CleanFleet

# FINAL REPORT


December 1995

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# Glossary

| | | |
|---|---|---|
| AC | = | Alternating current |
| AFV | = | Alternative fuel vehicle |
| Btu | = | British thermal unit |
| CNG | = | Compressed natural gas |
| EPACT | = | Federal Energy Policy Act of 1992 |
| est | = | Estimate or estimated |
| EV | = | Electric vehicle (in particular, a full-size cargo van) |
| f.o.b. | = | Free on board (price before transportation and delivery charges) |
| FUDS | = | Federal urban driving schedule |
| gal | = | Gallon |
| GEQ | = | Gasoline equivalent gallon, on an energy basis |
| GVW | = | Gross vehicle weight |
| Inc | = | Income |
| kWh | = | Kilowatt hours |
| LADWP | = | Los Angeles Department of Water and Power |
| LEV | = | Low emission vehicle |
| LHV | = | Lower heating value |
| M-85 | = | Methanol fuel comprised of 85 percent methanol and 15 percent RFG by volume |
| mi | = | Mile |
| min | = | Minute |
| mo | = | Month |
| mm | = | Million |

## Glossary
## (Continued)

| | | |
|---|---|---|
| O&M | = | Operating and maintenance |
| OEM | = | Original equipment manufacturer |
| PRO | = | Propane gas |
| psig | = | Pounds per square inch gauge pressure |
| RFG | = | California Phase 2 reformulated gasoline |
| SCE | = | Southern California Edison |
| SCF | = | Standard cubic feet |
| SCFM | = | Standard cubic feet per minute |
| Therm | = | 100,000 Btu |
| UNL | = | Unleaded, regular grade gasoline |
| veh | = | Vehicle |
| w/o | = | Without |
| yr | = | Year |
| ZEV | = | Zero emission vehicle |

# FLEET ECONOMICS

*The costs that face a fleet operator in implementing alternative motor fuels into fleet operations are examined. Five alternatives studied in the CleanFleet project are considered for choice of fuel: compressed natural gas, propane gas, California Phase 2 reformulated gasoline, M-85, and electricity. The cost assessment is built upon a list of thirteen cost factors grouped into the three categories: infrastructure costs, vehicle owning costs, and operating costs. Applicable taxes are included. A commonly used spreadsheet was adapted as a cost assessment tool. This tool was used in a case study to estimate potential costs to a typical fleet operator in package delivery service in the 1996 time frame. In addition, because electric cargo vans are unlikely to be available for the 1996 model year from original equipment manufacturers, the case study was extended to the 1998 time frame for the electric vans. Results of the case study are presented in cents per mile of vehicle travel for the fleet. Several options available to the fleet for implementing the fuels are examined.*

## Introduction

This document, on estimated costs for a commercial fleet operator to implement any one of five alternative motor fuel options, is the eighth volume from the Final Report CleanFleet project. This volume presents a set of cost factors that a typical fleet operator needs to evaluate when selecting a motor fuel for operations. A methodology for estimating annual costs for each of the fuels is presented along with a case study for the 1996 time frame.

The report is organized into three major sections following the Introduction: identification of the set of cost factors, results from a case study for the 1996 time frame, and results for an electric vehicle (EV) fleet.

# Identification of Cost Factors to be Considered

The cost of implementing alternative motor fuels is a critical element in the decision-making process of a fleet operator. Generally, fulfilling the fleet's mission in compliance with government regulation must be accomplished at the lowest cost. A number of cost factors must be evaluated to make a wise selection of alternative fuels. In conjunction with representatives of the sponsoring organizations of the CleanFleet project, Battelle developed a list of cost factors that need to be considered. The host fleet, FedEx, played a major role in defining these factors.

The cost factors that were selected for use in the CleanFleet project fall into three major categories and are listed in Table 1. The three major categories are defined as infrastructure, owning, and operating costs. Each category is composed of several cost factors. Each of these factors is described briefly in the remainder of this section before the case study is presented. Considerations involving options within different cost factors are described later in the report.

**Table 1. List of Cost Factors for a Fleet Economics Assessment**

| Infrastructure Costs | Owning Costs | Operating Costs |
|---|---|---|
| Personnel Training | Base Vehicle Price | Fuel Cost |
| Fueling Facility | Modification Cost | Refueling Labor |
| Inside Vehicle Storage | Residual Value | Maintenance |
| Maintenance Facility | | Insurance |
| Mixed Fleet Complexity | | Cost Incentives |

## Infrastructure Costs

Infrastructure costs include personnel, facility, and fleet operations readiness for alternative fuels. Proper detailed preparations for implementing alternative fuels into the fleet, combined with diligent maintenance of the infrastructure, is critical to using alternative fuels in a cost-effective, successful operation.

**Personnel Training.** Among the training issues to be considered are initial training of vehicle and building maintenance staff, drivers, fuelers, dispatchers and schedulers, and security and safety staff. In some cases, evidence of training for certain job classifications may be required by authorities. Turnover of staff will require introductory training on an ongoing basis. Periodic review of training will help ensure safe operations. Basic training in the properties of the fuels and safe handling procedures could be provided to all staff. Specialized training will be required for certain staff (e.g., vehicle mechanics) to the level required for their jobs.

**Fueling Facility.** Fueling facility costs will depend upon how fuel is provided for fleet operations. For example, fuel may be stored on site, and employees may fuel vehicles from a central fuel storage tank. If a fuel storage tank is to be installed on site, a key decision will be whether to place the tank underground or aboveground. Issues to resolve in this regard include permitting, liability for fuel leaks, and the availability and cost of land. For example, placing a fuel tank aboveground implies that the "opportunity cost" of the land may be borne by the fuel storage facility. Some fleets make use of "mobile refueling" wherein a vendor brings a tanker of fuel to a site, and the vendor fuels the fleet vehicles. Other fleets may have the option of fueling vehicles at a retail service station or a facility for alternative fuel that is open to the public.

**Inside Vehicle Storage.** If fleet vehicles are stored indoors (or brought indoors for loading or repair), the building may require modifications. Because alternative fuels have properties that are different from gasoline, local fire marshals and building code officials may require that the building be modified to be suitable for the vehicles. In the CleanFleet experience, this ranged from no modifications required for two of the fuels to extensive upgrading of the building ventilation system and installation of flammable gas detectors in the buildings for the two gaseous fuels. If vehicles are brought indoors, this issue should be addressed with local authorities before a decision is made on which alternative fuel is to be introduced into the fleet and how this is to be accomplished.

**Maintenance Facility.** Possible costs for a maintenance facility include building modifications (as discussed in the preceding paragraph), different diagnostic and repair tools, and different hoists or pits.

**Mixed Fleet Complexity.** If both traditional gasoline or diesel fuel vehicles are combined with one or more alternative fuels, the fleet operator may experience increased costs due to the mix of the fuels. For example, possible limitations due to vehicle driving range or payload for some alternative fuel vehicles may mean that certain vehicles need to be restricted to certain routes. If the expected reliability of the new alternative fuel vehicles is less than that of the existing fleet, additional "spare" vehicles may be needed to maintain the fleet's mission. If the alternative fuel is stored on site along with the traditional fuel, increased complexity in ordering, receiving, tracking, and dispensing fuel needs to be anticipated. Additional record keeping may be required for such items as fuel addition to specific vehicles, training records, inventory of spare parts, and number of vehicles that can be fueled concurrently.

### Owning Costs

Owning costs that need to be considered were itemized for CleanFleet as base vehicle price, modification cost, and residual value. Depreciation and tax consequences that follow must also be recognized. They are treated by the fleet economic spreadsheet described in this report.

**Base Vehicle Price.** The price of a base vehicle is the price of a vehicle from an original equipment manufacturer that is ready for use in the fleet (not considering special requirements of the fleet specific to its operation, commonly called "upfitting," such as installation of electronic communication hardware). The vehicle may be either a traditional gasoline vehicle or an alternative fuel vehicle.

**Modification Cost.** Cost for modification may be experienced if the alternative fuel vehicles are procured by first purchasing gasoline vehicles and then having them modified by an after-market organization to operate on an alternative fuel. Among the issues to consider are product liability, product support, safety, reliability, durability, and availability of replacement parts for such vehicles. These issues may affect significantly the cost of owning and operating alternative fuel vehicles.

**Residual Value.** Residual value of an alternative fuel vehicle after its useful life to the fleet is another important consideration for a fleet operator. This is a difficult cost factor to evaluate because of the limited experience that original owners have disposing of alternative fuel vehicles. Nevertheless, this is an important economic issue for a fleet considering introduction of alternative fuels.

## Operating Costs

Five cost factors comprise the category of operating costs. They are price of fuel, cost of labor to refuel vehicles, maintenance on vehicles (both preventive and unscheduled), insurance, and cost incentives.

**Fuel Cost.** Price of fuel can be an important contributor to annual costs for the fleet. Therefore, in spite of uncertainty and potential volatility in price of some fuels, it is important to obtain the best estimate possible for fuel prices. The price of fuel will depend upon the option selected for fuel delivery to vehicles, and this decision will affect the costs for the fueling facility.

**Refueling Labor.** If fleet employees fuel vehicles, the cost of their labor for this application needs to be evaluated. The time required to fuel a vehicle depends upon the quantity of fuel or energy to be dispensed, the rate at which it can be dispensed, the required frequency of fueling, and whether the vehicle is fueled on site or off site. This in turn depends upon how the driving range of the vehicle is matched to the route requirements of the fleet.

**Maintenance.** Preventive and unscheduled maintenance on vehicles may be a significant contributor to annual costs. Decisions regarding turnover of the fleet and extent of service to be performed by fleet mechanics will affect this cost element. Special maintenance may be required for certain alternative fuel vehicles such as battery replacement for electric vehicles.

**Insurance.** Little solid information exists on the cost of insuring a fleet of alternative fuel vehicles. The cost of insurance (whether through self-insurance or an insurance carrier), will be based, in part, on risk of personal injury, damage to goods, and property damage. Whether or not a fleet is self-insured will certainly have an impact on this cost element.

**Cost Incentives.** The fleet operator should be aware of and consider the impact of cost incentives intended to encourage the use of alternative fuels. The cost incentives may include differing fuel taxes and direct tax credits or rapid depreciation of investments in vehicles and fuel stations. Emission credits may also have a significant impact, but are not included in this study.

# Results from the 1996 Case Study

The fleet economics tool developed in the CleanFleet project was applied as a case study for the 1996 time frame as an example for fleet operators. In this section of the report, the basis for the case study and the major results are summarized. Details of the case study are summarized on a fuel-by-fuel basis in the following section.

## Basis for the 1996 Case Study

The design of the CleanFleet project called for a credible, objective assessment of the costs for a fleet operator to implement any one of the five fuels being demonstrated. The analysis was to rest as much as possible on the CleanFleet experience and use the practical findings of the project.

The basis for the cost assessment is CleanFleet experience. However, the project sponsors recognized that the cost analysis could not be built by simply collecting and reporting the costs incurred in the CleanFleet demonstration itself for two primary reasons. First, the state of development of several cost elements was in flux, and they would not yield representative cost data if used alone. For example, out of necessity, the alternative fuel vehicles (AFVs) used in CleanFleet were 1992 model vans. All of them, except the Dodge CNG vans and the RFG vans (from all manufacturers), had to be acquired as low production volume modifications of gasoline-powered models.

Second, certain costs incurred by the project were specific to conducting the project and were necessitated by the project itself. They would not be representative of a fleet operator's normal business. Examples are fitting fuel door locks and mounting trip recorders. Also, the lack of established fuel prices and delivery systems for some fuels required that special systems be put in place for the project. Accordingly, a cost assessment based strictly on the “unadjusted” 1992-1994 experience would not be representative of the situation facing fleet operators in the mid-1990s.

To present a representative picture of fleet economics for the mid-1990s, the 1996 Case Study was prepared using CleanFleet data and experience as a starting point, but modified to reflect expected changes from CleanFleet results. The focus of the fleet economics case study is a hypothetical fleet operator. All cost and price information was evaluated from the perspective of the fleet operator.

The cost factors listed in Table 1 are not the only costs incurred by a fleet; rather, they are those costs that are most likely to be significantly different from using standard, unleaded gasoline for motor fuel. For example, the wages paid to drivers of the AFVs were not considered in the case study. They would be essentially the same on a per-mile-of-travel basis. Of course, if more vehicles had to be put into service on a daily basis to compensate for some constraint on use of AFVs, the mixed fleet costs, referred to in the preceding section, would need to be considered.

**General Case Study Assumptions.** The major underlying assumptions for the baseline case study were that

- The fleet operator is located in Los Angeles and is engaged in package delivery service similar to FedEx.
- The business currently operates a fleet of 150 full-size vans and is planning to replace 50 vans with new AFVs in 1996. The size of the vans is in the range of 7,200 to 8,600 pounds gross vehicle weight (GVW).
- The fleet operator has delivery routes that are suitable for all 50 vans at a single location for any of the five alternative fuels. The vehicles operating on liquid or gaseous fuels travel 20,000 miles a year (80 miles a day). For electric vehicles, accumulated miles depend on the driving range available from the vehicle.
- The vehicles are loaded, unloaded, and stored overnight inside an occupied building. The building (including the maintenance facility) can accommodate 150 vehicles.
- Vehicles are fueled on site. Fueling station capacity must be added for whichever fuel is selected for the 50 new vehicles, except for reformulated gasoline. The vehicle fleets must be fueled within a three-hour time period (similar to FedEx practice). Adequate land and space are available for an on-site fuel storage and dispensing facility.
- The fleet complies with all governing regulations.
- Safety is paramount in the fleet operations.
- Service level cannot fall below current levels. Fuels must be available, and vehicles must be able to perform their mission.

Embedded in these assumptions are several key features:

- A contemporary time frame (i.e., 1996) in which other fleet operators will be contemplating introduction of alternative fuels into their fleet operations.
- The 1996 time frame is compatible with both greater availability of AFVs and alternative fuels (including the introduction of California Phase 2 RFG to the market).
- A large enough acquisition of a single type of AFV that the fleet operator can benefit, to some extent, from economies of scale.
- Application of AFVs to revenue service as opposed to less representative trial evaluation.

This set of assumptions defines a baseline scenario for the 1996 Case Study. The impacts on fleet costs of a limited number of alternatives to the baseline case were evaluated and are described in the sections on costs specific to each fleet.

**Specific Assumptions.** Specific assumptions common to all fuels and cost elements for the case study include

- A discount rate of six percent per annum, which is an estimate of the average, after-tax cost of capital for the fleet operator, minus inflation.
- Hourly labor rates (including wages and fringe benefits) of $16.25 for drivers and fuelers and $22.25 for mechanics in 1996 dollars.
- Federal corporate tax rate of 35 percent and California state tax rate of 9.3 percent. State tax is deductible for federal tax computation. The total effective tax rate is 41 percent.

## Summary of Results

Figure 1 shows estimates of total costs per mile of vehicle travel for the 1996 Case Study for each of the fleets except electric vehicles, which are described in a separate section. The range of costs for each fuel reflects either uncertainty in key cost factors or the effects of different options that a fleet operator might select. The values shown are before income tax in 1996 dollars. Present fuel taxes for each fuel are included in the costs, so that fuel tax related incentives are included in Figure 1. Incentives that affect income tax deductions and credits are excluded. The impacts of differing fuel taxes and income tax incentives are examined in a later section. With the assumption of 50 vehicles travelling 20,000 miles annually, a one cent difference in cost per mile equates to a differential of $10,000 in annual costs for the 50-vehicle fleet.

The estimated cost to a fleet operator for 50 vehicles operating on unleaded gasoline is shown on the far left in Figure 1 even though such gasoline will not be available in Los Angeles in 1996 after RFG is introduced. This value of 33.6 cents/mile is shown strictly as a hypothetical baseline against which to compare costs for the other fuels.

The estimated cost for using RFG is shown as a range extending from 35.3 cents/mile to 36.1 cents/mile. The spread in values reflects an uncertainty in the price of RFG to a fleet in 1996. The RFG cost estimate assumes that no additional fueling station capacity is required. With this assumption, the cost per vehicle should be the same for the 50-vehicle RFG fleet or for use of RFG in the full 150-vehicle fleet.

Estimated costs for using CNG range from 40.1 cents/mile to 45.9 cents/mile. This range of costs reflects different options for fueling station design requirements, uncertainty of the fueling station operating and maintenance costs, and whether vehicles are stored and loaded indoors or outside.

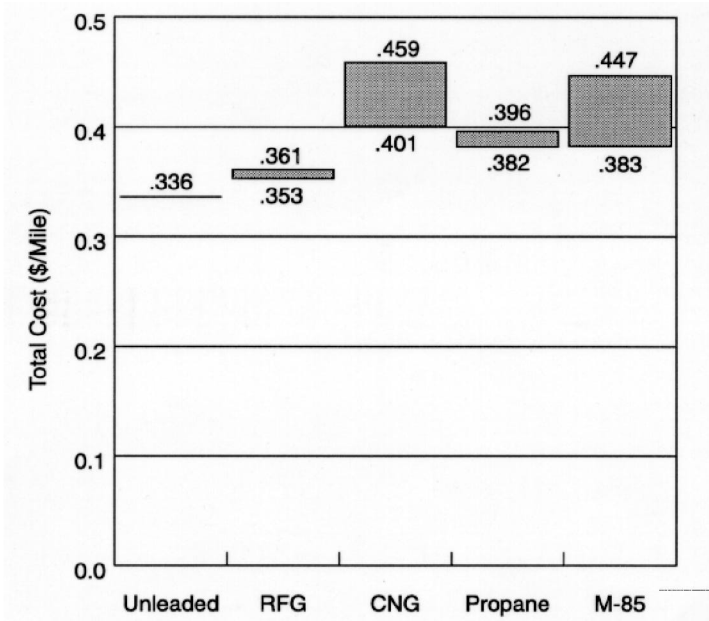


**Figure 1. Comparison of Total Cost Ranges for Alternative Fuel Fleets**

The primary fueling station design requirements affecting station cost are the period of time over which vehicles must be fueled and the need for redundancy. If vehicles are loaded and stored inside a building, significant facility modifications may be required.

Estimated costs for using propane gas range from 38.2 cents/mile to 39.6 cents/mile. The spread in values reflects whether or not propane gas vehicles are housed indoors. If they are, significant modifications to the building's ventilation system may be required by local authorities similar to the CNG case.

Estimated costs for using M-85 range from 38.3 cents/mile to 44.7 cents/mile. This range reflects uncertainty in the price of methanol in 1996. The price of methanol rose dramatically from historical levels of the past few years during 1994, but has fallen rapidly during the first half of 1995.

Figure 2 shows the breakdown of total costs per mile between infrastructure, owning, and operating costs for the baseline case. The infrastructure cost was a significant factor (on a per-mile basis) only for the case of CNG, where a fuel compressor station represents a large investment.

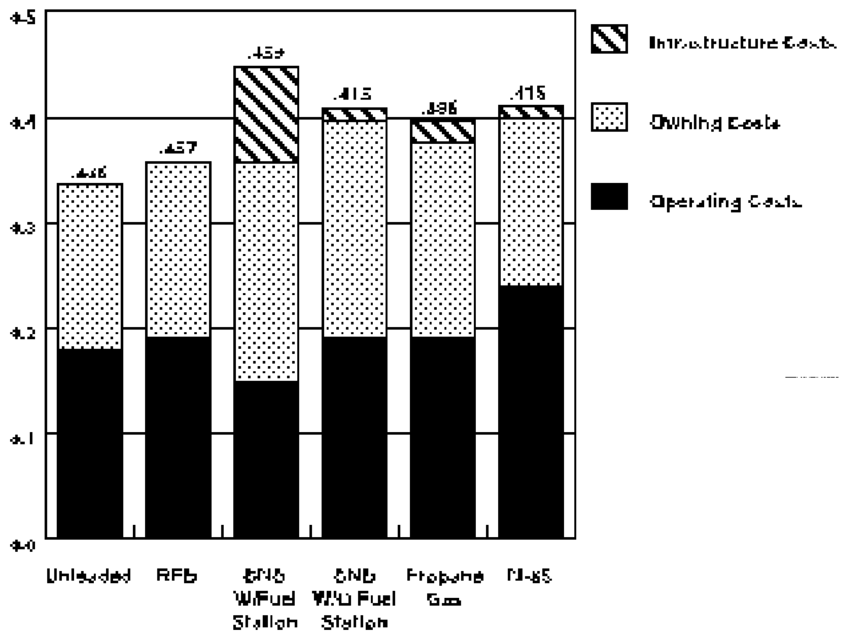


**Figure 2. Breakdown of Estimated Total Costs for the Baseline Cases**

Other infrastructure costs may represent a significant investment to the fleet operator but, when amortized over their economic life and over 50 vehicles, the cost per mile is small.

Table 2 provides the baseline analysis of costs. The baseline case uses assumptions for fleet operating practice similar to CleanFleet experience. Vehicles are stored and loaded inside, refueling of liquid and gaseous fuel vehicles occurs in three hours, and the natural gas compressor fueling station has redundant capacity. The fuel economy values are from CleanFleet measurements, and fuel prices are Battelle's estimates for 1996 (see Appendix A). An exceptional case is included for the CNG fleet: i.e., a CNG case with no fueling station (fueling station located at the fleet site, but owned and maintained by a gas utility or third party, with compressed gas purchased by the fleet at a higher price). The impacts of varying assumptions and ranges of cost estimates are discussed later in the description of fleet costs.

In Table 2 the effective annual cost per vehicle for each cost category is shown at the top of the cost category. The summary cost for each category is computed on a before-tax basis. For cost categories that include capital investments, the annual cost represents a uniform annual payment with net present value equal to the present value of all capital and operating costs. At the bottom of Table 2, total costs are reported in dollars per mile before income tax.

TABLE 2: 1996 CASE STUDY - EXCLUDING INCOME TAX EFFECTS

| Date: Aug 4, 1995 | Unleaded Gasoline | Reformulated Gasoline | Compressed Natural Gas | CNG w/o Fuel Station | Propane Gas | M-85 |
|---|---|---|---|---|---|---|
| INFRASTRUCTURE COSTS ($/yr/veh) | $0 | $0 | $2,063 | $300 | $436 | $195 |
| Personnel Training Costs ($/yr/veh) | $0 | $0 | $30 | $30 | $30 | $26 |
| Maintenance ($/fleet) | $0 | $0 | $1,602 | $1,602 | $1,602 | $267 |
| Drivers ($/fleet) | $0 | $0 | $975 | $975 | $975 | $975 |
| Fuelers ($/fleet) | $0 | $0 | $65 | $65 | $65 | $65 |
| Average Years Employment | 8 | 8 | 8 | 8 | 8 | 8 |
| Training Prep & Presentation | $0 | $0 | $8,000 | $8,000 | $8,000 | $8,000 |
| Amortization Period (yr) | 10 | 10 | 10 | 10 | 10 | 10 |
| Fueling Facility Costs ($/Yr/Veh) | $0 | $0 | $1,763 | $0 | $136 | $169 |
| Cost of Modifications/Additions | $0 | $0 | $450,000 | $0 | $60,000 | $75,000 |
| Economic Life (yr) | 15 | 15 | 15 | 15 | 15 | 15 |
| Residual Value | $0 | $0 | $0 | $0 | $0 | $0 |
| Operating Costs ($/yr) | $0 | $0 | $41,800 | $0 | $600 | $750 |
| Inside Vehicle Storage and Maintenance Facility Costs ($/yr/veh) | $0 | $0 | $270 | $270 | $270 | $0 |
| Cost of Modifications/Additions | $0 | $0 | $185,000 | $185,000 | $185,000 | $0 |
| Economic Life (yr) | 40 | 40 | 40 | 40 | 40 | 40 |
| Residual Value | $0 | $0 | $0 | $0 | $0 | $0 |
| Operating Costs, Annual | $0 | $0 | $1,200 | $1,200 | $1,200 | $0 |
| Special Tools/Facilities Costs | $0 | $0 | $0 | $0 | $0 | $0 |
| Mixed Fleet Costs ($/yr) | $0 | $0 | $0 | $0 | $0 | $0 |
| OWNING COSTS ($/yr/veh) | $3,210 | $3,210 | $4,220 | $4,220 | $3,675 | $3,271 |
| Base Vehicle Price | $15,900 | $15,900 | $20,900 | $20,900 | $15,900 | $16,200 |
| Conversion Cost | $0 | $0 | $0 | $0 | $2,300 | $0 |
| Economic Life (yr) | 5 | 5 | 5 | 5 | 5 | 5 |
| Residual Value | $3,180 | $3,180 | $4,180 | $4,180 | $3,640 | $3,240 |
| OPERATING COSTS ($/yr/veh) | $3,504 | $3,924 | $2,889 | $3,770 | $3,807 | $4,833 |
| Fuel Cost ($/yr/veh) | $2,075 | $2,494 | $899 | $1,780 | $2,173 | $3,198 |
| Untaxed Fuel Cost ($/GEQ) | $0.605 | $0.756 | $0.349 | $0.778 | $0.666 | $1.135 |
| Federal Excise Tax ($/GEQ) | $0.185 | $0.189 | $0.058 | $0.058 | $0.247 | $0.198 |
| State Excise Tax ($/GEQ) | $0.181 | $0.185 | $0.031 | $0.031 | $0.034 | $0.156 |
| Sales Tax(Cal+loc) ($/GEQ) | $0.080 | $0.093 | $0.000 | $0.000 | $0.075 | $0.117 |
| Total Fuel Taxes ($/GEQ) | $0.446 | $0.467 | $0.089 | $0.089 | $0.356 | $0.471 |
| Taxed Fuel Cost ($/GEQ) | $1.051 | $1.223 | $0.438 | $0.867 | $1.022 | $1.606 |
| Fuel Economy (mi/GEQ) | 10.13 | 9.81 | 9.74 | 9.74 | 9.41 | 10.04 |
| Refueling Labor ($/yr/veh) | $229 | $231 | $770 | $770 | $434 | $435 |
| Fueling Rate (Gal Equiv/min) | 9 | 9 | 6 | 6 | 6 | 6 |
| Vehicle Range (mi) | 346 | 328 | 150 | 150 | 187 | 202 |
| Refuels per Year | 63 | 63 | 250 | 250 | 125 | 125 |
| Vehicle Movement Time (min) | 10 | 10 | 10 | 10 | 10 | 10 |
| Maintenance ($/yr/veh) | $600 | $600 | $620 | $620 | $600 | $600 |
| General Maintenance ($/mi) | $0.030 | $0.030 | $0.030 | $0.030 | $0.030 | $0.030 |
| Specific Maintenance ($/veh) | neg | neg | $100 | $100 | neg | neg |
| Specific Maintenance Time Interval (mo) | | | 36 | 36 | | |
| Insurance ($/yr/veh) | $600 | $600 | $600 | $600 | $600 | $600 |
| FLEET SIZE (vehicles) | 50 | 50 | 50 | 50 | 50 | 50 |
| ANNUAL MILES TRAVELED (mi/yr/veh) | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 |
| TOTAL COSTS PER VEHICLE MILE TRAVELED -BEFORE INCOME TAX | | | | | | |
| INFRASTRUCTURE COSTS | $0.000 | $0.000 | $0.103 | $0.015 | $0.022 | $0.010 |
| OWNING COSTS | $0.161 | $0.161 | $0.211 | $0.211 | $0.184 | $0.164 |
| OPERATING COSTS | $0.175 | $0.196 | $0.144 | $0.188 | $0.190 | $0.242 |
| TOTAL COSTS | $0.336 | $0.357 | $0.459 | $0.415 | $0.396 | $0.415 |
| without fuel taxes | | | | | | |
| OPERATING COSTS | $0.131 | $0.149 | $0.135 | $0.179 | $0.152 | $0.195 |
| TOTAL COSTS | $0.292 | $0.309 | $0.449 | $0.405 | $0.358 | $0.368 |

NOTES:
1. Discount rate is 0.06
2. All costs are in constant 1996 dollars.
3. Vehicle maintenance and insurance rates are assumed to be the same for all fleets.

Table 3 employs the same assumptions as in Table 2, but also includes the effects of corporate income taxes (both federal and California). At the bottom of Table 3, total costs are reported in dollars per mile after income tax. The effects of tax incentives are not included in Table 3, but their impacts on total costs are described in a later section.

### Cost Impact of Fuel Taxes and Incentives

Table 4 provides a summary of total costs (in cents per mile) for each of the fleets both before income tax and after income tax. In addition, the impact of economic incentives and fuel taxes is shown in the lower two rows. The incentives considered are those defined in the federal Energy Policy Act of 1992 (EPACT), which allow rapid depreciation of vehicle incremental costs and fueling station investments for alternative fuels. The incentives have a very modest impact on total costs. The total cost without fuel tax is shown because of the significant differences in fuel taxes among the fuels.

### Cost Elements Common to the Fuels

Several cost elements had similar assumptions for estimating costs for the various fleets. These assumptions and costs are summarized first before discussing costs specific to each fuel.

**Personnel Training.** The estimates for training personnel assume that the fleet staff has been trained previously for a gasoline fleet. Thus, no additional training is required for the unleaded or RFG fleets. For the other fleets, one hour of training was assumed for 60 drivers and four fuelers. Training for mechanics was assumed to consist of three mechanics receiving 24 hours of training for CNG, propane gas, and electric fleets, and three mechanics receiving four hours of training for the M-85 fleet. This level of training is consistent with the training in the CleanFleet project. It assumes that detailed work on alternative fuel systems would be conducted at a dealership, not by the fleet mechanics. The personnel training costs are amortized over an eight-year period, which is the estimated average employment period for the staff being trained. An $8,000 cost for training preparation and presentation, amortized over a ten-year period for each fleet, matches the cost for the CleanFleet project. In all cases, personnel training costs were insignificant factors in the overall fleet costs.

**Fueling Facility.** These costs represent the estimated cost of adding required fueling capacity for the 50 AFVs. In determining the required fueling capacity, it was assumed that the vehicles would be fueled in a three-hour period. Both capital investment and operating costs are included. The estimated capital investment costs were developed from discussions with and quotations from typical equipment vendors. The fueling system operating costs were a significant factor in total costs only for CNG. Operating costs from CleanFleet were used to estimate these costs. For the other fuels, annual operating costs were assumed to be one percent of capital cost.

TABLE 3: 1996 CASE STUDY - INCLUDING INCOME TAX EFFECTS

| Date: Aug 4, 1995 | Unleaded Gasoline | Reformulated Gasoline | Compressed Natural Gas | CNG w/o Fuel Station | Propane Gas | M-85 |
|---|---|---|---|---|---|---|
| INFRASTRUCTURE COSTS ($/yr/veh) | $0 | $0 | $1,405 | $240 | $337 | $136 |
| Personnel Training Costs ($/yr/veh) | $0 | $0 | $18 | $18 | $18 | $15 |
| Income Tax Savings ($/yr/veh) | $0 | $0 | $12 | $12 | $12 | $11 |
| Maintenance ($/fleet) | $0 | $0 | $1,602 | $1,602 | $1,602 | $267 |
| Drivers ($/fleet) | $0 | $0 | $975 | $975 | $975 | $975 |
| Fuelers ($/fleet) | $0 | $0 | $65 | $65 | $65 | $65 |
| Average Years Employment | 8 | 8 | 8 | 8 | 8 | 8 |
| Training Prep & Presentation | $0 | $0 | $8,000 | $8,000 | $8,000 | $8,000 |
| Amortization Period (yr) | 10 | 10 | 10 | 10 | 10 | 10 |
| Fueling Facility Costs ($/Yr/Veh) | $0 | $0 | $1,165 | $0 | $97 | $121 |
| Income Tax Savings ($/yr/veh) | $0 | $0 | $598 | $0 | $39 | $49 |
| Cost of Modifications/Additions | $0 | $0 | $450,000 | $0 | $60,000 | $75,000 |
| Economic Life (yr) | 15 | 15 | 15 | 15 | 15 | 15 |
| Residual Value | $0 | $0 | $0 | $0 | $0 | $0 |
| Operating Costs ($/yr) | $0 | $0 | $41,800 | $0 | $600 | $750 |
| Inside Vehicle Storage and Maintenance Facility Costs ($/yr/veh) | $0 | $0 | $222 | $222 | $222 | $0 |
| Income Tax Savings ($/yr/veh) | $0 | $0 | $48 | $48 | $48 | $0 |
| Cost of Modifications/Additions | $0 | $0 | $185,000 | $185,000 | $185,000 | $0 |
| Economic Life (yr) | 40 | 40 | 40 | 40 | 40 | 40 |
| Residual Value | $0 | $0 | $0 | $0 | $0 | $0 |
| Operating Costs, Annual | $0 | $0 | $1,200 | $1,200 | $1,200 | $0 |
| Special Tools/Facilities Costs | $0 | $0 | $0 | $0 | $0 | $0 |
| Mixed Fleet Costs ($/yr) | $0 | $0 | $0 | $0 | $0 | $0 |
| OWNING COSTS($/yr/veh) | $2,091 | $2,091 | $2,749 | $2,749 | $2,394 | $2,131 |
| Income Tax Savings ($/yr/veh) | $1,119 | $1,119 | $1,471 | $1,471 | $1,281 | $1,140 |
| Base Vehicle Price | $15,900 | $15,900 | $20,900 | $20,900 | $15,900 | $16,200 |
| Conversion Cost | $0 | $0 | $0 | $0 | $2,300 | $0 |
| Economic Life (yr) | 5 | 5 | 5 | 5 | 5 | 5 |
| Residual Value | $3,180 | $3,180 | $4,180 | $4,180 | $3,640 | $3,240 |
| OPERATING COSTS ($/yr/veh) | $2,066 | $2,314 | $1,703 | $2,223 | $2,245 | $2,850 |
| Fuel Cost ($/yr/veh) | $1,223 | $1,470 | $530 | $1,050 | $1,281 | $1,886 |
| Income Tax Savings ($/yr/veh) | $852 | $1,024 | $369 | $731 | $892 | $1,313 |
| Untaxed Fuel Cost ($/GEQ) | $0.605 | $0.756 | $0.349 | $0.778 | $0.666 | $1.135 |
| Federal Excise Tax ($/GEQ) | $0.185 | $0.189 | $0.058 | $0.058 | $0.247 | $0.198 |
| State Excise Tax ($/GEQ) | $0.181 | $0.185 | $0.031 | $0.031 | $0.034 | $0.156 |
| Sales Tax(Cal+loc) ($/GEQ) | $0.080 | $0.093 | $0.000 | $0.000 | $0.075 | $0.117 |
| Total Fuel Taxes ($/GEQ) | $0.446 | $0.467 | $0.089 | $0.089 | $0.356 | $0.471 |
| Taxed Fuel Cost ($/GEQ) | $1.051 | $1.223 | $0.438 | $0.867 | $1.022 | $1.606 |
| Fuel Economy (mi/GEQ) | 10.13 | 9.81 | 9.74 | 9.74 | 9.41 | 10.04 |
| Refueling Labor ($/yr/veh) | $135 | $136 | $454 | $454 | $256 | $256 |
| Income Tax Savings ($/yr/veh) | $94 | $95 | $316 | $316 | $178 | $178 |
| Fueling Rate (Gal Equiv/min) | 9 | 9 | 6 | 6 | 6 | 6 |
| Vehicle Range (mi) | 346 | 328 | 150 | 150 | 187 | 202 |
| Refuels per Year | 63 | 63 | 250 | 250 | 125 | 125 |
| Vehicle Movement Time (min) | 10 | 10 | 10 | 10 | 10 | 10 |
| Maintenance ($/yr/veh) | $354 | $354 | $365 | $365 | $354 | $354 |
| Income Tax Savings($/yr/veh) | $246 | $246 | $254 | $254 | $246 | $246 |
| General Maintenance ($/mi) | $0.030 | $0.030 | $0.030 | $0.030 | $0.030 | $0.030 |
| Specific Maintenance ($/veh) | neg | neg | $100 | $100 | neg | neg |
| Specific Maintenance Time Interval (mo) | | | 36 | 36 | | |
| Insurance ($/yr/veh) | $354 | $354 | $354 | $354 | $354 | $354 |
| Income Tax Savings($/yr/veh) | $246 | $246 | $246 | $246 | $246 | $246 |
| Insurance Cost($/yr/veh) | $600 | $600 | $600 | $600 | $600 | $600 |
| FLEET SIZE (vehicles) | 50 | 50 | 50 | 50 | 50 | 50 |
| ANNUAL MILES TRAVELED (mi/yr/veh) | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 |
| TOTAL COSTS PER VEHICLE MILE TRAVELED -AFTER INCOME TAX | | | | | | |
| INFRASTRUCTURE COSTS | $0.000 | $0.000 | $0.070 | $0.012 | $0.017 | $0.007 |
| OWNING COSTS | $0.105 | $0.105 | $0.137 | $0.137 | $0.120 | $0.107 |
| OPERATING COSTS | $0.103 | $0.116 | $0.085 | $0.111 | $0.112 | $0.142 |
| TOTAL COSTS | $0.208 | $0.220 | $0.293 | $0.261 | $0.249 | $0.256 |
| without fuel taxes | | | | | | |
| OPERATING COSTS | $0.077 | $0.088 | $0.080 | $0.106 | $0.090 | $0.115 |
| TOTAL COSTS | $0.182 | $0.192 | $0.287 | $0.255 | $0.226 | $0.228 |
| TOTAL COSTS W/ EPACT INCENTIVES INCLUDED | $0.208 | $0.220 | $0.290 | $0.259 | $0.247 | $0.255 |

NOTES:
1. Discount Rate is 0.060
2. Corp Inc Tax Rate (US + Cal) is 0.410
3. US Corp Inc Tax Rate is 0.350
4. Cal Corp Inc Tax Rate is 0.093
5. Cal tax is deductible for US tax computation
6. All costs are in constant 1996 dollars.
7. Vehicle maintenance and insurance rates are assumed to be the same for all fleets.

**Table 4. Impact of Income Taxes, Fuel Taxes, and Incentives on Total Fleet Costs**

| | Total Cost (cents/mile) | | | | | |
|---|---|---|---|---|---|---|
| | UNL | RFG | CNG | CNG[a] | PRO | M-85 |
| Before income tax without incentives[b] | 33.6 | 35.7 | 45.9 | 41.5 | 39.6 | 41.5 |
| After income tax without incentives[b] | 20.8 | 22.0 | 29.3 | 26.1 | 24.9 | 25.6 |
| After income tax; incentives included[b] | 20.8 | 22.0 | 29.0 | 25.9 | 24.7 | 25.5 |
| After income tax without incentives and without fuel taxes | 18.2 | 19.2 | 28.7 | 25.5 | 22.6 | 22.8 |

[a] CNG without fuel station (i.e., fuel station owned by gas utility).
[b] Fuel taxes are included in top three rows.

**Building Modifications.** Building modifications may be required for fleets that load and store vehicles inside buildings and for vehicle maintenance facilities. The only major building modifications likely to be required for alternative fuel fleets are flammable gas detection and ventilation systems for the gaseous fuels—CNG and propane gas. This was the case in CleanFleet. The gas detection and ventilation system installed at the propane gas site was used as the model for estimating costs. Depending upon the nature of fleet operations and local requirements, lower-cost approaches may be used to provide safety with gaseous fuels.

Certain special tools or facilities for maintaining an alternative fuel fleet would be required. In CleanFleet, these costs were insignificant, amounting to less than $1,000, because all major repairs were performed by the vehicle dealer or organization that modified the vehicles. This situation was assumed to hold for the 1996 Case Study. In the longer term, specialized diagnostic and repair equipment requiring a significant investment may be developed for alternative fuel fleets.

**Mixed Fleet Complexity.** Additional costs resulting from operating a mixed fleet (i.e., both gasoline and alternative fuel) are highly dependent upon specific fleet operations. This cost element was not considered in the case study.

**Vehicle Owning Costs.** The vehicle cost estimates were developed from discussions with vehicle manufacturers and literature reviews. It is expected that, in 1996, delivery vans will be available from one or more original equipment manufacturers (OEMs) for unleaded and reformulated gasoline and CNG. It is not clear at present whether M-85 compatible vehicles will be available from OEMs in 1996. Vehicle conversions will be required for propane gas and electric vehicles in 1996. A five-year (100,000-mile) life with 20 percent residual value is assumed for all fleets.

**Fuel Cost.** Two components determine total fuel cost for a fleet: the price of the fuel, including fuel taxes, and the quantity of fuel required. In Table 2 fuel costs are broken down to show the base cost without taxes as well as the federal, state, and sales taxes. All costs are expressed on a gasoline equivalent gallon (GEQ) basis, where one GEQ has a net heating value of 115,000 Btu or 121.3 mega-

Joules. The conversion factors between various fuel quantities and a GEQ are provided in Table 5. The conversion factors were computed from measurements of average fuel composition during the CleanFleet program. Heating value is expressed as the lower heating value (LHV) in millions (mm) of Btu per unit quantity of fuel.

**Table 5. Conversion of Fuel Quantities to Gasoline Equivalent Gallons**

| Fuel | Heating Value (mmBtu/unit)-LHV | Conversion |
|---|---|---|
| Equivalent gasoline | 0.1150/gallon | 1 GEQ = 1 gallon |
| Regular, unleaded gasoline | 0.1144/gallon | 1 GEQ = 1.006 gallon |
| Reformulated gasoline | 0.1119/gallon | 1 GEQ = 1.029 gallon |
| CNG | 0.0937/therm | 1 GEQ = 1.226 therm |
| Propane gas | 0.0832/gallon | 1 GEQ = 1.348 gallon |
| M-85 | 0.0664/gallon | 1 GEQ = 1.735 gallon |

The required quantity of fuel depends upon distance driven (assumed to be 20,000 miles per year) and the vehicle's fuel economy. The fuel economy values in miles/GEQ given in Table 2 were also derived from measurements during the CleanFleet program. The fuel economy for each fleet (a fleet consisted of similar vehicles from the same OEM and with the same fuel) was compared to its control fleet (similar vehicles from the same OEM at the same site running on unleaded gasoline), and a percentage difference was computed. Where there were multiple fleets with the same fuel, an average of the percentage difference from the respective control fleets was calculated. The average percentage difference was then applied to a single fuel economy number, which was the overall average fuel economy for the unleaded control vehicles. The fuel economy computations and resulting values are shown in Table 6. Because these values for fuel economy are stated on an energy equivalent basis (i.e., GEQ), differences in fuel economy reflect differences in efficiency of the vehicles in converting stored chemical energy in the fuel to distance travelled.

**Table 6. Computation of Fleet Fuel Economy**

| Fuel/OEM | | Average Fleet Fuel Economy[a] (mi/GEQ) | Control Fleet Fuel Economy[a] (mi/GEQ) | % Difference | Average % Difference | Computed Fleet Fuel Economy (mi/GEQ) |
|---|---|---|---|---|---|---|
| RFG | Chev | 9.86 | 10.33 | -4.5 | -3.2 | 9.81 |
| | Dodge | 9.81 | 9.73 | +0.8 | | |
| | Ford | 9.66 | 10.27 | -5.9 | | |
| CNG | Chev | 9.33 | 10.49 | -11.1 | -3.9 | 9.74 |
| | Dodge | 9.67 | 10.04 | -3.7 | | |
| | Ford | 10.76 | 10.43 | +3.2 | | |
| PRO | Chev | 8.71 | 9.75 | -10.7 | -7.1 | 9.41 |
| | Ford | 9.19 | 9.52 | -3.5 | | |
| M-85 | Ford | 10.49 | 10.58 | -0.9 | -0.9 | 10.04 |
| Control Fleet Average | | | 10.13 | | | |

[a] Fuel economy values from CleanFleet project extrapolated to 80 mi/day.

**Refueling Labor.** Differences in labor cost for refueling between alternative fuel fleets result primarily from differences in vehicle driving range. Driving range depends upon the quantity of fuel storage on the vehicle, energy content of the fuel, and efficiency of the vehicle in transforming the chemical energy of the fuel into distance travelled. The project vans and fuels were used as the basis for each of these three factors. Consequently, the fuel storage capacity on these vans had a direct effect on the driving range and hence fueling costs. For example, a CNG vehicle with a range of 150 miles is obviously refueled more frequently than the unleaded gasoline vehicle with a range of 346 miles. A second, and generally less important, difference in cost results from different pumping rates for the various fueling stations.

For ease of estimating, the annual refueling costs are computed as the sum of two elements. The first element is the product of the number of refuels per year, the vehicle movement time, and the labor rate for fuelers. To compute the number of refuels per year, it was assumed the vehicle travels 80 miles per day and is refilled when the fuel remaining at the end of a day is less than the quantity necessary for the next day. With this assumption, the CNG vehicles (150-mile range) are refueled each day and the RFG vehicles (328-mile range) are refueled once every three days. The vehicle ranges are based on measurements made in the CleanFleet program. The vehicle movement time, estimated as 10 minutes from CleanFleet measurements, represents the time required to perform all vehicle handling functions associated with refueling except the fuel pumping operation. The second element of refueling labor associated with pumping time was computed from the total quantity of fuel consumed per year divided by the pumping rate, determined during the CleanFleet demonstration.

**Maintenance.** The maintenance cost experience for the CleanFleet vehicles was not sufficient to develop realistic estimates for vehicle maintenance costs for the various fleets. Most of the maintenance requirements for CNG, propane gas, and M-85 vehicles that occurred were due to the developmental status of the fuel systems and control systems. Also, large populations are generally required to compute meaningful averages for maintenance costs. Because of these considerations, no attempt was made to estimate maintenance costs for the 1996 Case Study based on CleanFleet experience. Instead, an estimate of 3 cents per mile, based on a previous Battelle study of maintenance costs for light duty trucks and vans, was used for each fleet. This assumes that 1996 AFVs will be fully developed and exhibit reliability levels comparable to gasoline vehicles.

The specific maintenance category is provided for particular maintenance activities during the vehicle life, such as CNG tank inspection or electric vehicle battery replacement.

**Insurance.** Separate insurance rates for alternative fueled vehicles have not been established, mainly due to limited experience. Of the various factors that influence the cost of insurance, it seems likely that the relative value of vehicles will be a factor. In the meantime, a typical rate of $600 per year per vehicle was used for all fleets.

**Income Tax Savings, Depreciation, and Cost Incentives.** Within each cost category, the annual savings in income taxes due to fleet costs are computed and reported in Table 3. Annual operating costs are multiplied by the effective tax rate of 41 percent. Appropriate depreciation schedules were applied to each investment; the present values of the resulting tax savings per dollar of investment are shown in Table 7.

**Table 7. Depreciation Schedules and Tax Savings Factors**

| Class of Investment | Depreciation Schedule | Present Value of Tax Savings per Investment Dollar |
|---|---|---|
| Personnel Training | Expensed in year of investment | $0.41 |
| Fueling Station | 15-year, 150% declining balance; straight line after year 6 | $0.275 |
| Building Modifications | 39-year straight line | $0.157 |
| Vehicles | 5-year, double-declining balance; straight line after year 3 | $0.358 |

All investments were assumed to occur in the first quarter. No residual value was used in depreciation calculations; the revenue from the residual value of the vehicles was reduced by a factor of (1-tax rate).

Cost incentives, intended to encourage the use of alternative fuels, allow direct tax credits or rapid depreciation of investments in vehicles and fueling stations. EPACT established the following incentives:

- For electric vehicles, the lower of $4,000 or 10 percent of the vehicle price can be applied as a tax credit in the year of purchase.
- For other alternative fuels, the lower of $2,000 or the incremental vehicle price can be expensed in the year of purchase.
- For an alternative fuel, up to $100,000 of the cost of a fueling station can be expensed in the first year.

California currently allows a state income tax credit equal to 55 percent of the incremental vehicle cost if the vehicle meets LEV emission standards. However, the credit is scheduled to be phased out on January 1, 1996; therefore, it was not included in the 1996 Case Study.

### Description of Fleet Costs

This section describes the principal cost factors for each alternative fuel fleet. The separate assumptions pertinent to each fleet and the bases for cost estimates are discussed. In addition, the impact of several different operating strategies and assumptions on total costs are estimated.

**Unleaded Gasoline Fleet.** With the assumptions used for the 1996 Case Study, no investment in facilities or staff training is required for a gasoline vehicle fleet.

The vehicle cost for the unleaded gasoline fleet is estimated at $15,900. This was based on average dealer prices for several cargo vans in 1994, then inflated to 1996 dollars at 3 percent per year. The vehicle cost estimates for the other fleets were developed by estimating the differential cost relative to the unleaded gasoline vehicle.

The starting point for the unleaded gasoline fuel cost was $1.02 per gallon after taxes ($0.578 per gallon before taxes) wholesale price in 1994, based on a survey of wholesale gasoline prices in California. After adjustments for energy content and inflation to the untaxed cost, the estimate in 1996 is $1.052 per GEQ after taxes ($0.605 per GEQ before taxes).

**RFG Fleet.** As with unleaded gasoline, it is expected that no investment in facility modifications or staff training will be required for implementing a 50-vehicle RFG fleet in 1996. Because no infrastructure investments are required, the cost estimate for reformulated gasoline does not depend on the size of fleet being converted to RFG.

The price premium for California Phase 2 reformulated gasoline over unleaded regular gasoline is estimated to be in the range of 10 to 17 cents per gallon before taxes in 1996. The estimate of the most likely premium is 13.3 cents. After adjusting for differing energy content, the estimated differential is 15.1 cents per GEQ before taxes (17.2 cents per GEQ after taxes) for a total cost of $1.224 per GEQ. The effect of the premium price for RFG on total costs, assuming premiums of 10, 13.3, and 17 cents per gallon, is shown in Figure 3.

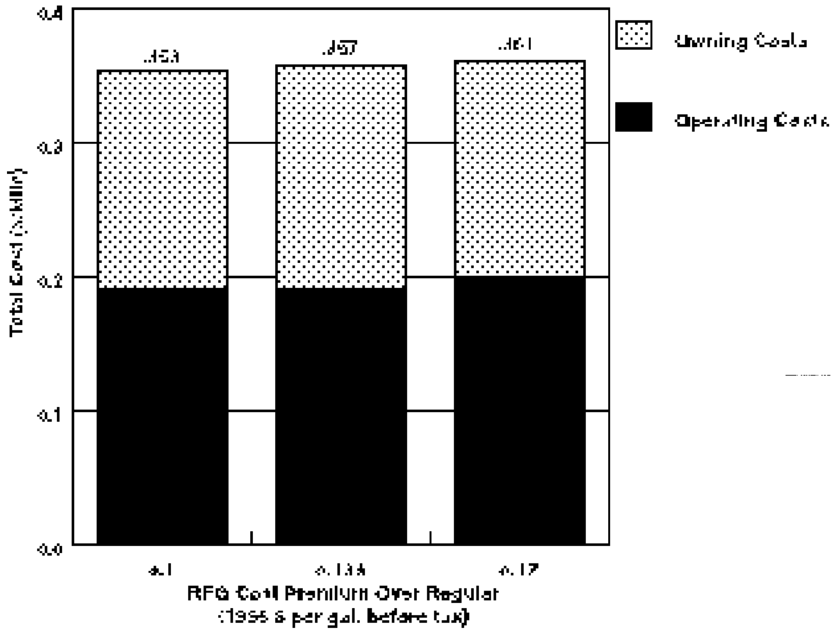


**Figure 3. Reformulated Gasoline Price Range — Impact on Total Costs**

**CNG Fleet.** The economic analysis for the CNG fleet is complicated because a number of options are available to the fleet operator for fueling a CNG fleet. The fuel cost, including the cost of compression, can vary significantly depending on the approach taken by the fleet operator. Furthermore, because of the development status of CNG fueling stations at the time of the CleanFleet program, there is significant uncertainty in the cost estimates for the fueling station investment and operating costs. As a result, the following discussion of CNG fleet economics is more extensive than for most of the other fleets.

Two cases for a CNG fleet are presented in Table 2: one case in which the compressed gas fueling station is owned and operated by the fleet operator, and a second case with the fueling station owned by a gas utility or other outside party. In the latter case, a natural gas utility, or third party, owns and operates a CNG fueling station at the fleet site and sells compressed gas at a higher price than uncompressed gas.

With the assumption of 80 miles per day per vehicle, a CNG fleet of 50 full-size vans will consume about 410 GEQ [51,800 standard cubic feet (SCF)] of fuel per day. In the CleanFleet program, the fueling station was designed to fuel the entire fleet in three hours and to provide 100 percent redundancy for the compressor and drive motor. For a fleet of 50 vehicles, these criteria can be met with a station incorporating two 150 SCFM (76 GEQ/hr) compressors and six ASME storage vessels with 35 GEQ effective capacity each. The installed cost of this system, with a two-hose fast-fill dispenser, is estimated to be $450,000. This estimate is based on quotes from equipment manufacturers.

In the CleanFleet program a compressor station with two 50 SCFM compressors was installed at the CNG fleet site. The total cost of the fueling station was $556,000. The construction and installation cost was $170,000 and included considerable effort working with local authorities to obtain permits. Now that experience installing a number of natural gas fueling stations has been acquired, a typical construction and installation cost is $65,000. In addition, the cost of major fueling station components (compressors, filter/driers, storage vessels, and dispensers) all have come down.

A fleet operator may choose to reduce the required investment by relaxing the fueling station design requirements. Dropping the requirement for compressor redundancy could reduce the investment to about $350,000. The Southern California Gas Company does not recommend the redundancy; instead, it provides a mobile compressor station that can be moved to the site for emergencies. Also, if there is a nearby public CNG fueling station, there would be less incentive to provide redundant capacity at the fleet site. If, in addition, the fleet operator is willing to fuel vehicles over a five- or six-hour period, a reduced capacity station with three storage vessels and a single 100 SCFM compressor costing about $300,000 would be adequate.

The operating and maintenance costs for a CNG compressor station are significant cost factors. During the CleanFleet program the cost of electric energy to drive the compressors was 16.5 cents per GEQ (1.5 kWh/GEQ or 1.2 kWh/therm at an average cost of 11 cents/kWh); maintenance costs were about $10,000 per year for a fleet of 21 vehicles. For a 50-vehicle fleet, maintenance costs were scaled upward from the 21-vehicle fleet cost, yielding an estimated annual cost of $25,000. Electric energy consumption costs were assumed to remain constant on a cents-per-GEQ basis.

Alternative approaches with potential for large reductions in fueling station operating costs should be considered by the fleet operator. Overnight fueling can reduce electrical energy costs from 16.5 cents per GEQ to about 6.2 cents per GEQ by taking advantage of lower, off-peak electric rates. Using a natural gas engine to drive the compressor can lower the energy cost to an estimated 4.2 cents per GEQ. However, the potential for increased maintenance costs and limited durability of the natural gas engine should be given consideration. Furthermore, in an area that is not in attainment with national ambient air quality standards, such as the South Coast Air Quality Management District, the fleet may encounter difficulties in obtaining a permit for installation and operation of a natural gas-driven compressor (due to emissions). The high cost for compressor station maintenance experienced during the CleanFleet demonstration may be largely due to the developmental status of the station. Uncertainty exists in the factor selected for scaling from the CleanFleet experience of 21 vehicles to 50 vehicles. The Southern California Gas Company reports that an annual maintenance cost of $10,000 is typical for a 50-vehicle station in 1994. This equates to approximately 10 cents per GEQ.

If the fleet operator loads or stores vehicles inside buildings, additional equipment will be required to provide safety for a gaseous fuel fleet. In the CleanFleet program, gas detection and ventilation systems (sized for five air changes per hour) were added to the buildings for the CNG and propane gas fleets. At the CNG site the local fire marshal required that the ventilation system be run on a routine basis at regular intervals to purge carbon monoxide from the buildings. This added a great deal of cost, because it required that a large heating system be added. The total installed cost of the system was $382,000. The routine operation of the ventilation system was not required at the CleanFleet demonstration's propane gas site. The routine operation of the ventilation system is not expected to be typical. Because the requirement was based on carbon monoxide purging, it could be applied to any vehicle fleet. The system installed at the propane gas fleet site was selected as a typical model for a gaseous fuel with an estimated cost of $185,000 for a building housing 150 vehicles.

Here, also, alternative approaches that affect the required investment are available to a fleet operator. If vehicles are stored and loaded outside, no investment is expected. An alternative that has been implemented for other CNG fleets consists of adding a gas detection and alarm system without the added ventilation. The building is then evacuated if the alarm is triggered. An estimated cost for the gas detection and alarm system is $50,000. If a forced ventilation system is not employed, the time required for the concentration of flammable gas in the building to diminish to a safe level may be unacceptable to fleet operations. In any event, the fleet operator needs to evaluate the benefits and associated costs for protection systems, and the operator needs to meet all code requirements and gain approval from the fire marshal for bringing AFVs indoors.

Annual operating expenses for the gas detection and ventilation system are expected to be relatively modest and are estimated at $1,200 per year. The estimated cost is composed of $600 for routine calibration of gas detectors and $600 for inspection and replacement of the filter and drive belt.

It is expected that OEM-produced CNG cargo vans will be available in 1996. An estimated premium of $5,000 above the cost of a gasoline vehicle was developed from discussions with vehicle manufacturers. It was assumed that each of the CNG vans would be equipped with three or four storage tanks, as in the CleanFleet program, and filled to a maximum of 3,000 psig. In the CleanFleet program the average cost premium for the CNG vehicles was $5,870.

The estimate for the 1996 CNG fuel price was developed from formulas in the Southern California Gas Company rate filing. For compressed gas at 3,000 psi the fuel price is computed starting from the price for Phase 2 reformulated gasoline; the computed differential in fully taxed fuel prices is 35.8 cents per GEQ lower than for RFG. The price of uncompressed gas is 35 cents per therm (42.9 cents per GEQ) lower than the cost of compressed gas. The estimated fuel economy for CNG vehicles is 9.74 mi/GEQ.

Maintenance for CNG vehicles is expected to be similar to gasoline vehicles in 1996. The storage tanks are expected to require only visual inspection, not recertification testing, at three-year intervals, at an estimated cost of $100 per vehicle.

The baseline cases for the CNG fleet, shown in Table 2, include the gas detection and ventilation system. For the case with a fueling station, the station sized for three-hour fueling with 100 percent compressor redundancy is assumed. The impacts of the alternatives described above on total costs are summarized in Table 8. The effects of selected combinations of the system alternatives are illustrated in Figure 4.

**Table 8. Impact of System Alternatives on Total Costs — CNG Fleet**

| Case | Total Costs, $/mile | Comments |
|---|---|---|
| Baseline - with fuel station | 0.459 | |
| Fuel station - no redundancy | 0.448 | Fuel station cost reduced from $450,000 to $350,000 |
| Fuel station<br>No redundancy<br>Six-hour fueling | 0.443 | Fuel station cost reduced from $450,000 to $300,000 |
| Fuel station<br>Reduced operating and maintenance costs | 0.433 | O&M cost reduced from 38 cents per GEQ to 16 cents per GEQ |
| Baseline with fuel station;<br>Outdoor vehicle parking | 0.445 | Building modification cost of $185,000 eliminated |
| Baseline without fuel station;<br>Outdoor vehicle parking | 0.401 | Building modification cost eliminated and third-party-owned fueling station used |

**Propane Gas Fleet.** Implementing a propane gas fleet will require an investment for a fueling station and may require investment in building modifications for propane detection and ventilation.

A propane gas fueling station for a fleet of 50 vehicles will typically consist of an aboveground storage tank and a dispenser equipped with two hoses. It is advantageous to provide greater than 10,000-gallon storage to take advantage of lower fuel prices for 10,000-gallon deliveries. Assuming a 15,000-gallon tank, cost estimates for a propane fueling station, obtained from fueling system suppliers, range from $50,000 to $70,000. A cost of $60,000 was selected for Table 2. In the CleanFleet program the fueling station was provided by the propane supplier, which is common practice for small fueling sites.

In the CleanFleet program a flammable gas detection system and an air ventilation system, sized for five air changes per hour, were installed in a building that houses 100 vehicles. The installed cost, including engineering, was $137,000. An estimate of $185,000 for a 150-vehicle building was obtained by scaling up by a factor of 1.35. With this system an alarm sounds, and the ventilation system is turned on automatically any time a gas detector registers at least 20 percent of the lower flammability limit. The operating costs for the system are estimated at $1,200 per year: $600 for sensor calibration and $600 for inspection and replacement of filters and belts in the ventilation system.

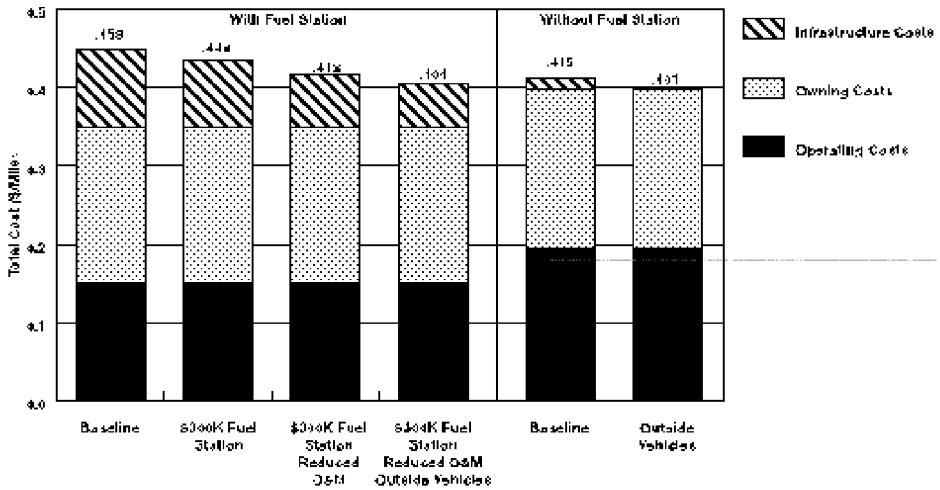


**Figure 4. CNG Alternatives — Impact on Total Costs**

It is expected that the OEMs will not manufacture propane cargo vans in 1996. Cost estimates for modifying a cargo van for propane operation vary over a range of $1,800 to $3,000. A modification cost of $2,300 was selected as the most likely case. For the CleanFleet program, the average conversion cost was $3,230.

The cost of propane fuel in 1996 is estimated at $0.666 per GEQ before fuel taxes ($1.022 per GEQ after taxes). This estimate was developed from a 1994 price of $0.475 per physical gallon to a fleet operator and assumes delivery quantities of 10,000 gallons and no cost premium for the HD-5 propane specification. (HD-5 specifies a maximum concentration of propene in propane gas of 5 percent by volume and other limits.)

The cost estimates for the propane gas fleet, based on the above assumptions, are shown in Table 2. The cost impact of two alternatives is shown in Figure 5. The two alternatives are

- Gas detection and alarm system costing $50,000

- Outdoor loading and parking of vehicles with no building modifications required.

**M-85 Fleet.** The cost for an M-85 fueling station with capacity to fuel 50 vans is estimated at$75,000, the same as for a comparable gasoline station.

A $300 cost differential relative to a gasoline vehicle was estimated for an OEM-produced, M-85 compatible van based on conversations with vehicle manufacturers. In the CleanFleet program the M-85 vans were flexible fuel vehicles, with a price premium of $2,000 per vehicle.

The M-85 fuel price estimate is based on an estimated methanol cost of 60 cents per gallon, f.o.b. California port, in 1996. Assuming the 15 percent gasoline fraction is Phase 2 reformulated gasoline (costing 73.5 cents per gallon), and adding 4 cents for distribution cost yields an estimated wholesale price of

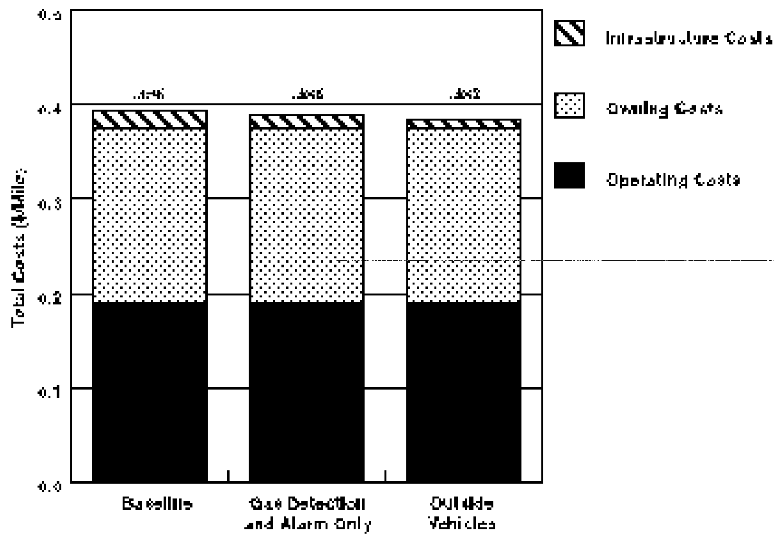


**Figure 5. Propane Gas Alternatives — Impact on Total Costs**

65.4 cents per gallon for M-85 before taxes. Adjusting for energy content results in a wholesale price of $1.135 per GEQ before taxes, and $1.606 after taxes.

The price of methanol is difficult to forecast because of recent market fluctuations. A price range of $0.40 to $0.80 per gallon (f.o.b. California port) is expected to bracket the 1996 price. The impact of the lower and higher methanol prices on total fleet costs is shown in Figure 6.

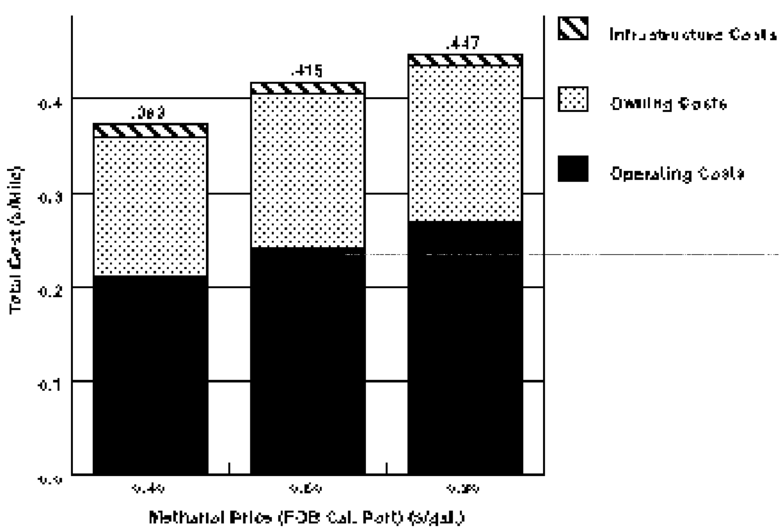


**Figure 6. Methanol Price Range — Impact on Total Costs**

## Electric Vehicle Fleet

It is very difficult to forecast the cost of operating a fleet of electric vehicles because of the current state of the technology development and the current lack of OEM-produced electric vehicles (EVs). The two electric cargo vans that participated in the CleanFleet demonstration are not considered representative of EV technology in the 1996 or later time frame. The only electric vehicles expected to be available in 1996 will be conversions of gasoline vehicles or limited production prototypes from OEMs. It is not even clear that electric cargo vans will be available as conversions in 1996. In 1998, when the California zero emission vehicle (ZEV) standard is presently scheduled to come into effect, OEM-produced EVs should be available, but electric versions of full-size cargo vans are not expected to be available from OEMs at that time.

Despite these limitations, an economic assessment for a fleet of electric cargo vans was developed. The objectives were to provide some insight into the key economic issues involved in operating an electric fleet and to provide the fleet operator with a starting point to perform a similar analysis at the time he or she might consider investing in an electric fleet.

When considering the EV cost estimates, it is important to remember two points. First, this case study applies to full-size electric vans; it is not directly applicable to electric passenger cars. Second, these estimates are uncertain because of rapidly changing technology and the changing market for EVs. Costs would be expected to decline in a growing market served by higher volume production of EVs.

The economic assessment for EVs considered two scenarios: a 1996 implementation with electric conversion cargo vans and a 1998 implementation of an OEM-produced full-size cargo van. Literature sources were used to estimate the cost factors. Because the literature sources were generally for passenger cars, pickup trucks, or minivans, it was necessary to extrapolate to the case of full-size cargo vans. Furthermore, the range of cost estimates in the literature was so broad that it was necessary to provide low and high estimates for the 1998 case.

The cost estimates presented here for an EV fleet should be considered more speculative than the estimates provided for the liquid and gaseous fuel fleets. No estimates of vehicle cost or performance factors were provided by the OEMs participating in CleanFleet, and cost estimates presented here do not imply their agreement.

The cost factors assumed for these three electric fleet scenarios are summarized in Table 9. The results of the EV fleet analysis are presented in Tables 10 through 12 and in Figure 7. The principal cost factors for an EV fleet are vehicle price, price of electrical energy consumption, battery life and replacement cost, and vehicle maintenance costs.

The conversion cost (premium over the base vehicle price) for a full-size cargo van in 1996 is estimated to be $30,000. Currently, electric conversions of pickup trucks with GVW in the 4,000- to 5,000-pound range can be purchased for a cost premium in the range of $15,000 to $30,000 depending on the converter and vehicle options selected. The high end of the range was selected because of the larger capacity requirements for a full-size cargo van. The $30,000 premium conversion cost was also the approximate cost of conversion for the EVs used in the CleanFleet demonstration.

**Table 9. Cost Factors for Electric Fleets**

| Cost Factor | Electric Conversion | EV-'98 Tech. Low Est. | EV-'98 Tech. High Est. |
|---|---|---|---|
| Charger Cost ($/vehicle) | 1,000 | 0 | 0 |
| Electric Capacity Modifications ($/vehicle) | 1,000 | 1,000 | 1,000 |
| Energy Consumption (kWh/mi-AC) | 2.0 | 0.86 | 1.22 |
| Vehicle Range (miles) | 36 | 70 | 45 |
| Battery Capacity (kWh)[(a)] | 50 | 48 | 44 |
| Battery Cost ($/kWh)[(a)] | 100 | 100 | 160[(c)] |
| Battery Life (cycles)[(a)] | 530 | 530 | 800 |
| Battery Replacement Interval (yrs) | 2.5 | 2.5 | 3.6 |
| Battery Replacement Costs ($/kWh)[(b)] | 95, 90, 80 | 90, 80 | 140, 120[(c)] |
| Miles Per Day | 30 | 60 | 40 |

(a) Battery capacity, cost, and cycle life are based on 80% depth of discharge.
(b) Battery replacement costs are assumed to decline over time.
(c) Battery costs are assumed to be higher for 800-cycle batteries than for 530-cycle batteries.

Estimates of the cost of OEM-produced electric vehicles vary over a broad range with no apparent consensus (see references 1-4). The California Air Resources Board[(1)] has estimated the EV cost to be the same as that of a gasoline vehicle plus the cost of the battery. Sierra Research and Charles River Associates[3] have estimated the cost premium to be about $21,000, including the battery cost, for passenger cars. The cost premiums selected for this analysis are $4,000 plus the battery cost for the low estimate and $10,000 plus the battery cost for the high estimate. To meet the State of California sales mandates, electric vehicles may be sold at prices comparable to gasoline vehicle prices. This pricing scenario was not considered for the EV fleet study because there was no firm basis to assume that full-size electric vans would be priced in this manner in 1998.

As EV technology matures and production volumes increase, the price of OEM-produced EVs is expected to approach (and eventually be less than) the price of gasoline vehicles, plus the price of the battery. Using this assumption for the case study would decrease the low estimate of total costs by 4.3 cents/mi before income tax (2.8 cents/mi after income tax) and decrease the high estimate by 13.2 cents/mi before income tax (8.3 cents/mi after income tax).

TABLE 10: ELECTRIC VEHICLE CASE STUDY - EXCLUDING INCOME TAX EFFECTS

| Date: Aug 4, 1995 | Electric Conversion | EV-'98 Tech Low Est | EV-'98 Tech High Est |
|---|---|---|---|
| INFRASTRUCTURE COSTS ($/yr/veh) | $236 | $133 | $133 |
| Personnel Training Costs ($/yr/veh) | $30 | $30 | $30 |
| Maintenance ($/fleet) | $1,602 | $1,602 | $1,602 |
| Drivers ($/fleet) | $975 | $975 | $975 |
| Fuelers ($/fleet) | $0 | $0 | $0 |
| Average Years Employment | 8 | 8 | 8 |
| Training Prep & Presentation | $8,000 | $8,000 | $8,000 |
| Amortization Period (yr) | 10 | 10 | 10 |
| Fueling Facility Costs ($/Yr/Veh) | $206 | $103 | $103 |
| Cost of Modifications/Additions | $100,000 | $50,000 | $50,000 |
| Economic Life (yr) | 15 | 15 | 15 |
| Residual Value | $0 | $0 | $0 |
| Operating Costs ($/yr) | $0 | $0 | $0 |
| Inside Vehicle Storage and Maintenance Facility Costs ($/yr/veh) | $0 | $0 | $0 |
| Cost of Modifications/Additions | $0 | $0 | $0 |
| Economic Life (yr) | 40 | 40 | 40 |
| Residual Value | $0 | $0 | $0 |
| Operating Costs, Annual | $0 | $0 | $0 |
| Special Tools/Facilities Costs | $0 | $0 | $0 |
| Mixed Fleet Costs ($/yr) | $0 | $0 | $0 |
| OWNING COSTS ($/yr/veh) | $5,888 | $3,983 | $4,226 |
| Base Vehicle Price | $15,900 | $24,700 | $32,940 |
| Conversion Cost | $30,000 | $0 | $0 |
| Economic Life (yr) | 10 | 7 | 10 |
| Residual Value | $4,590 | $4,940 | $3,294 |
| OPERATING COSTS ($/yr/veh) | $2,716 | $2,586 | $2,575 |
| Fuel Cost ($/yr/veh) | $630 | $544 | $513 |
| Untaxed Fuel Cost ($/GEQ) | $1.415 | $1.415 | $1.415 |
| Federal Excise Tax ($/GEQ) | $0.000 | $0.000 | $0.000 |
| State Excise Tax ($/GEQ) | $0.000 | $0.000 | $0.000 |
| Sales Tax(Cal+loc) ($/GEQ) | $0.000 | $0.000 | $0.000 |
| Total Fuel Taxes ($/GEQ) | $0.000 | $0.000 | $0.000 |
| Taxed Fuel Cost ($/GEQ) | $1.415 | $1.415 | $1.415 |
| Fuel Economy (mi/GEQ) | 16.85 | 39.04 | 27.60 |
| Refueling Labor ($/yr/veh) | $22 | $22 | $22 |
| Fueling Rate (Gal Equiv/min) | na | na | na |
| Vehicle Range (mi) | 33 | 88 | 44 |
| Refuels per Year | 250 | 250 | 250 |
| Vehicle Movement Time (min) | 0.33 | 0.33 | 0.33 |
| Maintenance ($/yr/veh) | $1,464 | $1,420 | $1,440 |
| General Maintenance ($/mi) | $0.030 | $0.020 | $0.040 |
| Specific Maintenance ($/yr/veh) | $1,239 | $1,120 | $1,040 |
| Specific Maintenance Time Interval (mo) | 30 | 30 | 43 |
| Insurance ($/yr/veh) | $600 | $600 | $600 |
| FLEET SIZE (vehicles) | 50 | 50 | 50 |
| ANNUAL MILES TRAVELED (mi/yr/veh) | 7500 | 15000 | 10000 |
| TOTAL COSTS PER VEHICLE MILE TRAVELED -BEFORE INCOME TAX | | | |
| INFRASTRUCTURE COSTS | $0.031 | $0.009 | $0.013 |
| OWNING COSTS | $0.785 | $0.266 | $0.423 |
| OPERATING COSTS | $0.362 | $0.172 | $0.258 |
| TOTAL COSTS | $1.179 | $0.447 | $0.693 |
| without fuel taxes | | | |
| OPERATING COSTS | $0.362 | $0.172 | $0.258 |
| TOTAL COSTS | $1.179 | $0.447 | $0.693 |

NOTES:
1. Discount rate is 0.060.
2. All costs are in constant 1996 dollars.
3. Vehicle insurance rates are assumed to be the same for all fleets.

TABLE 11: ELECTRIC VEHICLE CASE STUDY - INCLUDING INCOME TAX EFFECTS

| Date: Aug 4, 1995 | Electric Conversion | EV-'98 Tech Low Est | EV-'98 Tech High Est |
|---|---|---|---|
| INFRASTRUCTURE COSTS ($/yr/veh) | $167 | $92 | $92 |
| | | | |
| Personnel Training Costs ($/yr/veh) | $18 | $18 | $18 |
| Income Tax Savings ($/yr/veh) | $12 | $12 | $12 |
| Maintenance ($/fleet) | $1,602 | $1,602 | $1,602 |
| Drivers ($/fleet) | $975 | $975 | $975 |
| Fuelers ($/fleet) | $0 | $0 | $0 |
| Average Years Employment | 8 | 8 | 8 |
| Training Prep & Presentation | $8,000 | $8,000 | $8,000 |
| Amortization Period (yr) | 10 | 10 | 10 |
| | | | |
| Fueling Facility Costs ($/Yr/Veh) | $149 | $75 | $75 |
| Income Tax Savings ($/yr/veh) | $57 | $28 | $28 |
| Cost of Modifications/Additions | $100,000 | $50,000 | $50,000 |
| Economic Life (yr) | 15 | 15 | 15 |
| Residual Value | $0 | $0 | $0 |
| Operating Costs ($/yr) | $0 | $0 | $0 |
| | | | |
| Inside Vehicle Storage and Maintenance Facility Costs ($/yr/veh) | $0 | $0 | $0 |
| Income Tax Savings ($/yr/veh) | $0 | $0 | $0 |
| Cost of Modifications/Additions | $0 | $0 | $0 |
| Economic Life (yr) | 40 | 40 | 40 |
| Residual Value | $0 | $0 | $0 |
| Operating Costs, Annual | $0 | $0 | $0 |
| Special Tools/Facilities Costs | $0 | $0 | $0 |
| | | | |
| Mixed Fleet Costs ($/yr) | $0 | $0 | $0 |
| | | | |
| OWNING COSTS($/yr/veh) | $3,800 | $2,590 | $2,727 |
| Income Tax Savings ($/yr/veh) | $2,089 | $1,392 | $1,499 |
| Base Vehicle Price | $15,900 | $24,700 | $32,940 |
| Conversion Cost | $30,000 | $0 | $0 |
| Economic Life (yr) | 10 | 7 | 10 |
| Residual Value | $4,590 | $4,940 | $3,294 |
| | | | |
| OPERATING COSTS ($/yr/veh) | $1,601 | $1,525 | $1,518 |
| | | | |
| Fuel Cost ($/yr/veh) | $371 | $321 | $302 |
| Income Tax Savings ($/yr/veh) | $259 | $223 | $210 |
| Untaxed Fuel Cost ($/GEQ) | $1.415 | $1.415 | $1.415 |
| | | | |
| Federal Excise Tax ($/GEQ) | $0.000 | $0.000 | $0.000 |
| State Excise Tax ($/GEQ) | $0.000 | $0.000 | $0.000 |
| Sales Tax(Cal+loc) ($/GEQ) | $0.000 | $0.000 | $0.000 |
| Total Fuel Taxes ($/GEQ) | $0.000 | $0.000 | $0.000 |
| | | | |
| Taxed Fuel Cost ($/GEQ) | $1.415 | $1.415 | $1.415 |
| | | | |
| Fuel Economy (mi/GEQ) | 16.85 | 39.04 | 27.60 |
| | | | |
| Refueling Labor ($/yr/veh) | $13 | $13 | $13 |
| Income Tax Savings ($/yr/veh) | $9 | $9 | $9 |
| Fueling Rate (Gal Equiv/min) | na | na | na |
| Vehicle Range (mi) | 33 | 88 | 44 |
| Refuels per Year | 250 | 250 | 250 |
| Vehicle Movement Time (min) | 0.33 | 0.33 | 0.33 |
| | | | |
| Maintenance ($/yr/veh) | $863 | $837 | $849 |
| Income Tax Savings($/yr/veh) | $601 | $583 | $591 |
| General Maintenance ($/mi) | $0.030 | $0.020 | $0.040 |
| Specific Maintenance ($/yr/veh) | $1,239 | $1,120 | $1,040 |
| Specific Maintenance Time Interval (mo) | 30 | 30 | 43 |
| | | | |
| Insurance ($/yr/veh) | $354 | $354 | $354 |
| Income Tax Savings($/yr/veh) | $246 | $246 | $246 |
| Insurance Cost($/yr/veh) | $600 | $600 | $600 |
| | | | |
| FLEET SIZE (vehicles) | 50 | 50 | 50 |
| ANNUAL MILES TRAVELED (mi/yr/veh) | 7500 | 15000 | 10000 |
| | | | |
| TOTAL COSTS PER VEHICLE MILE TRAVELED -AFTER INCOME TAX | | | |
| | | | |
| INFRASTRUCTURE COSTS | $0.022 | $0.006 | $0.009 |
| OWNING COSTS | $0.507 | $0.173 | $0.273 |
| OPERATING COSTS | $0.213 | $0.102 | $0.152 |
| TOTAL COSTS | $0.742 | $0.281 | $0.434 |
| | | | |
| without fuel taxes | | | |
| OPERATING COSTS | $0.213 | $0.102 | $0.152 |
| TOTAL COSTS | $0.742 | $0.281 | $0.434 |
| | | | |
| TOTAL COSTS W/ EPACT INCENTIVES INCLUDE | $0.692 | $0.260 | $0.404 |

NOTES:

| | |
|---|---|
| 1. Discount Rate is | 0.060 |
| 2. Corp Inc Tax Rate (US + Cal) is | 0.410 |
| 3. US Corp Inc Tax Rate is | 0.350 |
| 4. Cal Corp Inc Tax Rate is | 0.093 |

5. Cal tax is deductible for US tax computation
6. All costs are in constant 1996 dollars.
7. Vehicle insurance rates are assumed to be the same for all fleets.

**Table 12. Impact of Income Taxes and Incentives on Electric Fleet Costs**

| | Total Costs (cents/mile) | | |
|---|---|---|---|
| | Electric Conversion | '98 Technology Low Estimate | '98 Technology High Estimate |
| Before income tax without incentives | 117.9 | 44.7 | 69.3 |
| After income tax without incentives | 74.2 | 28.1 | 43.4 |
| After income tax; incentives included | 69.2 | 26.0 | 40.4 |

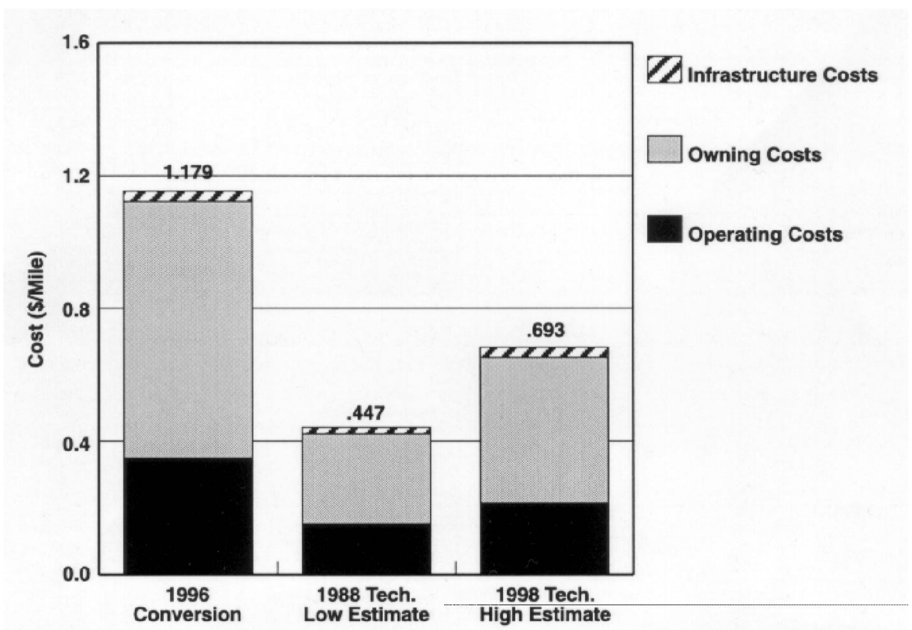


**Figure 7. Total Costs for Electric Vehicle Cases**

Lead-acid batteries are expected to be the battery technology used for EVs in 1996 and 1998. Cost estimates for the lead-acid batteries range from $100/kWh to $160/kWh for more advanced versions of these batteries. Battery life estimates range from 500 to 1000 recharge cycles for the battery pack as a whole, based on 80 percent depth of discharge. For the EV case study, two scenarios were assumed. For the 1996 conversion vehicle and for the 1998 low estimate, a battery cost of $100/kWh and battery life equivalent to 530 cycles at 80 percent depth of discharge were assumed. For the 1998 high estimate, a battery cost of $160/kWh and equivalent life of 800 cycles at 80 percent depth of discharge were assumed. The total battery cost over the vehicle life was roughly equivalent for the two cases because the extended life offsets the higher cost. Battery replacement costs were assumed to decline over time as shown in Table 9. A battery salvage value equal to 10 percent of the replacement cost and a labor cost of $60 per battery replacement were also assumed.

The cost of batteries is a major contributor to the estimated fleet costs. Battery packs in EVs are comprised of individual battery modules. Development work is underway by battery manufacturers to improve energy and thermal management of individual modules in a battery pack. Improved systems management for the battery pack itself is expected to prolong the life of battery packs significantly. This would have a significant impact on lowering the cost of batteries over the life of the EV. For example, increasing the battery cycle life from 530 to 900 cycles (keeping all other parameters at their value for the low estimate) would decrease the total cost per mile by 2.4 cents/mi before taxes and 3.2 cents/mi after taxes.

The energy consumption values shown in Table 9 are alternating current (AC) values, measured ahead of the charger. The value of 2.0 kWh/mi energy consumption for the 1996 conversion van is similar to the measured values during the CleanFleet demonstration. The estimated range of energy consumption values for the 1998 EVs was developed by first examining values reported for energy consumption on the Federal Urban Driving Schedule (FUDS) (or similar cycles) by current and prototype EVs of similar curbweight, and then applying a multiplier to reflect a more typical driving cycle for pickup and delivery vans. The estimated energy consumption for a full-size cargo van (6,500-lb test weight) on the Urban Driving Cycle is in the 0.6 to 0.85 kWh/mi range. The driving cycle multiplier is estimated to be 1.4, which is the average ratio of fuel economy for the unleaded gasoline fleet measured in the CleanFleet program to fuel economy values reported for those vehicles in the FUDS.

The price of electric energy for EVs depends on whether charging occurs during off-peak or on-peak rate periods. The off-peak average cost is estimated at 4.2 cents/kWh (average of winter and summer rates); the estimate for on-peak average cost is 19.3 cents/kWh. For the case study it was assumed that all charging would occur during off-peak hours. If 10 percent of the charging were to occur during the on-peak period, the total operating cost would increase by 1.0 cents/mi for the 1998 low estimate and by 1.5 cents/mi for the 1998 high estimate (before income taxes).

Very little information related to EV maintenance requirements and costs is available at present. Furthermore, the rapid development of EV technology makes it extremely difficult to predict maintenance requirements in future EV models. Several studies suggest that maintenance for EVs will be less than for gasoline vehicles because oil and filter changes and smog checks will be eliminated. Furthermore, batteries for 1998 EVs are expected to be maintenance-free, requiring no watering or electrolyte testing. However, maintenance costs associated with battery inspections, replacement of prematurely failed battery modules, and drive train and motor controller failures could result in increased maintenance costs. For the case study, EV maintenance costs were assumed to be 2 cents/mi for the low estimate case and 4 cents/mi for the high estimate case.

At present electric chargers can be provided for approximately $2,000 per vehicle. This cost is expected to drop to about $1,000 per vehicle in 1996. OEM-produced EVs in 1998 are expected to have the charger electronics on board the vehicle, taking advantage of the power electronics for motor control.

Building modifications will likely be required to bring the AC power to the vehicle charging sites. This will include wiring, switchgear, and some relatively simple controls to avoid simultaneous peak charging. Based on an investigation conducted by Southern California Edison, a typical cost for a fleet of 50 vehicles is $1,000 per vehicle.

EPACT incentives for EVs are the lower of $4,000 or 10 percent of the vehicle price to be applied as a tax credit in the year of purchase. Another incentive for purchasing electric vehicles will be available from the Mobile Source Air Pollution Reduction Review Committee (MSRC) in the South Coast Air Basin. Purchases of EVs from qualified EV manufacturers will be eligible for a $5,000 incentive applied to the purchase price. This incentive was not included in the EV case studies because full-size electric vans may not be available from manufacturers under the MSRC's program.

The estimated total cost for the 1996 EV conversion case is $1.179/mi before income tax and incentives. While this cost is exceptionally high, electric vans still may be of interest to a fleet operator wishing to gain experience with EVs in the 1996 time frame. For the 1998 case, the range of estimated total cost is 44.7 cents/mi to 69.3 cents/mi before income taxes and incentives. It is important to remember the considerable uncertainty in the EV fleet cost estimates due to the lack of OEM-produced vehicles at the present time, rapidly evolving technology, and the wide range and lack of agreement of cost estimates that have been published.

## Conclusions

An estimate of fleet operating costs for each of five alternative fuels for a hypothetical fleet operator has been provided. It was assumed that the fleet consists of 150 vehicles, of which 50 will be replaced with alternative fuel vehicles in 1996. Full-size vans operating in package delivery service in the Los Angeles area were assumed. It was determined that costs can vary considerably depending on the nature of the fleet business. Furthermore, many of the cost elements are in states of flux because of the developmental state of the technologies, particularly for vehicles and fueling stations. We recommend that a fleet operator perform a similar analysis, using assumptions appropriate to his or her business, and reexamine the principal cost factors at the time and location that the alternative fuel fleet is introduced.

## References

1. California Air Resources Board, Mobile Source Division, “Technical Support Document—Zero Emission Vehicle Update,” April 1994.

2. Abacus Technology Corp., “Encouraging the Purchase and Use of Electric Motor Vehicles,” prepared for the U.S. Department of Energy-Office of Transportation Technologies, May 1995.

3. Sierra Research, Inc., and Charles River Associates, “The Cost Effectiveness of Further Regulating Mobile Source Emissions,” February 1994.

4. “Electric Vehicle Progress” newsletter, interview with Jean-Yves Helmer of Peugeot, May 1, 1994, p. 4.

# APPENDIX A

# Estimated Price of Alternative Fuels

# APPENDIX A

## Estimated Price of Alternative Fuels

This appendix describes the methods used and the bases for developing estimates of the price of alternative fuels for fleets in the Los Angeles, California, area for 1996. These estimates have been broken down into untaxed cost, federal excise tax, state excise tax, and combined state and Los Angeles County sales tax. In accordance with the design of the 1996 Case Study, the estimated prices of the fuels are the prices that the hypothetical fleet operator would pay, including all taxes and incentives.

The price estimates are presented in Table A-1. The cost data are divided into two groups:

- estimated 1994 costs represent estimates of the average fuel cost to a fleet operator in the Los Angeles area in 1994, and were developed from cost surveys and interviews with fuel suppliers

- 1996 costs represent Battelle's forecast for fuel prices in 1996 and are expressed in 1996 dollars.

The 1996 forecast in units of dollars per gasoline equivalent gallon (GEQ) were used in the fleet cost analysis shown in Table 2. The energy conversion factors, based on measurements of fuel properties during the CleanFleet demonstration, were shown in Table 5.

The prices are given in $/million Btu lower heating value (LHV), because this is more closely related to the energy an engine can use than is the higher heating value (HHV). When lower heating value is measured, the water formed in combustion is all in the vapor phase; when higher heating value is measured, the water formed is all condensed to the liquid phase. Most public policy analyses use higher heating values. The cost per gasoline equivalent gallon (GEQ) is also given using the Clean-Fleet's definition of 115,000 Btu (LHV) per GEQ. Because the unleaded gasoline used currently has a different heating value, 114,400 Btu/gallon LHV, the cost per physical gallon differs from the cost per GEQ.

TABLE A-1: PROJECTED FLEET PRICES OF ALTERNATIVE MOTOR VEHICLE FUELS IN 1996 IN LOS ANGELES.

Date: Aug 4, 1995

| FUEL | COST COMPONENT | Estimated 1994 $/MM Btu LHV | Estimated 1994 $/gallon Gasoline Equiv. (GEQ) | Estimated 1994 $/Physical Gallon | | 1996 (1996 $) $/MM Btu LHV | 1996 (1996 $) $/gallon Gasoline Equiv. (GEQ) | 1996 (1996 $) $/Physical Gallon | | 1996 (1994 $) $/MM Btu LHV | 1996 (1994 $) $/gallon Gasoline Equiv. (GEQ) | 1996 (1994 $) $/Physical Gallon |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unleaded Gasoline, Regular | Untaxed Fleet, Del. | 5.06 | 0.582 | 0.578 | (a) | 5.263 | 0.605 | 0.602 | | 5.059 | 0.582 | 0.578 |
| | Federal Excise Tax | 1.61 | 0.185 | 0.184 | | 1.610 | 0.185 | 0.184 | | 1.547 | 0.178 | 0.177 |
| | State Excise Tax | 1.57 | 0.181 | 0.180 | (b) | 1.575 | 0.181 | 0.180 | (b) | 1.513 | 0.174 | 0.173 |
| | Sales Tax (CA+local) | 0.68 | 0.078 | 0.078 | (c) | 0.697 | 0.080 | 0.080 | (c) | 0.670 | 0.077 | 0.077 |
| | TOTAL | 8.92 | 1.026 | 1.020 | | 9.144 | 1.052 | 1.045 | | 8.789 | 1.011 | 1.005 |
| Reformulated Gasoline, Regular | Untaxed Fleet, Del. | | | | | 6.57 | 0.756 | 0.735 | (d) | 6.32 | 0.727 | 0.706 |
| | Federal Excise Tax | | | | | 1.65 | 0.189 | 0.184 | | 1.58 | 0.182 | 0.177 |
| | State Excise Tax | | | | | 1.61 | 0.185 | 0.180 | (b) | 1.55 | 0.178 | 0.173 |
| | Sales Tax (CA+local) | | | | | 0.81 | 0.093 | 0.091 | (c) | 0.78 | 0.090 | 0.087 |
| | TOTAL | | | | | 10.64 | 1.224 | 1.189 | | 10.23 | 1.176 | 1.143 |
| LPG (Propane) | Untaxed Fleet, Del. | 5.57 | 0.640 | 0.475 | (e) | 5.79 | 0.666 | 0.494 | (f) | 5.57 | 0.640 | 0.475 |
| | Federal Excise Tax | 2.15 | 0.247 | 0.183 | | 2.15 | 0.247 | 0.183 | | 2.06 | 0.237 | 0.176 |
| | State Excise Tax | 0.29 | 0.034 | 0.025 | (b) | 0.29 | 0.034 | 0.025 | (b) | 0.28 | 0.033 | 0.024 |
| | Sales Tax (CA+local) | 0.64 | 0.073 | 0.054 | (g) | 0.65 | 0.075 | 0.056 | (g) | 0.63 | 0.072 | 0.054 |
| | TOTAL | 8.64 | 0.994 | 0.737 | | 8.89 | 1.022 | 0.758 | | 8.54 | 0.982 | 0.729 |
| | | | For 4th Quarter Only | | | | | | | | | |
| Methanol Fuel M-85 | Untaxed Fleet, Del. | 10.56 | 1.215 | 0.700 | (h) | 9.87 | 1.135 | 0.654 | (i) | 9.49 | 1.091 | 0.629 |
| | Federal Excise Tax | 1.72 | 0.198 | 0.114 | | 1.72 | 0.198 | 0.114 | | 1.65 | 0.190 | 0.110 |
| | State Excise Tax, Sticker | 1.36 | 0.156 | 0.090 | (b) | 1.36 | 0.156 | 0.090 | (b) | 1.31 | 0.150 | 0.087 |
| | Sales Tax (CA+local) | 1.01 | 0.117 | 0.067 | (g) | 1.01 | 0.117 | 0.067 | (g) | 0.92 | 0.106 | 0.061 |
| | TOTAL | 14.65 | 1.685 | 0.971 | | 13.96 | 1.606 | 0.925 | | 13.36 | 1.537 | 0.886 |
| | | | | $/therm | | | | $/therm | | | | $/therm |
| CNG Fuel 3,000 psig | Untaxed Fleet | 0.00 | 0.000 | 0.000 | (j) | 6.76 | 0.778 | 0.634 | (k) | 6.50 | 0.747 | 0.610 |
| | Federal Excise Tax | 0.50 | 0.058 | 0.047 | | 0.50 | 0.058 | 0.047 | | 0.48 | 0.055 | 0.045 |
| | State Excise Tax, Sticker | 0.27 | 0.031 | 0.025 | (l) | 0.27 | 0.031 | 0.025 | (l) | 0.26 | 0.030 | 0.024 |
| | Sales Tax (CA+local) | 0.00 | 0.000 | 0.000 | (g) | 0.00 | 0.000 | 0.000 | (g) | 0.00 | 0.000 | 0.000 |
| | TOTAL | 0.77 | 0.088 | 0.072 | | 7.53 | 0.866 | 0.706 | | 7.24 | 0.832 | 0.679 |
| Electricity for EVs | Fuel Cost | 0.0400 $/Kwh (m) | | | | 0.0000 $/Kwh (n) | | | | 0.0000 $/Kwh (m) | | |
| | | 11.72 $/MMBtu | | | | 12.1970 $/MMBtu | | | | 11.7233 $/MMBtu | | |

TABLE A-1 CONTINUED

ASSUMPTIONS

| | | |
|---|---|---|
| Annual inflation 1996/1994 | 1.020 | GDP Implicit Price Deflator 2Q 1994/2Q 1993 |
| Annual crude price escalation 1996/1994 (real prices) | 1.00 | Estimated by Battelle |
| 1994 $ extra for RFG, $/gal | 0.133 | (vs. 1996 unleaded formulation) |
| 1996 price of methanol fob CA port, in 1996 $ | 0.60 | Estimated by Battelle |

NOTES

(a) Lundberg survey for all 1994.

(b) Superfund fee of 0.0035 cents per gallon and state oil spill fee of 0.0095 cents per gallon are not included in the calculated taxes. State excise taxes for CNG and propane are based on a $72 sticker for a vehicle with unladen weight between 4000 and 8000 lbs.

(c) 8.25% of total of fuel cost and state and federal excise taxes (Los Angeles County). Orange County is 7.75%.

(d) Regular unleaded gasoline plus $0.133 (in 1996 $).

(e) Estimate from Mutual Propane. Yearly average.

(f) Assumes prices grow at same rate as unleaded regular.

(g) 8.25% of fuel cost and federal excise tax but not state excise tax (Los Angeles County). Orange County is 7.75%. No sales tax on CNG according to The So Cal Gas Co.

(h) Jonathan Teague, Cal. Energy Comm. Current calculated M85 price of $0.66 per physical gallon plus $0.04/gal for delivery.

(i) ($0.60 per gallon FOB-California port +$0.04 delivery)*0.85 + RFG price * 0.15

(j) Average for all 1994 from So Cal Gas Co for 3000 psig gas. Includes meter charge of $13/month.

(k) Computed from formula from So Cal Gas Co 1995 rate filing.

(l) Computed from sticker price of $72

(m) Based on current rate for LA Dept of Water and Power, Residential Rate 8 PM-10 AM and weekends less 2.5 cents. Assumes no change in real electricity rates for EVs in 1996. Current commercial EV rate for SCE is $0.054-0.059.

(n) Based on rate filing by SCE for TOU-EV-3, commercial EVs. Assumes all charging done 9 PM to 12 noon. LADWP is expected to file a similar request by mid-1995.

## General Inflation Rate

Some of the components of fuel prices are expected to escalate at the rate of inflation and others such as tax rates will stay constant in nominal dollars until changed by law. Although the impact of inflation at a low rate for two years is small, it has nevertheless been calculated. Two inflation measures were considered, the Consumer Price Index for All Urban Consumers (CPI-U) and the Gross Domestic Product (GDP) Implicit Price Deflator. The trend in the latter was adopted because that measure tries to take into account inflation throughout the economy, not just in the purchases by households. The GDP Deflator grew at an annual rate of 2.0 percent from the second quarter 1993 to second quarter 1994. This rate was used for the projection to 1996. (The CPI-U grew at about 2.7 percent.)

## Crude Oil Prices

Most of the fuel prices forecast for the 1996 Case Study are driven by the cost of gasoline and in turn by the price of crude oil. The price of crude oil obviously is subject to many forces. There have been large fluctuations in the price of crude oil in recent years, but nothing like those occurring between 1978 and 1986. The average refiners' acquisition cost was $16.50 in January 1992, rose to $20.10 in July, and then dropped slowly to a low of $12.51 in December of 1993. Since then it has risen to $17.61 as of July 1994 [*Monthly Energy Review*, DOE/EIA-0035(94/10)].

Lawrence Goldstein, president of the Petroleum Research Foundation, predicted a rise from the forecast $17.15 average in 1994 for “the U.S. benchmark crude” to $19.15 in 1995 (*Wall Street Journal*, Nov. 1, 1994, p. C16). The price on November 2, 1994, was $18.95. Drewery Shipping Associates forecasts that West Texas Intermediate (WTI) will rise from $18.90 in 1994 to $21.80 in 1996, a 7.4 percent per year growth (*Oil and Gas Journal*, Aug. 22, 1994, pp. 16-22). The U.S. DOE projected an annual increase from 1992 to 2000 of 1.6 percent per year for both crude oil and gasoline [*Annual Energy Outlook 1994*, DOE/EIA-0383 (94)]. On the other hand, futures prices for WTI on the New York Mercantile Exchange show a drop in 1995, then a rise to near the current level in June of 1997 (*Wall Street Journal*, Nov. 3, 1994, p. C16). Our current forecast is that the prices of crude oil and gasoline in California will rise at the same rate as the GDP.

## Base Price for Unleaded Gasoline

The unleaded wholesale price estimate for all of 1994 of $1.02 with taxes ($0.578 without taxes) is based on Lundberg surveys of wholesale regular gasoline prices throughout California. Gasoline prices fluctuate seasonally, being highest from June through September. On a national basis, the monthly average has had a range of 12 cents per gallon before taxes in 1992 and 14 cents in 1993 [*Monthly Energy Review*, DOE/EIA-0035(94/10)]. Quarterly 1994 data from California show a range of about 11 cents.

To estimate the 1996 price, the price before taxes was inflated by 2 percent per year to convert to 1996 dollars.

### Extra Cost for California Phase 2 Reformulated Gasoline

Gasoline sold in California starting June 1, 1996, must meet the Phase 2 specifications of the California Air Resources Board (ARB). Refinery modifications are under way, and it appears that the March 1 refining start-up deadline can be achieved and shortages avoided if remaining problems in permitting can be resolved (*Oil and Gas Journal*, Oct. 10, 1994, pp. 2, 23-28). The California Energy Commission forecasts a premium over regular gasoline of 12 to 17 cents per gallon; a major oil company, 11 to 16; and Tosco, 10 to 14 (Fuels, California Energy Commission, Feb. 1994; interview with a major oil company; Thomas O'Malley, Tosco, paper at Pacific Oil Conference on Reformulated Gasoline, Reno, September 1994). Assuming that phase-in of RFG into the California economy is accomplished with no major problems, the extra price of RFG is estimated to be 13.3 cents (before taxes in 1996 dollars).

### Propane Gas

The current estimates for propane gas prices (47.5 cents per gallon) are based on interview data with a wholesaler and assume delivery in lots of 10,000 gallons, the capacity of a transport. Smaller lots would be roughly 59 to 72 cents per gallon. In principle, if the supplier owns the tank, the cost would be higher than if the user did, but the cost per gallon difference is quite small. The future price assumes that the cost grows with inflation. A possible problem in California is the requirement of the ARB that all highway fuel meet HD-5 specifications (*Butane-Propane News*, December 1993, pp. 6-7). However, industry spokesmen indicated that this was not expected to be a problem and that most highway propane fuel sold now meets this specification.

It is worth noting that the price of propane gas west of the Rocky Mountains is only loosely coupled to the Mount Belvieu, Texas, price (which is the standard for the Eastern United States) because there is no pipeline for shipments of propane gas to the West Coast. Thus, the summer-winter swings in prices are more moderate on the West Coast. If the price on the West Coast rises roughly 15 cents a gallon above the mid-continent price, it is economical to ship propane in by truck.

The California state excise tax of 6 cents per gallon can be replaced by a tax sticker costing $72 for a vehicle of 4,000 to 8,000 pounds unladen weight. Because this is advantageous for a vehicle traveling 20,000 miles per year, the sticker equivalent has been used for the analysis.

### Methanol

The price of methanol in the past has gone through great swings as the demand for this chemical has fluctuated with the state of the economy. Methanol is a useful solvent and a feedstock for making many important chemicals such as formaldehyde for adhesives, acetic acid, and polyester resins. Therefore, demand keeps pace with the economy. Since the phasing out of lead in gasoline, methanol has also been used in making increasingly larger amounts of methyl tertiary-butyl ether (MTBE), now about 30 percent of the total use of methanol. From 1970 to 1993, the contract price of methanol (f.o.b. Gulf Coast) cycled between 30 and 80 cents per gallon, with an early 1991 price of 60 cents per gallon, a low of about 32 cents per gallon in mid-1992, and a rise to 54 cents on January 1, 1994.

In 1994, there was a dramatic rise in methanol prices due to economic growth, rapid increase in MTBE production, and several short-term plant closings. Gulf Coast contract prices rose to about $1.50 per gallon in November 1994. In the first half of 1995, methanol prices have declined rapidly. Contract prices of 65 cents and spot prices in the 40- to 45-cent-per-gallon range were reported in April and May of 1995.

Battelle estimates that the 1996 methanol price (f.o.b. California port) will be in the range of 40 to 80 cents per gallon, with a most likely estimate of 60 cents per gallon. The West Coast prices are typically 6 to 8 cents per gallon higher than the Gulf Coast prices. Using the 60-cent estimate for methanol, assuming the 15 percent gasoline fraction is Phase 2 reformulated gasoline, and adding 4 cents per gallon for transportation and delivery, the estimated M-85 wholesale price is 65.4 cents per gallon before taxes and 92.5 cents per gallon after taxes.

In the past, the California Energy Commission has attempted to stabilize the price of methanol through its California Fuel Methanol Reserve Program by arranging long-term contracts with suppliers. The Commission is currently negotiating new contracts with a goal of making M-85 available at a price competitive with California Phase 2 RFG (average of regular and premium). This would be consistent with an M-85 price of about 53 cents per gallon before tax and a methanol price (f.o.b. California port) of about 45 cents per gallon. Because this effort is still in the negotiation stage, the end result is not clear at this time.

### Compressed Natural Gas

The estimated price of natural gas in 1996 was obtained by applying a formula used by the Southern California Gas Company in its 1995 rate filing. For compressed gas at 3,000 psi, the pre-tax CNG price will be the average wholesale price for the Los Angeles, Sacramento, and Fresno areas of Phase 2 RFG minus 31 cents per gallon and minus excise taxes that apply to CNG. For uncompressed natural gas, the price is reduced by 35 cents per therm (42.9 cents per GEQ).

The state excise tax of 8 cents per gallon equivalent can be replaced by a tax sticker of $72 per year. Because it is clearly advantageous to do this if the vehicle travels 20,000 miles per year, the calculation uses the sticker equivalent. As this report was being prepared in mid-1995, state sales tax was not being collected on the sale of CNG. Subsequently, Battelle learned that, in accordance with California Revenue and Taxation Code Section 6353, sales tax applies to the sale or use of fuel to propel a motor vehicle. Sales tax or use tax is applicable on the sale of CNG in the same manner as on the sale of propane gas.

### Electricity for Vehicles

Customers in the City of Los Angeles are served by the Los Angeles Department of Water and Power (LADWP), and the rest of the metropolitan area is served by Southern California Edison (SCE).

Currently, the typical cost for a commercial LADWP EV customer is 4 cents/kWh, and it is 5.4 to 5.9 cents for SCE customers. SCE has filed a tariff request with the Public Utilities Commission that will have the following rates for commercial establishments:

| | | |
|---|---|---|
| Summer Off-peak | 4.000 | cents/kWh |
| Winter Off-peak | 4.340 | |
| Summer On-peak | 30.481 | |
| Winter On-peak | 8.158 | |

In addition, there is a separate meter charge of $5.00 per month and a customer charge of 43 cents per day. These have been included, assuming 50 vehicles averaging 20,000 miles per year, for the 1996 Case Study. LADWP is planning to file for new rates in mid-1995 and expects them to be similar to those being sought by SCE. The calculations here assume half summer off-peak and half winter off-peak. If the vehicles cannot be recharged between 9 PM and noon, the very high on-peak rates will apply.

# APPENDIX B

## Description of Equations Used in Table 3 and Table 11

# APPENDIX B

## Description of Equations Used in Table 3 and Table 11

The following description is intended to assist the reader in working through the 1996 Case Study cost analyses. The equations used to compute the cost factors in Table 3 and Table 11, which are the case study results with income taxes included, are presented. For Tables 2 and 10, the equations are identical except that all income tax effects are excluded. Tables 3 and 11 are reproduced at the end of Appendix B with line numbers in the far left column. The line numbers are used to reference a value or variable in the corresponding row.

### Definition of Symbols

The following symbols are used in the equations below; the value in parentheses corresponds to the value used in the baseline case.

| | | |
|---|---|---|
| i | = | Discount rate (.06) |
| t | = | Corporate income tax rate (.41) |
| CRF (P, i, n) | = | Capital recovery factor - corresponds to a uniform series of annual payments for n periods discounted at the rate i and having a present value equal to P. |
| | | ■ Lotus uses the symbol @ PMT (P, i, n) |
| | | ■ $\text{CRF}(P, i, n) = P * \left[\frac{i * (1+i)^n}{(1+i)^n - 1}\right]$ |
| SPV (A, i, n) | = | Series present value - corresponds to the present value of a series of n uniform payments of amount A discounted at the rate i |
| | | ■ Lotus uses the symbol @ PV |
| | | ■ $\text{SPV}(A, i, n) = A * \left[\frac{(1+i)^n - 1}{i * (1+i)^n}\right]$ |
| INT ($\chi$) | = | Integer portion of variable $\chi$ |
| Xln | = | Reference to a variable or constant at line number ln in Table 3 or Table 11. |

## Description of Equations

The equations are described in groups corresponding to the cost categories in Tables 3 and 11.

Infrastructure Costs

X1 = X2 + X10 + X16 + X23

Personnel Training Costs

X2 = (CRF ((X4 + X5 + X6), i, X7)
+ CRF (X8, i, X9)) / X54 - X3

X3 = (CRF ((X4 + X5 + X6) * t, i, X7)
+ CRF (X8 * t, i, X9)) / X54

Fueling Facility Costs

X10 = (CRF (X12 - X14 / ((1+i) ^ X13), i, X13)
+ X15) / X54 - X11

X11 = (CRF (X12 * 0.2747 - X14 / ((1 + i) ^ X13)
+ X15 * t)) / X54

Note 1: The residual value (X14) is discounted to its present value using the expression (X14 / ((1 + i) ^ X13)). The factor 0.2747 represents the present value of the tax savings from depreciation deductions per dollar of investment using the 15-year, 150-percent declining balance method of amortization.

Inside Vehicle Storage and Maintenance Facility Costs

X16 = (CRF (X18 - X20) / ((1 + i) ^ X19) + X22, i, X19)
+ X21) / X54 - X17

X17 = ((X18 / X19) * t + X21 * t
+ t * CRF (X22 - X20 / ((1 + i) ^ X19), i, X19)) / X54

Note 2: Facility investments are amortized using straight line depreciation for 40 years. Thus, the annual tax savings associated with the facility investment is the investment divided by 40 years and multiplied by the tax rate - ((X18 / X19) * t).

Owning Costs

X24 = CRF (X26 + X27 - X29 / ((1 + i) ^ X28), i, X28))
- X25

X25 = CRF ((X26 + X27) * 0.3578 - X29 * t/((1 + i) ^ X28),
i, X28))

Note 3: The factor 0.3578 represents the present value of the tax savings from depreciation deductions per dollar of investment using the five-year, double-declining balance method of amortization.

Operating Costs

X30 = X31 + X40 + X46 + X51

Fuel Cost

X31 = ((X38 / X39) * X55)) - X32

X32 = (X38 / X39) * t * X55

Refueling Labor

X40 = ((16.25 / 60) / (X39 * X42)) * X55
+ ((16.25 / 60) * X44 * X45)) - X41

X41 = (((16.25 / 60) / (X39 * X42)) * X54
+ ((16.25 /60) * X44 * X45)) * t

X44 = (250 / INT (X43 / (X55 / 250)))

Note 4: The factor (16.25 / 60) is the labor rate for drivers or fuelers in units of dollars per minute. The factor (1 / (X39 * X42)) represents the fuel pumping portion of refueling time per mile traveled.

The factor (INT (X43 / (X55 / 250))) is the integral portion of the vehicle range divided by miles traveled per day. It represents days between refills.

Maintenance

- for UNL, RFG, PRO, M-85 fleets

X46 = (X48 * X55) - X47

X47 = (X48 * X55 * t)

- for CNG fleets

X46 = CRF (X49 * (1 + i / 12) ^ (-X50), i, X28)
+ X48 * X55 - X47

X47 = (CRF (X49 * (1 + i / 12) ^ (-X50), i, X28)
+ X48 * X55) * t

- for electric fleets

X46 = CRF (PV - BAT - REPL, i, X28)
+ X48 * X55 - X47

X47 = (CRF (PV - BAT - REPL, i, X28)
+ X48 * X55) * t

Note 5: For CNG fleets the specific maintenance cost (X49) is discounted to its present value and an equivalent annual cost is computed.

For electric fleets, the present value of future battery replacement costs (PV - BATT - REPL) is used (see discussion below) to compute an equivalent annual cost.

Insurance

X51 = X53 - X52

X52 = X53 * t

Total Costs per Vehicle Mile Traveled - After Income Tax

X56 = X1 / X55

X57 = X24 / X55

X58 = X30 / X55

X59 = X56 + X57 + X58

Without Fuel Taxes

X60 = (X30 / X55) - (X37 / X39) * (1 - t)

X61 = X56 + X57 + X60

Depreciation Schedules and Resulting Tax Savings

The accelerated depreciation schedules and resulting income tax savings are shown in Table B-1. The 5-year, double-declining balance is used to amortize vehicle acquisition cost, and the 15-year, 150-percent declining balance schedule is used to amortize fueling facility investments.

**Table B-1. Accelerated Depreciation Schedules and Resulting Tax Savings**

| Year | 5-Year, Double-Declining Balance | | |
|---|---|---|---|
| | **Depreciation Rate** | **Rate × Tax** | **Present Value** |
| 1 | 0.3500 | 0.1437 | 0.1355 |
| 2 | 0.2600 | 0.1067 | 0.0950 |
| 3 | 0.1560 | 0.0640 | 0.0538 |
| 4 | 0.1101 | 0.0452 | 0.0358 |
| 5 | 0.1101 | 0.0452 | 0.0338 |
| 6 | 0.0138 | 0.0057 | 0.0040 |
| Total | | | 0.3578 |
| | **15-Year, 150-Percent Declining Balance** | | |
| 1 | 0.0875 | 0.0359 | 0.0339 |
| 2 | 0.0913 | 0.0375 | 0.0334 |
| 3 | 0.0821 | 0.0337 | 0.0283 |
| 4 | 0.0739 | 0.0303 | 0.0240 |
| 5 | 0.0665 | 0.0273 | 0.0204 |
| 6 | 0.0599 | 0.0246 | 0.0173 |
| 7 | 0.0590 | 0.0242 | 0.0161 |
| 8 | 0.0591 | 0.0243 | 0.0152 |
| 9 | 0.0590 | 0.0242 | 0.0143 |
| 10 | 0.0591 | 0.0243 | 0.0135 |
| 11 | 0.0590 | 0.0242 | 0.0128 |
| 12 | 0.0591 | 0.0243 | 0.0121 |
| 13 | 0.0590 | 0.0242 | 0.0114 |
| 14 | 0.0591 | 0.0243 | 0.0107 |
| 15 | 0.0590 | 0.0242 | 0.0101 |
| 16 | 0.0074 | 0.0030 | 0.0012 |
| Total | | | 0.2747 |

## Battery Replacement Costs

The present values of the estimated battery replacement costs were computed for each of the three cases investigated for an electric fleet. The battery salvage value—equal to 10 percent of the replacement cost—was subtracted from the replacement battery cost to arrive at the cost shown below. The computed values are shown below in Table B-2.

**Table B-2. Present Value of Battery Replacement Costs**

| Replacement | Replacement Time (mo) | Cost, $ | Present Value, $ |
|---|---|---|---|
| **1996 Electric Conversion** | | | |
| 1 | 30 | 4,515 | 3,888 |
| 2 | 60 | 4,290 | 3,180 |
| 3 | 90 | 3,840 | 2,451 |
| Total | | | 9,519 |
| **1998 Technology - Low Estimate** | | | |
| 1 | 30 | 4,128 | 3,554 |
| 2 | 60 | 3,696 | 2,740 |
| Total | | | 6,294 |
| **1998 Technology - High Estimate** | | | |
| 1 | 43 | 5,784 | 4,668 |
| 2 | 86 | 4,992 | 3,251 |
| Total | | | 7,919 |

TABLE 3: 1996 CASE STUDY - INCLUDING INCOME TAX EFFECTS

| Date: Aug 4, 1995 | Unleaded Gasoline | Reformulated Gasoline | Compressed Natural Gas | CNG w/o Fuel Station | Propane Gas | M-85 |
|---|---|---|---|---|---|---|
| INFRASTRUCTURE COSTS ($/yr/veh) | $0 | $0 | $1,405 | $240 | $337 | $136 |
| Personnel Training Costs ($/yr/veh) | $0 | $0 | $18 | $18 | $18 | $15 |
| Income Tax Savings ($/yr/veh) | $0 | $0 | $12 | $12 | $12 | $11 |
| Maintenance ($/fleet) | $0 | $0 | $1,602 | $1,602 | $1,602 | $267 |
| Drivers ($/fleet) | $0 | $0 | $975 | $975 | $975 | $975 |
| Fuelers ($/fleet) | $0 | $0 | $65 | $65 | $65 | $65 |
| Average Years Employment | 8 | 8 | 8 | 8 | 8 | 8 |
| Training Prep & Presentation | $0 | $0 | $8,000 | $8,000 | $8,000 | $8,000 |
| Amortization Period (yr) | 10 | 10 | 10 | 10 | 10 | 10 |
| Fueling Facility Costs ($/Yr/Veh) | $0 | $0 | $1,165 | $0 | $97 | $121 |
| Income Tax Savings ($/yr/veh) | $0 | $0 | $598 | $0 | $39 | $49 |
| Cost of Modifications/Additions | $0 | $0 | $450,000 | $0 | $60,000 | $75,000 |
| Economic Life (yr) | 15 | 15 | 15 | 15 | 15 | 15 |
| Residual Value | $0 | $0 | $0 | $0 | $0 | $0 |
| Operating Costs ($/yr) | $0 | $0 | $41,800 | $0 | $600 | $750 |
| Inside Vehicle Storage and Maintenance Facility Costs ($/yr/veh) | $0 | $0 | $222 | $222 | $222 | $0 |
| Income Tax Savings ($/yr/veh) | $0 | $0 | $48 | $48 | $48 | $0 |
| Cost of Modifications/Additions | $0 | $0 | $185,000 | $185,000 | $185,000 | $0 |
| Economic Life (yr) | 40 | 40 | 40 | 40 | 40 | 40 |
| Residual Value | $0 | $0 | $0 | $0 | $0 | $0 |
| Operating Costs, Annual | $0 | $0 | $1,200 | $1,200 | $1,200 | $0 |
| Special Tools/Facilities Costs | $0 | $0 | $0 | $0 | $0 | $0 |
| Mixed Fleet Costs ($/yr) | $0 | $0 | $0 | $0 | $0 | $0 |
| OWNING COSTS($/yr/veh) | $2,091 | $2,091 | $2,749 | $2,749 | $2,394 | $2,131 |
| Income Tax Savings ($/yr/veh) | $1,119 | $1,119 | $1,471 | $1,471 | $1,281 | $1,140 |
| Base Vehicle Price | $15,900 | $15,900 | $20,900 | $20,900 | $15,900 | $16,200 |
| Conversion Cost | $0 | $0 | $0 | $0 | $2,300 | $0 |
| Economic Life (yr) | 5 | 5 | 5 | 5 | 5 | 5 |
| Residual Value | $3,180 | $3,180 | $4,180 | $4,180 | $3,640 | $3,240 |
| OPERATING COSTS ($/yr/veh) | $2,066 | $2,314 | $1,703 | $2,223 | $2,245 | $2,850 |
| Fuel Cost ($/yr/veh) | $1,223 | $1,470 | $530 | $1,050 | $1,281 | $1,886 |
| Income Tax Savings ($/yr/veh) | $852 | $1,024 | $369 | $731 | $892 | $1,313 |
| Untaxed Fuel Cost ($/GEQ) | $0.605 | $0.756 | $0.349 | $0.778 | $0.666 | $1.135 |
| Federal Excise Tax ($/GEQ) | $0.185 | $0.189 | $0.058 | $0.058 | $0.247 | $0.198 |
| State Excise Tax ($/GEQ) | $0.181 | $0.185 | $0.031 | $0.031 | $0.034 | $0.156 |
| Sales Tax(Cal+loc) ($/GEQ) | $0.080 | $0.093 | $0.000 | $0.000 | $0.075 | $0.117 |
| Total Fuel Taxes ($/GEQ) | $0.446 | $0.467 | $0.089 | $0.089 | $0.356 | $0.471 |
| Taxed Fuel Cost ($/GEQ) | $1.051 | $1.223 | $0.438 | $0.867 | $1.022 | $1.606 |
| Fuel Economy (mi/GEQ) | 10.13 | 9.81 | 9.74 | 9.74 | 9.41 | 10.04 |
| Refueling Labor ($/yr/veh) | $135 | $136 | $454 | $454 | $256 | $256 |
| Income Tax Savings ($/yr/veh) | $94 | $95 | $316 | $316 | $178 | $178 |
| Fueling Rate (Gal Equiv/min) | 9 | 9 | 6 | 6 | 6 | 6 |
| Vehicle Range (mi) | 346 | 328 | 150 | 150 | 187 | 202 |
| Refuels per Year | 63 | 63 | 250 | 250 | 125 | 125 |
| Vehicle Movement Time (min) | 10 | 10 | 10 | 10 | 10 | 10 |
| Maintenance ($/yr/veh) | $354 | $354 | $365 | $365 | $354 | $354 |
| Income Tax Savings($/yr/veh) | $246 | $246 | $254 | $254 | $246 | $246 |
| General Maintenance ($/mi) | $0.030 | $0.030 | $0.030 | $0.030 | $0.030 | $0.030 |
| Specific Maintenance ($/veh) | neg | neg | $100 | $100 | neg | neg |
| Specific Maintenance Time Interval (mo) | | | 36 | 36 | | |
| Insurance ($/yr/veh) | $354 | $354 | $354 | $354 | $354 | $354 |
| Income Tax Savings($/yr/veh) | $246 | $246 | $246 | $246 | $246 | $246 |
| Insurance Cost($/yr/veh) | $600 | $600 | $600 | $600 | $600 | $600 |
| FLEET SIZE (vehicles) | 50 | 50 | 50 | 50 | 50 | 50 |
| ANNUAL MILES TRAVELED (mi/yr/veh) | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 |
| TOTAL COSTS PER VEHICLE MILE TRAVELED -AFTER INCOME TAX | | | | | | |
| INFRASTRUCTURE COSTS | $0.000 | $0.000 | $0.070 | $0.012 | $0.017 | $0.007 |
| OWNING COSTS | $0.105 | $0.105 | $0.137 | $0.137 | $0.120 | $0.107 |
| OPERATING COSTS | $0.103 | $0.116 | $0.085 | $0.111 | $0.112 | $0.142 |
| TOTAL COSTS | $0.208 | $0.220 | $0.293 | $0.261 | $0.249 | $0.256 |
| without fuel taxes | | | | | | |
| OPERATING COSTS | $0.077 | $0.088 | $0.080 | $0.106 | $0.090 | $0.115 |
| TOTAL COSTS | $0.182 | $0.192 | $0.287 | $0.255 | $0.226 | $0.228 |
| TOTAL COSTS W/ EPACT INCENTIVES INCLUDED | $0.208 | $0.220 | $0.290 | $0.259 | $0.247 | $0.255 |

NOTES:
1. Discount Rate is 0.060
2. Corp Inc Tax Rate (US + Cal) is 0.410
3. US Corp Inc Tax Rate is 0.350
4. Cal Corp Inc Tax Rate is 0.093
5. Cal tax is deductible for US tax computation
6. All costs are in constant 1996 dollars.
7. Vehicle maintenance and insurance rates are assumed to be the same for all fleets.

TABLE 11: ELECTRIC VEHICLE CASE STUDY - INCLUDING INCOME TAX EFFECTS

| Date: Aug 4, 1995 | Electric Conversion | EV-'98 Tech Low Est | EV-'98 Tech High Est |
|---|---|---|---|
| INFRASTRUCTURE COSTS ($/yr/veh) | $167 | $92 | $92 |
| Personnel Training Costs ($/yr/veh) | $18 | $18 | $18 |
| Income Tax Savings ($/yr/veh) | $12 | $12 | $12 |
| Maintenance ($/fleet) | $1,602 | $1,602 | $1,602 |
| Drivers ($/fleet) | $975 | $975 | $975 |
| Fuelers ($/fleet) | $0 | $0 | $0 |
| Average Years Employment | 8 | 8 | 8 |
| Training Prep & Presentation | $8,000 | $8,000 | $8,000 |
| Amortization Period (yr) | 10 | 10 | 10 |
| Fueling Facility Costs ($/Yr/Veh) | $149 | $75 | $75 |
| Income Tax Savings ($/yr/veh) | $57 | $28 | $28 |
| Cost of Modifications/Additions | $100,000 | $50,000 | $50,000 |
| Economic Life (yr) | 15 | 15 | 15 |
| Residual Value | $0 | $0 | $0 |
| Operating Costs ($/yr) | $0 | $0 | $0 |
| Inside Vehicle Storage and Maintenance Facility Costs ($/yr/veh) | $0 | $0 | $0 |
| Income Tax Savings ($/yr/veh) | $0 | $0 | $0 |
| Cost of Modifications/Additions | $0 | $0 | $0 |
| Economic Life (yr) | 40 | 40 | 40 |
| Residual Value | $0 | $0 | $0 |
| Operating Costs, Annual | $0 | $0 | $0 |
| Special Tools/Facilities Costs | $0 | $0 | $0 |
| Mixed Fleet Costs ($/yr) | $0 | $0 | $0 |
| OWNING COSTS($/yr/veh) | $3,800 | $2,590 | $2,727 |
| Income Tax Savings ($/yr/veh) | $2,089 | $1,392 | $1,499 |
| Base Vehicle Price | $15,900 | $24,700 | $32,940 |
| Conversion Cost | $30,000 | $0 | $0 |
| Economic Life (yr) | 10 | 7 | 10 |
| Residual Value | $4,590 | $4,940 | $3,294 |
| OPERATING COSTS ($/yr/veh) | $1,601 | $1,525 | $1,518 |
| Fuel Cost ($/yr/veh) | $371 | $321 | $302 |
| Income Tax Savings ($/yr/veh) | $259 | $223 | $210 |
| Untaxed Fuel Cost ($/GEQ) | $1.415 | $1.415 | $1.415 |
| Federal Excise Tax ($/GEQ) | $0.000 | $0.000 | $0.000 |
| State Excise Tax ($/GEQ) | $0.000 | $0.000 | $0.000 |
| Sales Tax(Cal+loc) ($/GEQ) | $0.000 | $0.000 | $0.000 |
| Total Fuel Taxes ($/GEQ) | $0.000 | $0.000 | $0.000 |
| Taxed Fuel Cost ($/GEQ) | $1.415 | $1.415 | $1.415 |
| Fuel Economy (mi/GEQ) | 16.85 | 39.04 | 27.60 |
| Refueling Labor ($/yr/veh) | $13 | $13 | $13 |
| Income Tax Savings ($/yr/veh) | $9 | $9 | $9 |
| Fueling Rate (Gal Equiv/min) | na | na | na |
| Vehicle Range (mi) | 33 | 88 | 44 |
| Refuels per Year | 250 | 250 | 250 |
| Vehicle Movement Time (min) | 0.33 | 0.33 | 0.33 |
| Maintenance ($/yr/veh) | $863 | $837 | $849 |
| Income Tax Savings($/yr/veh) | $601 | $583 | $591 |
| General Maintenance ($/mi) | $0.030 | $0.020 | $0.040 |
| Specific Maintenance ($/yr/veh) | $1,239 | $1,120 | $1,040 |
| Specific Maintenance Time Interval (mo) | 30 | 30 | 43 |
| Insurance ($/yr/veh) | $354 | $354 | $354 |
| Income Tax Savings($/yr/veh) | $246 | $246 | $246 |
| Insurance Cost($/yr/veh) | $600 | $600 | $600 |
| FLEET SIZE (vehicles) | 50 | 50 | 50 |
| ANNUAL MILES TRAVELED (mi/yr/veh) | 7500 | 15000 | 10000 |
| TOTAL COSTS PER VEHICLE MILE TRAVELED -AFTER INCOME TAX | | | |
| INFRASTRUCTURE COSTS | $0.022 | $0.006 | $0.009 |
| OWNING COSTS | $0.507 | $0.173 | $0.273 |
| OPERATING COSTS | $0.213 | $0.102 | $0.152 |
| TOTAL COSTS | $0.742 | $0.281 | $0.434 |
| without fuel taxes | | | |
| OPERATING COSTS | $0.213 | $0.102 | $0.152 |
| TOTAL COSTS | $0.742 | $0.281 | $0.434 |
| TOTAL COSTS W/ EPACT INCENTIVES INCLUDE | $0.692 | $0.260 | $0.404 |

NOTES:
1. Discount Rate is 0.060
2. Corp Inc Tax Rate (US + Cal) is 0.410
3. US Corp Inc Tax Rate is 0.350
4. Cal Corp Inc Tax Rate is 0.093
5. Cal tax is deductible for US tax computation
6. All costs are in constant 1996 dollars.
7. Vehicle insurance rates are assumed to be the same for all fleets.