel delivery system. Fuel was delivered to the engine through a gas ring upstream of the throttle body. An Engelhard catalyst designed for natural gas exhaust was employed. The Chevrolet control vans used 4.3-liter V6 engines.

Emissions Benefits

Exhaust emissions from the NGVs were generally much less than emission levels from the gasoline control vans, and the low emisison levels of the NGVs were stable as the vans accumulated mileage. The potential of the nonmethane organic gases (NMOG) in the exhaust (which is regulated to a specific mass emissions level) to contribute to forming ozone (or, more loosely, smog) in the atmosphere was 90 percent less than the OFP of the NMOG in the exhaust of the corresponding control vans. Emission levels of nitrogen oxides (NO_x) from the NGVs were less than the NO_x levels from the control vans for two of the OEMs (49 and 43 percent) and greater for the other manufacturer (Ford, 63 percent), reflecting the state of the technology. Emissions of carbon monoxide ranged from 68 to 77 percent less for the NGVs compared to their control vans. In general, emission levels of the four air toxics addressed in the CleanAir Act Amendments (CAAA) of 1990 were also reduced compared to the control vans. These four compounds are formaldehyde, acetaldehyde, benzene, and 1,3-butadiene. Most striking were the low mass emissions of NMOG and the corresponding low OFP of the NGV exhaust.

Operations

To achieve these emission benefits, the NGVs must, of course, be placed into service and perform reliably. The production Dodge NGVs and the NGVs modified by Ford were purchased without problem. However, purchase and delivery of the Chevrolet NGVs that were modified by a third party were stalled by issues of product liability and liability for the vans during modification. In the intervening years, as more vehicles were modified outside of the CleanFleet project, these issues have been clarified for major distribution channels (e.g., Ford’s Qualified Vehicle Manufacturer program). Nevertheless, for locally run after-market modifications, a fleet operator needs to examine closely the third-party modifier’s responsibility for the vehicles and subsequent warranty and product liability.

Infrastructure also must be put in place for NGVs. For CleanFleet, this included providing a fueling station and modifying the building into which NGVs were driven and parked overnight. Southern California Gas Company installed two natural gas compressors, cascade storage, and a dispenser at the FedEx host site. The two compressors were installed in parallel to provide redundancy. Over the two-year demonstration period, the system operated reliably although issues were dealt with such as (1) carry-over of lubricant from the compressors through the cascade system and dispenser into the vans, (2) inadequate capacity to fill all 21 vans in rapid succession, and (3) failure of one of the compressors. In addition, natural gas in the reference cylinder in the dispenser had to be replenished a few times to maintain its pressure and enable the system to fill the NGVs all the way to 3,000 pounds per square inch pressure. The compressor facility was a major mechanical system on the property and, as such, required preventive and unscheduled maintenance. An important decision for a fleet in implementing compressed natural gas as a motor fuel is how to supply the CNG: (1) by installing and operating a compressor facility and purchasing the natural gas uncompressed from the local utility or (2) by purchasing the gas compressed from the local utility (in which case the utility is responsible for the compressor facility).

The building into which FedEx brought its vans also required preparation for the NGVs. The local fire marshall and building code officials required that the building ventilation be increased to five air changes per hour and linked to a system of flammable gas detectors that were installed near the ceiling throughout the building. Also, pre-existing open-flame unit heaters were disconnected. As officials become more accustomed to natural gas as a transportation fuel, their requirements might be modified. In any event, a lesson learned from the project was to work closely with local officials throughout the process of incorporating NGVs into the fleet.

Once in operation, the safety, fuel economy, maintenance requirements, and reliability of the vans were closely monitored. The FedEx NGV fleet operated safely throughout the demonstration. A few leaks on the vans and in the compressor facility were quickly stopped. Limited measurements of natural gas vapors in the air when the vans were fueled found gas concentrations to be far below any health-based levels set by the Occupational Safety and Health Administration (OSHA) and the American Conference of Government and Industrial Hygienists (ACGIH).

The relative fuel economy of the NGVs compared to their gasoline controls was determined from laboratory-based emissions measurements as well as daily operations. The average relative fuel economy (or energy efficiency) based upon the two types of determinations was +3.6 and -2.6 percent for the Ford vans, -4.3 and -9.4 percent for the Dodge vans, and -12.8 and -16.4 percent for the Chevrolet vans. Figure 3 shows the results, with the bars representing the 95 percent statistical confidence interval about the mean (shown as the horizontal line within the bars). When the bar is completely above or below the line of zero percent difference (e.g., Chevrolet), it can be said with 95 percent confidence that the mean energy efficiency of the AFVs differed from that of their control vans. The low efficiency for the Chevrolet vans (which is statistically significant) reflects the different engines (5.7-liter CNG vs. 4.3-liter gasoline), as well as limited optimization of the fuel delivery system. These findings point to some loss in fuel efficiency for model year 1992 NGVs compared to gasoline vans. Coupled with the fuel storage capacity of the vans, these efficiencies yielded driving ranges on fully fueled NGVs ranging from 116 to 139 miles for a FedEx delivery route of average length and number of starts and stops. These ranges were adequate for over half the delivery routes in FedEx urban operations. However, some routes proved too long for the NGVs, and gasoline vans had to be used on these routes.

Maintenance requirements on the NGVs reflected the state of technology. The production NGVs and those modified by the manufacturer required minor maintenance. The Chevrolet NGVs equipped with IMPCO's AFE system required maintenance on hardware and software throughout the demonstration, again reflecting development problems. The average availability of the Chevrolet, Dodge, and Ford NGVs was 94, 93, and 94 percent (Figure 4). The corresponding availability of the control vans using regular unleaded (UNL) gasoline was 95, 91, and 98 percent.

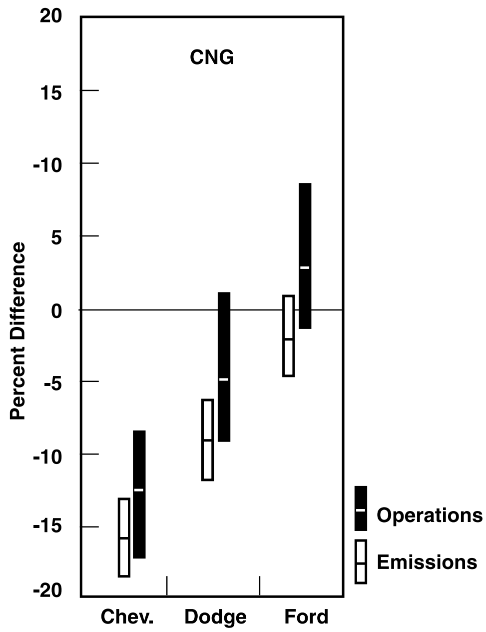

Figure 3. Relative fuel economy (efficiency) for CNG vans was compared to the control vehicles.

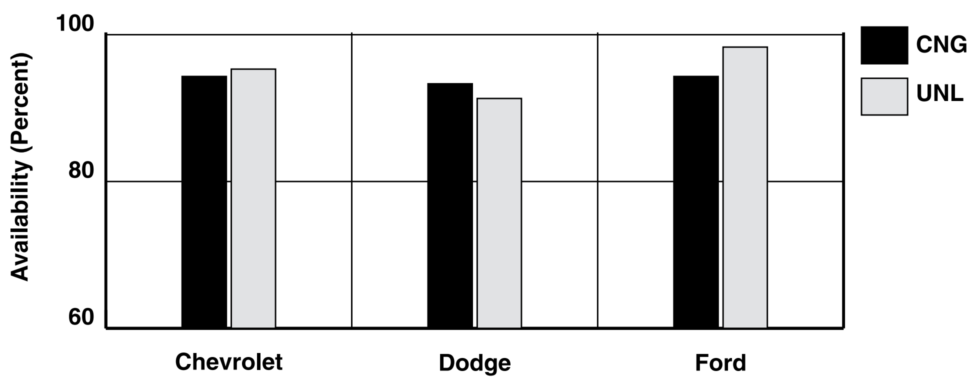

Figure 4. The availability of CNG and control vans is shown.

FedEx employees who participated in the demonstration had a uniformly positive attitude about using a "clean-burning" van. Attitudes about NGV performance were mixed for two reasons. First, none of the employees believed that they could rely on the fuel gauge to indicate the quantity of fuel. Coupled with a shorter driving range than the gasoline vans, this uncertainty caused anxiety in the drivers. Second, the problems related to stalling and rough operation of the vans with the AFE fuel system caused many of the drivers to be apprehensive about their safety, fearing that a stall could lead to a traffic accident. The consensus among the drivers was that the NGVs, in general, had less horsepower and only a marginally acceptable driving range. Nevertheless, their attitude about CNG showed a positive shift during the demonstration as they gained experience with the previously "unknown" fuel.

Fleet Economics

The experience of the CleanFleet demonstration was used as a starting point to develop an estimate of the cost to a fleet for using any one of the alternative fuels in the 1996 time frame. A case study was developed based on the assumption that a commercial package delivery service in Los Angeles had a fleet of 150 vans, of which 50 were to be powered by an alternative fuel. Fueling was assumed to be on site, similar to current FedEx practice. Using the cost factors shown in Table 2, the total cost to a fleet in cents per mile for the 50-van fleet were estimated. (In this case, 1 cent per mile equals $10,000 per year.) Estimates were made both before and after corporate income tax and with and without incentives.

Figure 5 shows a range of cost estimates for a fleet using NGVs before income tax and without incentives. The four cases on the left reflect the assumption that a fleet owns and operates the natural gas compressor station. The two cases on the right reflect the assumption that a fleet operator purchases CNG

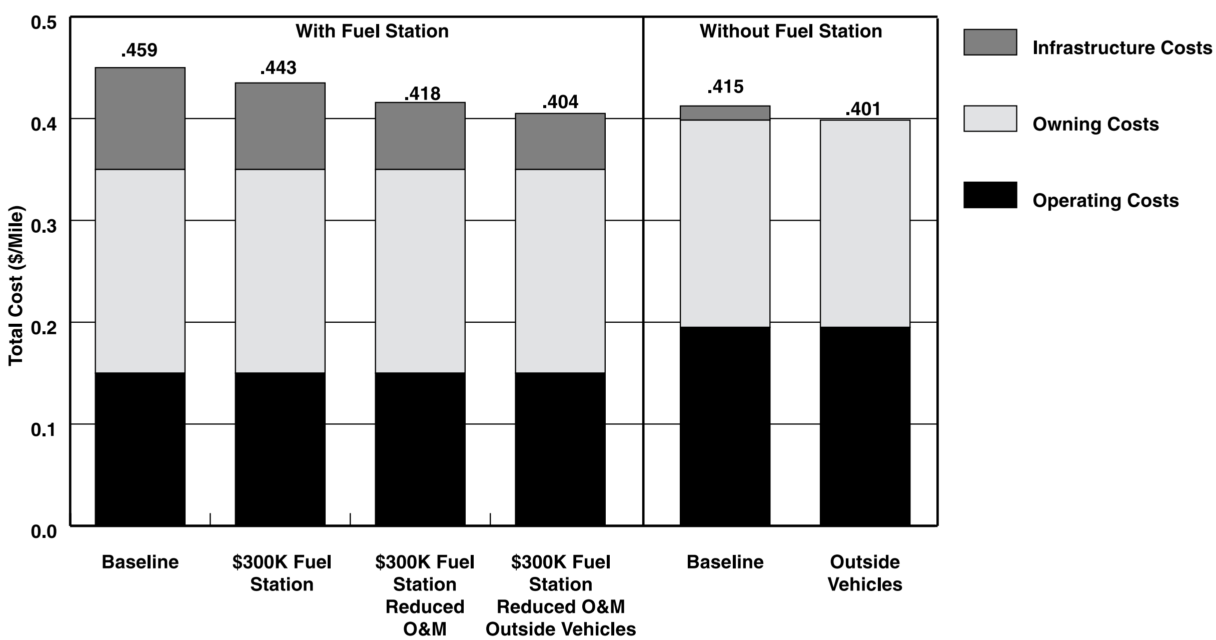

Figure 5. Costs were estimated for a CNG fleet in a 1996 economic case study.

from a utility that owns and operates the compressor station. The baseline case on the far left (45.9 cents per mile) is closest to CleanFleet experience (i.e., redundancy in compressors, fast fueling, and building modifications). Relaxing requirements for redundancy in the compressor and achieving smaller operating and maintenance (O&M) costs for it are reflected in the next two estimates of 44.3 and 41.8 cents per mile. Finally, if no building modifications are required (because the vans are parked outside), the cost is reduced further to 40.4 cents per mile. These costs and those for the purchase of CNG (41.5 cents per mile with building modifications and 40.1 cents per mile without building modifications) compare to an estimated cost of 34.6 cents per mile for 50 vans using regular gasoline. The most important finding from the economic analysis of CNG use by a fleet is that the decisions that a fleet operator makes on options for operation can have a large impact on the cost of using this fuel.

Propane Gas

The principal CleanFleet findings concerning the use of propane gas were that:

1. The OFP of exhaust emissions was about 70 percent less than the exhaust from the gasoline control vans, and this did not degrade significantly with mileage over the course of the demonstration.

2. If propane gas vehicles are to be brought indoors, extensive modifications to the building's heating and ventilation system and installation of flammable gas detectors may be required by local fire marshals and building code officials.

3. Production vans that operated on propane gas were not available in 1992 from the OEMs. The propane gas vans used in CleanFleet were gasoline vans modified with two generations of after-market fuel management systems. The efficiency of these vans in using the energy of the fuel to travel was less than that of the control vans. The newer after-market fuel system required maintenance throughout the demonstration, reflecting its developmental status. To acquire fuel efficient propane vehicles with even lower emissions, fleet operators need access to reliable, optimized AFVs.

4. In the 1996 time frame, the cost to a fleet to introduce and use 50 propane gas vans in the Los Angeles area is projected to be greater than for gasoline, but at the low end of the range of costs for the other alternative fuels evaluated in the demonstration (38.2 to 39.6 cents per mile, depending upon fleet operational practices).

Vehicle Technology

The propane gas vans from Ford and Chevrolet were gasoline vans modified to operate on propane gas using IMPCO Technologies' adaptive digital processing (ADP) (Ford) and advanced fuel electronic (AFE) (Chevrolet) fuel management systems. The ADP system was a proven, stand-alone electronic fuel system with feedback control. The AFE system for propane gas was essentially the same as for CNG with different software settings and fuel storage hardware. The Ford propane gas vans featured a 4.9-liter, inline engine and a standard catalyst system for gasoline exhaust. The Ford control vans used 4.9-liter engines as well. The Chevrolet vans were gasoline vans with propane gas compatible engines (5.7-liter V8) that were modified to operate on propane gas, and they employed an Engelhard catalyst chosen for exhaust from propane combustion. The Chevrolet control vans used 4.3-liter V6 engines. Thus, the CleanFleet propane gas vans represented two versions of fuel system technology that could be used to modify gasoline vans to operate on propane gas.

Emissions Benefits

Exhaust emissions from the propane gas vans were generally less than emission levels from the gasoline control vans, and the propane gas emission levels were stable over mileage. The OFP of the exhaust was 68 to 71 percent less than the OFP of the exhaust of the corresponding control vans. Emission levels of NO_x from the Chevrolet propane gas vans were less than from the control vans (66 percent) and greater for the Ford vans (28 percent), reflecting the state of the technology. Emissions of carbon monoxide were about 48 percent less for the propane gas vans compared to their control vans. In general, emission levels of the four air toxics addressed in the CAAA were also reduced compared to the control vans. Although the emission levels of propane gas (as unburned fuel) caused the mass emissions of NMOG to exceed the NMOG emissions from the gasoline control vans, the OFP of the propane gas exhaust was less because propane is relatively unreactive in the atmosphere. These emissions results point out the potential for further reduction of emissions with optimization of propane gas vehicles for emission levels.

Operations

The propane gas vans faced the same issues of product liability and liability for the vans during modification as the NGVs. Again, for locally run after-market modifications, the fleet operator needs to closely examine the third-party modifier’s responsibility for the vehicles and subsequent warranty and product liability.

Infrastructure also must be put in place for propane gas AFVs. For CleanFleet, the local fire marshall and building code officials required that the building ventilation be increased to five air changes per hour and linked to a system of flammable gas detectors that were installed near the floor of the building. As was learned from the experience with natural gas, it is important to work closely with local officials throughout the process of incorporating propane gas AFVs into the fleet.

Once in operation, the safety, fuel economy, maintenance requirements, and reliability of the vans were closely monitored. The FedEx propane gas fleet operated safely throughout the demonstration. A few leaks on the vans were quickly stopped. Limited measurements of concentrations of propane gas vapors in the air where the vans were fueled found the levels to be below any health-based levels set by OSHA and the ACGIH.

The average relative fuel economy (or efficiency) from the two types of determinations (operations and emissions measurements) was -3.9 and -5.9 percent for the Ford vans and -11.8 and -10.7 percent for the Chevrolet vans (see Figure 6). The low efficiency for the Chevrolet vans (which is statistically significant) reflects the different engines (5.7-liter CNG vs. 4.3-liter gasoline), as well as limited optimization of the fuel delivery system. These findings point to some loss in fuel efficiency for propane gas AFVs with after-market modifications compared to gasoline vans. Coupled with the quantity of fuel storage onboard the vans, these efficiencies yielded driving ranges on fully fueled vans of about 155 miles for a FedEx delivery route of average length and number of starts and stops. This range was adequate for the delivery routes in FedEx’s urban operations if the vans were fueled each night.

Required maintenance on the propane gas vans reflected the state of technology. The Ford vans equipped with the older, proven ADP fuel system from IMPCO required relatively minor maintenance after some initial problems were ironed out. The Chevrolet propane gas vans equipped with IMPCO’s AFE system required maintenance throughout the demonstration on hardware and software, reflecting

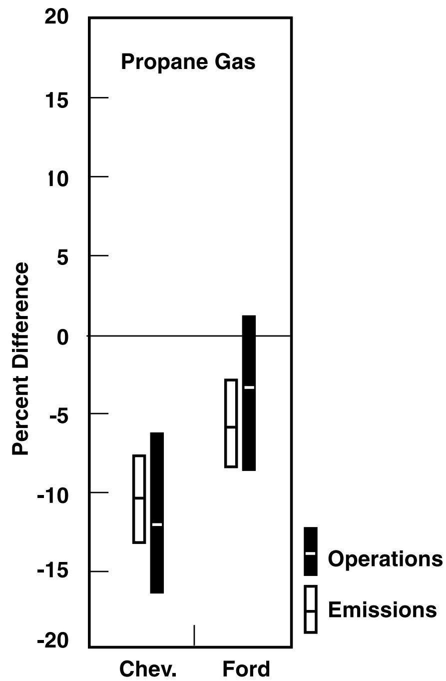

Figure 6. Relative fuel economy (efficiency) for propane gas vans was compared to the control vehicles.

development problems (similar to the AFE systems used for the Chevrolet NGVs). The average availability of the Chevrolet and Ford propane gas vans was 88 and 96 percent (Figure 7). The corresponding availability of the control vans was 91 and 96 percent.

FedEx employees who participated in the demonstration had a positive attitude about using a "clean-burning" fuel. Attitudes about vehicle performance were mixed for two reasons. First, none of the employees believed that they could rely on the fuel gauge to indicate the quantity of fuel. Coupled with a shorter driving range than the gasoline vans, this caused anxiety in the drivers. Second, the problems related to stalling and rough operation of the vans with the AFE fuel system caused many of the drivers to become apprehensive about their safety, fearing that a stall could lead to a traffic accident.

Fleet Economics

Figure 8 shows a range of estimated costs for using propane gas in the 1996 case study. Costs range from 38.2 cents per mile to 39.6 cents per mile depending upon the need for building modifications. The 39.6 cents per mile for the baseline case reflects the assumption that vans are stored indoors and the need for a forced air ventilation system with five air changes per hour linked to flammable gas detectors (the CleanFleet experience). The middle case assumes that flammable gas detectors and an alarm are needed, but that an enhanced ventilation system is not required. The remaining case assumes that the fleet

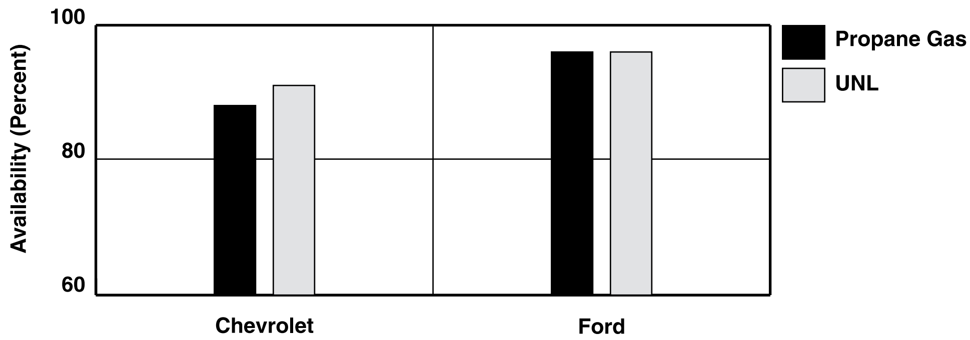

Figure 7. The availability of propane gas and control vans is shown.

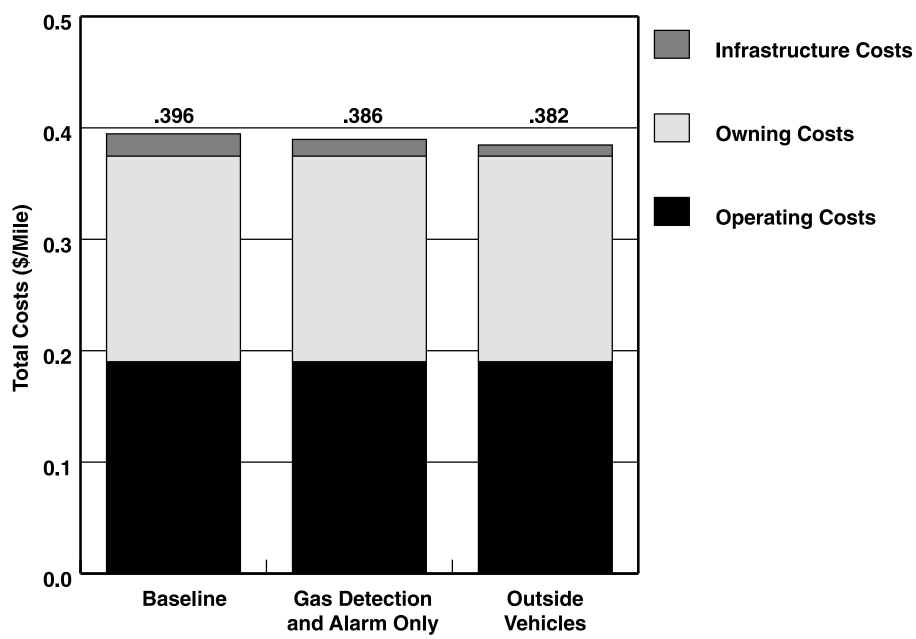

Figure 8. Costs were estimated for a propane gas fleet in a 1996 economc case study.

operator does not store vans indoors, and building modifications are not necessary. The range of costs is at the low end of the estimated 1996 case study costs for fuels other than the gasolines. For propane gas, the range shown depends upon the building infrastructure changes that are required.

California Phase 2 RFG

Principal findings from the use of California Phase 2 RFG were that:

1. Emission levels of most pollutants were moderately reduced in RFG exhaust compared to exhaust from control gasoline. The OFP of RFG exhaust was 17 to 29 percent less, which is consistent with other studies by the ARB. The OFP of the exhaust had about the same degradation with mileage for RFG and control gasoline. From a fleet perspective, all infrastructure is already in place to implement Phase 2 RFG, and RFG will be sold commercially beginning in 1996.

2. The efficiency of the RFG vans was the same as the gasoline control vans. On a physical gallon basis, the fuel economy of the RFG vans was about 2 percent less than that of the control vans because of the difference in energy content between the two fuels.

3. The safety, maintenance, reliability, and durability of the RFG vans were the same as the control vans.

4. The cost to a fleet operator of using RFG is estimated to be slightly higher than for standard gasoline because a higher price is projected for fuel (an additional 10 to 17 cents per gallon). The estimated cost to a fleet operator ranges from 35.3 to 36.1 cents per mile for 50 vans each travelling 20,000 miles annually.

Vehicle Technology

The RFG vans were standard model year 1992 production vans identical to the gasoline control vans. The RFG vans had not been optimized for future low emission exhaust standards.

Emissions Benefits

The OFP of RFG exhaust was 17 to 29 percent less than that of the control van exhaust. NO_x emission levels averaged 1 to 32 percent less for the three OEMs. CO levels averaged 1 to 19 percent less. Formaldehyde levels were slightly elevated (arising from incomplete combustion of the oxygenate, methyl tert-butyl ether) in the RFG exhaust compared to the control gasoline; the other three air toxics were generally less, with benzene being substantially less.

Operations

From a fleet perspective, all infrastructure is in place to use Phase 2 RFG, and it will be used beginning in 1996. The efficiency of the vans using RFG was the same as the vans using regular gasoline on a statistical basis (see Figure 9). Because RFG has about 2 percent less energy content than regular gasoline on a per gallon basis, the driving range of vans on RFG would be expected to be about 2 percent less. This small difference might not be noticed by a fleet that fuels the vans about every third day in urban operations.

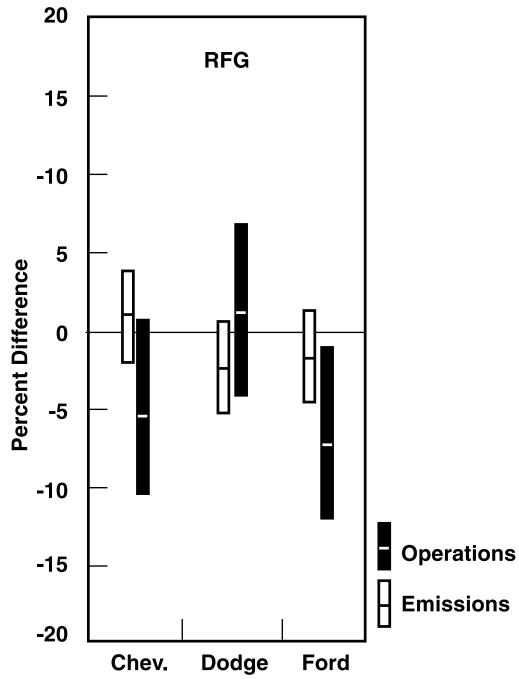

Figure 9. Relative fuel economy (efficiency) for RFG vans was compared to the control vehicles.

The safety, maintenance, reliability, and availability of the RFG vans were equivalent to the control vans. Availability of the vans for duty was 98 or 99 percent for the RFG and control vans (see Figure 10).

Employees who participated in the demonstration were positive about using a “clean-burning gasoline.” Use of the RFG vans compared to the control vans on regular gasoline was essentially transparent to the workers.

Fleet Economics

Results from the 1996 case study are shown in Figure 11. The estimated cost to a fleet operator ranges from 35.3 cents per mile to 36.1 cents per mile, and this range depends upon the price of RFG in 1996. Because RFG is so similar to regular gasoline in an operational sense, the uncertainty in the cost estimates for using RFG is less than for the other fuels.

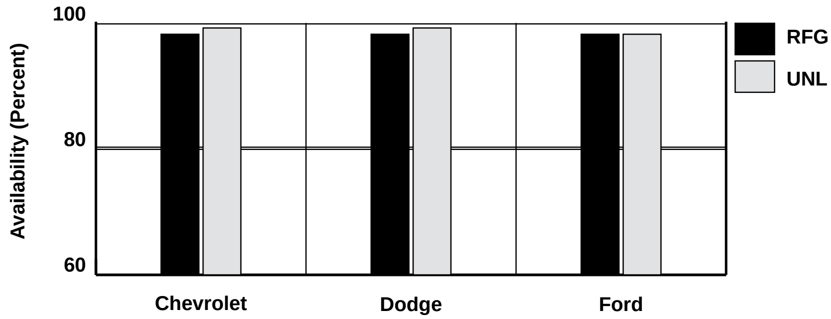

Figure 10. The availability of RFG and control vans is shown.

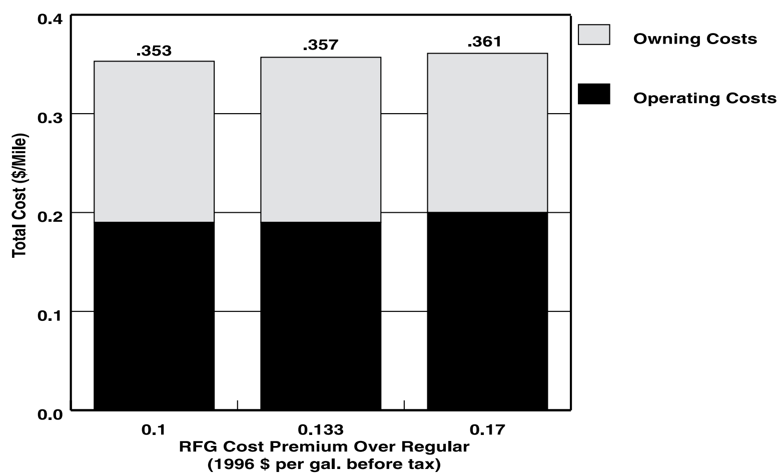

Figure 11. Costs were estimated for an RFG fleet in a 1996 economic case study.

M-85

The principal CleanFleet findings from the use of M-85 were that:

1. The OFP of the M-85 exhaust was about 59 percent less than that of the exhaust from the control vans. The OFP of the exhaust rose slightly with mileage.

2. From a fleet perspective, infrastructure requirements for using M-85 are principally the need to use materials that are compatible with methanol in the fuel storage and dispensing equipment. No modifications were required for the building in which M-85 vans were stored.

3. The efficiency of the M-85 vans in using the energy content of M-85 to travel was equivalent to the control vans. The driving range of the M-85 vans was about 57 percent of the gasoline vans, consistent with the relative energy content of a gallon of M-85 compared to regular gasoline. This range was adequate for urban fleet operations.

4. Estimated costs for a fleet to use M-85 in 50 vans in 1996 range from 38.3 to 44.7 cents per mile and depend primarily upon the price of M-85.

Vehicle Technology

The M-85 vans were Ford flexible fuel vehicles that were capable of operating on a mixture of methanol and gasoline ranging from 0 percent methanol to 85 percent methanol and 15 percent gasoline. The catalyst on the M-85 vans was the standard catalyst for 1992 model year gasoline vans; it had not been optimized to remove formaldehyde during cold start operation.

Emissions Benefits

The OFP of the M-85 exhaust was, on average, 59 percent less than that of the control van exhaust. NO_x levels in the M-85 exhaust were within 2 percent of the levels in the control vans, and CO levels were about 50 percent less. Formaldehyde levels were considerably higher in the M-85 exhaust (330 percent), reflecting the lack of and need for a catalyst system optimized to remove formaldehyde during cold start operations.

Operations

No building modifications were required by local officials for bringing M-85 vans into the facility. An above-ground storage tank was installed to provide M-85 on site. The permitting process required extensive preparation in working with local authorities. In addition to requirements for the placement of the tank itself, the city required construction of a masonry wall and opaque gate to shield the tank installation from public view. This experience points out that if a fleet operator decides to modify or install new facilities for an alternative fuel, the entire site may be opened up to review by code officials unrelated to the characteristics of the fuel itself. This consideration may influence a decision on whether to store an alternative fuel on site.

A fuel storage and dispensing facility must be constructed of materials that are compatible with methanol. Although the facility used for CleanFleet was specified to be compatible with methanol and was warranted as such, some of the materials used by the contractor were not compatible with methanol. Changes were made to resolve the problem. The lessons learned were to specify precisely each component of the system and to work with a contractor to ensure that all parts of the system are compatible with methanol.

The M-85 vans were operated safely throughout the demonstration. The efficiency of the M-85 vans in using the energy stored in the fuel was the same as the control vans operating on gasoline (see Figure 12). The driving range of the M-85 vans was about 57 percent of the gasoline vans, which is consistent with the relative energy content of a gallon of M-85 and regular gasoline. This range was adequate for urban fleet operations.

The M-85 vans required maintenance characteristic of nonproduction vehicles with some special parts needing to be replaced. The availability of the M-85 vans averaged 97 percent versus 99 percent for the control vans (Figure 13).

Employees who participated in the demonstration had positive attitudes about using a “clean-burning” fuel. Most of these people reported no health-related problems and believed that the performance of the M-85 vans was about the same as the control vans. Thirty-one percent expressed concern about exposure to vehicle exhaust and reported eye irritation (formaldehyde, a product of combustion, is an eye irritant).

Fleet Economics

Results of the 1996 case study are illustrated in Figure 14. The estimated total cost to a fleet ranges from 38.3 to 44.7 cents per mile, with the best estimate at 41.5 cents per mile. This range is driven by uncertainty in the cost of M-85. In 1994 and 1995, the price of methanol varied substantially.

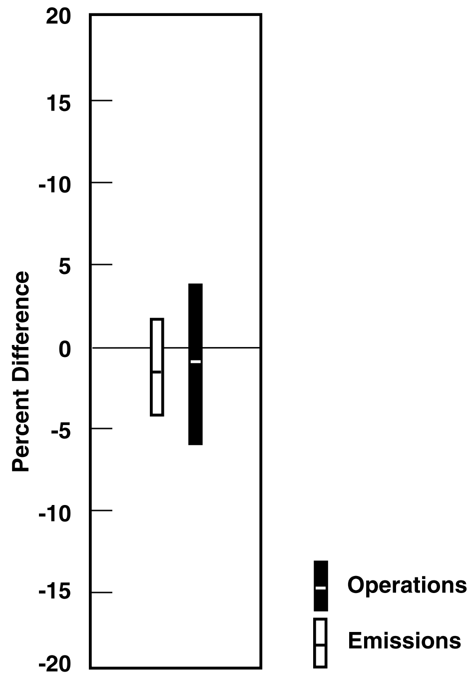

Figure 12. Relative fuel economy (efficiency) for M-85 vans was compared to the control vehicles.

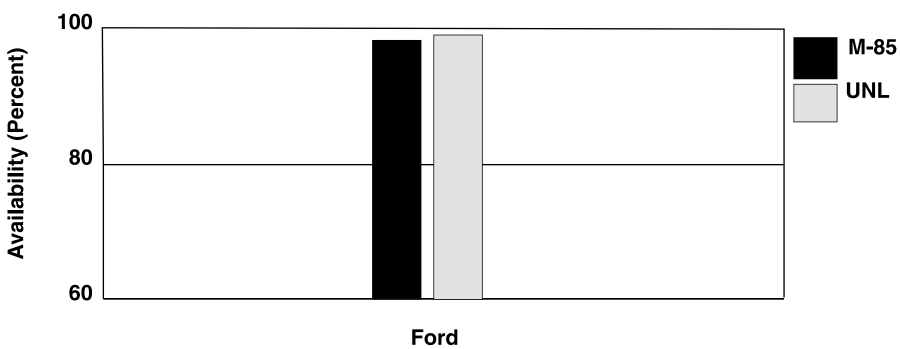

Figure 13. The availability of M-85 and control vans is shown.

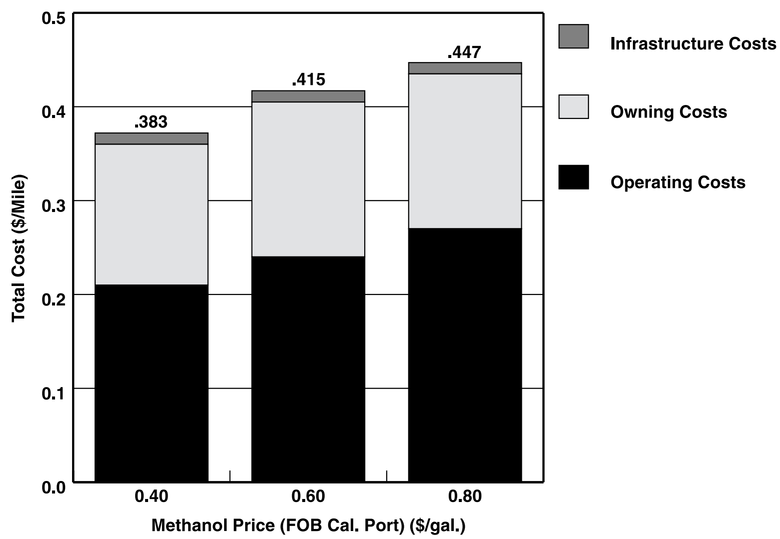

Figure 14. Costs were estimated for an M-85 fleet in a 1996 economic case study.

Electric Vans

The principal findings from using EVs were that:

1. EVs can be used successfully in city fleet operations where the length of the route is matched to the driving range of the EVs. EVs, like other AFVs, must be sufficiently rugged for commercial applications.

2. Battery technology is critical to achieving reliable EV performance. The nickel-cadmium (NiCd) battery pack used in the demonstration provided about twice the driving range and was more rugged than the lead-acid (PbA) battery pack.

3. The battery charger must be considered with the battery as a complete system. The NiCd charger/battery system provided more reliable charging and was more efficient than the PbA charger/battery system because the LeMarche charger used for the NiCd battery was a more efficient, advanced system that had less tendency to waste energy by overcharging the batteries.

4. The cost factors most important to using EVs in a fleet are the price of the EV including batteries, the life of the battery pack, and the efficiency of the EV (e.g., kilowatt hours per mile).

Vehicle Technology

The demonstration began with two G-Vans from Conceptor Industries operating on PbA batteries. Part way through the demonstration, one of the EVs was removed from service, and Southern California Edison installed a NiCd battery pack in it. The PbA battery pack weighed about 1,140 kilograms (kg), and the NiCd battery pack weighed about 850 kg.

Emissions Benefits

The EVs are defined by the California Air Resources Board as having no vehicle tailpipe or evaporative emissions, and thus they are called zero-emission vehicles. This remains constant over mileage. Emissions from plants that generate electric power were not addressed in the CleanFleet project.

Operations

The only facility modifications required to introduce EVs into service were electrical service for the chargers and installation of an eyewash stand near the EVs. Throughout the demonstration the EVs were operated safely.

The average energy consumption of the PbA EVs was 2.3 kWh per mile. The NiCd EV averaged 1.9 kWh per mile. These figures include the energy consumed by the chargers. The driving range of the PbA EVs was about 25 miles; the driving range of the NiCd EV was about 50 miles. These results are specific to the FedEx duty cycle experienced during the demonstration. Southern California Edison has experienced a driving range longer than 25 miles with PbA batteries. The PbA battery EVs required maintenance on the battery packs and traction motors, which were replaced on both PbA EVs. In contrast, the NiCd EV did not require significant maintenance.

FedEx employees were excited about using zero emission vehicles. This excitement was tempered by concerns about driving range.

Fleet Economics

Production full-size electric vans will not be available from OEMs in 1996. Consequently, cost estimates were developed for using 50 EVs in 1996 and also in 1998. Because of the uncertainty in the state of EV technology for cargo vans in 1998, both low and high estimates were made. The key cost factors were vehicle price, price of electrical energy consumption, battery life and replacement cost, and vehicle maintenance costs. Results are shown in Figure 15. Incentives can represent a significant cost reduction to a fleet. For example, the effect of incentives after income tax could lower the total cost by 2 to 3 cents per mile.

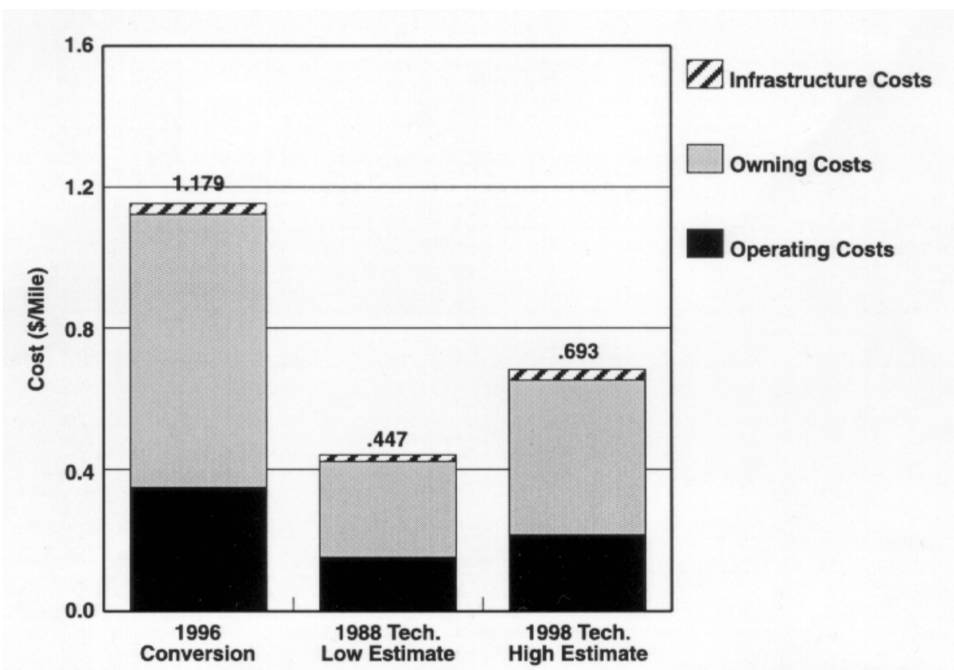

Figure 15. Costs were estimated for an electric van fleet in 1996 and 1998.