Clean Cities
Alternative Fuel Information Series

Alternative Fuel
CASE STUDY

May 1999

U.S. DEPARTMENT of ENERGY,
OFFICE of ENERGY EFFICIENCY and RENEWABLE ENERGY

Experience with Bi-Fuel LPG Pickups in Texas

The State of Texas, a strong proponent of using alternative fuels and alternative fuel vehicles (AFVs) since the early 1990s, requires state agencies to purchase AFVs. In 1996, Texas Department of Transportation (TxDOT) representatives elected to incorporate some 400 bi-fuel liquefied petroleum gas (LPG) pickups into their fleet. The vehicle choice was based on the reasonably well-developed LPG infrastructure in Texas, the relative convenience of purchasing LPG or having it delivered on site, and the availability of an original equipment manufacturer (OEM) vehicle.

TxDOT operates more than 5,000 AFVs, most fueled by either compressed natural gas (CNG) or LPG. The fleet is distributed in 25 districts throughout Texas. Many of these districts have central on-site fueling capabilities for gasoline, diesel, and in some cases, alternative fuels.

Because information on real-world fleet experience with LPG vehicles was needed, and because two districts, Houston and Corpus Christi, were willing to share information about operating their vehicles, a project was launched to evaluate and compare bi-fuel LPG and gasoline vehicles.

The Houston and Corpus Christi districts combined operate more than 500 AFVs. The pickup trucks are used to transport both personnel and light equipment for road design and maintenance, right-of-way acquisition, construction oversight, and state roadway transportation planning. In many of these vehicle vocations, the vehicles accumulate low mileage and may idle for extended periods of time. A number of the vehicles travel 50 miles or less per day.

In the Houston district, both gasoline and LPG are available on site, but the Corpus Christi district does not have LPG on site. The vehicles in both districts are fueled on or off site, as needed.

Fleet Facts

Fleet Type:	Pickups (used in road work)
Fleet Size:	9,000 vehicles with some 5,000 AFVs (in 1996)
Alternative Fuel:	LPG (study vehicles) and compressed natural gas
Study Vehicles:	31 bi-fuel LPG pickups, 4 gasoline pickups
Locations:	Houston and Corpus Christi
Mileage Accumulation:	15,000 to 20,000 miles annually

Fleet Evaluation

Operations, maintenance, and cost data from selected vehicles from the Houston and Corpus Christi district fleets were collected over a 2-year period, which covered 18 months of vehicle operation.

All the study vehicles were 1996 Ford F150 pickups: 31 were bi-fuel LPG models and 4 were standard gasoline models. The table on the next page summarizes the general specifications of the LPG and gasoline versions of the F150. Ford modified the bi-fuel vehicles to come equipped for operation on either LPG or gasoline. The most significant differences include additional equipment to deliver LPG to the engine and control engine operation, increased vehicle weight, and the addition of an LPG fuel tank.

It should be noted that Ford has continued with its development of this vehicle since the 1996 model year. The more recent models have incorporated improved engine calibrations and hardware.

In 1998, the bi-fuel LPG vehicle was certified to EPA's low emission vehicle standards. In 1999, Ford plans to certify this vehicle to EPA's ultra low-emission vehicle standards when operating on LPG.

By the Numbers: Vehicle Specifications

Specification	Bi-Fuel LPG F150	Gasoline F150
Model Year	1996	1996
Engine Displacement	4.9L	4.9L
Engine Configuration	I6	I6
Engine Horsepower	145	145
Fuel Capacity	48 gallons (LPG) + 18.2 gallons (gasoline)	19 gallons + 18.2 gallons(2 tanks)
Compression Ratio	8.8:1	8.8:1
Gross Vehicle Weight Rating	6250 lb	6000 lb
EPA-Estimated mpg:city highway	14* 18*	14 18

* Fuel economy for gasoline; fuel economy numbers for LPG are unavailable.

The Fleet's LPG Experience

Among the study vehicles, usage was similar for the LPG and three of the gasoline vehicles. The fourth gasoline vehicle was operated by the University of Texas personnel who were collecting the vehicle data. It was used in a more typical commuter mix of city and highway driving.

On a monthly basis, the LPG vehicles accumulated an average of just over 1,300 miles per month compared to just over 1,600 miles per month for the gasoline vehicles. Generally, the study vehicles accumulated from 16,000 to 19,000 miles annually.

The LPG usage in the bi-fuel vehicles averaged 78% (by volume) for the total study period. None of the bi-fuel vehicles were operated exclusively on LPG. All but two of the bi-fuel vehicles used LPG at least 50% of the time, and 24 of them averaged 75% or more use of LPG.

Fuel Economy and Vehicle Range

Each participating state agency agreed to keep and submit fuel usage logs, as well as fuel receipts. In addition, the state provided monthly fuel use and cost data from its database records. The fuel use data were used to evaluate fuel economy and cost.

There are different ways to look at fuel economy when comparing AFVs to gasoline vehicles. Of most interest to vehicle drivers is actual volumetric fuel economy, which is calculated directly from the number of miles driven divided by the number of gallons of fuel used to drive those miles. For the bi-fuel vehicles, the fuel economy includes a percentage of miles driven on LPG and a percentage driven on gasoline. The average fuel economy for the bi-fuel LPG vehicles was approximately 10.1 miles per gallon (mpg, or about 12.7 miles per equivalent gallon of gasoline), which is lower than the average of 13.2 mpg for the gasoline vehicles. The difference in volumetric fuel economy is expected, because the energy content of LPG is approximately 30% lower than that of gasoline, and the fleet operated its bi-fuel vehicles on LPG a significant amount of the time. The difference in gasoline equivalent fuel economy of the two vehicle types is not significant, given the scope of the study.

The range of the vehicle (the number of miles that can be traveled on a tank of fuel) is also important to the fleet and its vehicle operators. The gasoline vehicles were outfitted with two fuel tanks with a total capacity of 37 gallons. The bi-fuel LPG vehicles were outfitted with the standard 18-gallon gasoline tank, plus a 48-gallon LPG tank. As a result, the bi-fuel vehicles offer a significantly longer total vehicle range than the gasoline-only vehicles. This may make the bi-fuel vehicles more convenient to operate because they require refueling less often.

Maintenance and Reliability

All scheduled and unscheduled maintenance and repair records and cost data were collected from the participating districts for the study vehicles. In addition, TxDOT provided access to centralized state vehicle and service records, which included paper and electronic data collection systems.

Although TxDOT performs some of its own routine maintenance, it also contracts with local maintenance and repair shops to do routine maintenance. All warranty repairs were done at the local Ford dealerships. The bi-fuel and gasoline vehicles followed the maintenance schedule recommended by the manufacturer, with the exception of oil changes. Oil changes were done every 3 months or 3,000 miles, whichever came first.

The bi-fuel and the gasoline study vehicles experienced very few incidents of unscheduled maintenance or repairs. Only three of the vehicles were no longer under warranty at the end of the study. Based on the available data, the bi-fuel vehicles are projected to average 7.6 unscheduled repairs in 50,000 miles of vehicle operation. It is estimated that of the average number of unscheduled repairs for the bi-fuel vehicles, 6.5 would be unrelated to the vehicles being bi-fuel.

Based on this study, we estimate that the bi-fuel LPG vehicles will experience about 15% more occurrences of unscheduled repairs (most related to the LPG systems) than do gasoline vehicles.

With the additional hardware on the LPG vehicles, one might expect to see an increase in the number of repairs. This information indicated that although the reliability of LPG vehicles is on average good, it is lower than would be expected from the gasoline vehicles.

Operating Costs

The operating costs considered in this study include the fuel usage cost, which is the cost of the fuel used per mile, and maintenance costs, which included parts, labor, and other costs. The other costs included items like recycling costs, parts disposal, and engine oil.

In addition to operating costs, fleets must also consider the initial purchase price of the vehicles. In this case, the LPG vehicles cost $2902 more than the gasoline vehicles.

Bi-Fuel LPG Purchase Price

Bi-Fuel F150 Pickup:	$18,050
Gasoline F150 Pickup	$15,148
Net Cost Difference:	$2,902

Note: The state received no rebates or incentives for its LPG vehicle purchases.

Fuel operating costs depend on the fuel economy, the fuel price, and in the case of the LPG vehicles, the percentage of LPG used. In addition, fleets owned by the State of Texas do not pay federal taxes on gasoline, but they do pay a state tax on LPG via an annual tax on AFVs. Fleets pay this state tax based on annual vehicle mileage accumulation and vehicle weight. For the F150s, a tax of $168 is accessed for vehicles accumulating 15,000 or more miles annually. The annual tax adds 0.98 cents per mile to the fuel costs for the LPG vehicles, based on their average annual mileage accumulation of 17,153 miles.

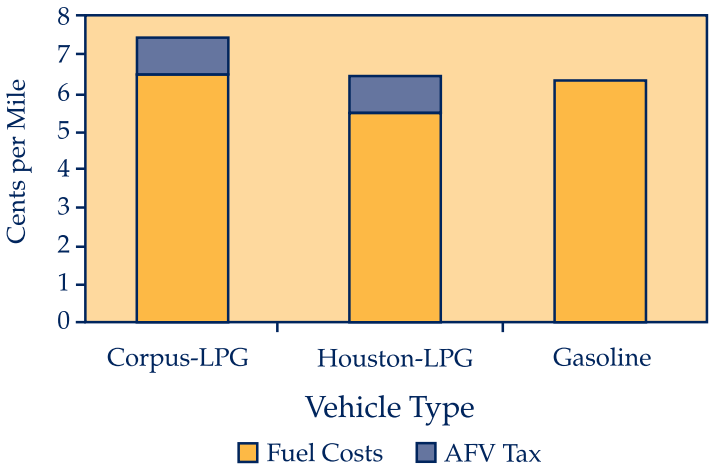
The price of gasoline fluctuated from a low of about $0.66 per gallon to $0.90 per gallon during the study (remember the state pays no federal tax on fuel). The average price of gasoline during the study was $0.80 per gallon. Districts using LPG-fueled vehicles have independent contracts for LPG fuel. As a result, the prices for LPG were different for the vehicles operated by the Houston and Corpus Christi districts.

In Houston, the price of LPG varied between about $0.43 and $0.59 cents per gallon, averaging $0.50 per gallon. In Corpus Christi, LPG ranged from $0.55 to $0.72 per gallon, with an average of $0.62 per gallon.

In evaluating the fuel usage cost for the bi-fuel LPG vehicles, we had to consider both gasoline and LPG costs because the vehicles used both fuels.

The fuel costs for the bi-fuel LPG vehicles averaged 6.56 cents per mile in Corpus Christi and 5.53 cents per mile in Houston. The gasoline vehicles averaged 6.28 cents per mile in fuel costs. The lower LPG price in Houston offset the lower LPG fuel economy, resulting in about a 12% lower fuel cost for the bi-fuel vehicles. Given the relative fuel economics, a fleet would break even on fuel costs if the price of LPG was approximately 30% lower than gasoline (e.g., if gasoline cost $0.80/gallon and LPG cost $0.56/gallon). The LPG price in the Corpus Christi district was not low enough to offset the fuel economy difference between LPG and gasoline. The result was that the LPG vehicles in the Corpus Christi district had higher fuel costs, on a cents per mile basis (about 4% higher), than did the gasoline vehicles. When the annual AFV tax is included in the fuel costs, the cost of fueling the LPG vehicles in both districts exceeds that for fueling the gasoline vehicles.

Fuel Costs



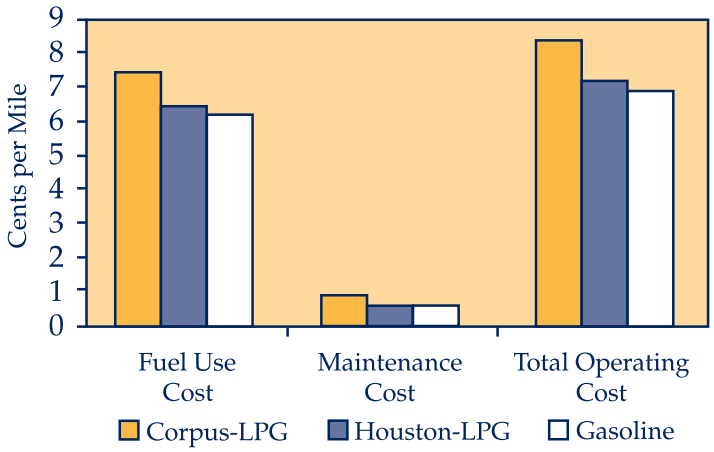
Overall, maintenance costs for this fleet of study vehicles were low. TxDOT does scheduled maintenance (such as oil changes) at fixed intervals, which are the same for its LPG and gasoline vehicles. The scheduled maintenance costs, then, were the same for the two vehicle types at 0.65 cents per mile, with one exception. The Corpus Christi district used reusable oil filters, which increased labor costs (because of the added labor to clean the filters), resulting in an increase in the scheduled maintenance cost to 0.82 cents per mile.

Because only three of the study vehicles were no longer under warranty at the end of the study, there were essentially no repair (unscheduled maintenance) costs, because any unscheduled repairs were covered under the vehicle warranty.

The total operating costs were 8.31 cents per mile for the LPG vehicles in the Corpus Christi district and 7.15 cents per mile for the LPG vehicles in the Houston district, compared to 6.93 cents per mile for the gasoline study vehicles. Looking at the Houston LPG costs

(which are directly comparable to the gasoline results because their maintenance was the same), it cost only about 3% more, on a cents per mile basis, to operate the LPG vehicles. Without the state AFV tax, the costs to operate LPG vehicles would drop about 10% below that of gasoline.

Operating Costs



This fleet's experience indicates that the price of fuel will significantly affect overall operating costs. In addition, the Corpus Christi district found that the use of reusable oil filters increased maintenance costs. The bi-fuel vehicles cost more to purchase, and finally, Texas' AFV tax makes it more costly to operate these LPG vehicles.

Lessons Learned from the State of Texas' Experience

• **Fueling infrastructure and available OEM vehicles play a role in AFV selection.** TxDOT and other Texas state agencies are required by state law to incorporate AFVs into their fleets. The existing alternative fuel infrastructure for both CNG and LPG makes them fuels of choice in this state's fleets. In addition, TxDOT was interested in the bi-fuel vehicles because they still offer flexibility when fuel is not as readily available, and also because the OEM offers these vehicles.

• **Operating costs are driven by fuel prices and by the Texas AFV tax.** In Houston, operating costs were only 3% different between the LPG and the gasoline vehicles, but in Corpus Christi the difference was nearly 20%. In both cases the LPG vehicles cost more to operate. The price of LPG was lower than gasoline on a per gallon basis throughout the study (and it was different in the two districts), but was not low enough to offset the lower energy content of the LPG and the Texas AFV tax. The AFV tax adds an extra burden to the fuel costs on a cent per mile basis, and actually made it more costly for this fleet to operate its AFVs than its gasoline vehicles.

Acknowledgment

This project is one of the focus fleet studies sponsored by the U.S. Department of Energy's Office of Technology Utilization and managed by DOE's National Renewable Energy Laboratory (NREL). These studies are designed to collect and provide objective information on real-world fleet experiences with AFVs and to demonstrate that AFVs can meet the vehicle needs of fleets. This AFV evaluation was a cooperative effort supported by the following organizations:

Participants	Role/Responsibility
Texas Department of Transportation Austin, Houston, and Corpus Christi	Served as host fleet for study; provided access to vehicle maintenance and fueling records
University of Texas – Dr. Ronald Matthews (contractor to NREL)	Worked directly with fleet to collect all operating and maintenance data and cost records
U.S. Department of Energy	Provided funding to conduct the evaluation study
National Renewable Energy Laboratory	Directed the evaluation study

Additional information is available in the detailed project report *Texas Bi-Fuel LPG Fleet Study: Final Report*, which is available on the World Wide Web at: http://www.ott.doe.gov/otu/field_ops/texas fleet.html. For more information on alternative fuels, AFVs, and related topics, contact the National Alternative Fuels Hotline at 1-800-423-1363 or the Alternative Fuels Data Center at http://www.afdc.doe.gov

Disclaimer

This study is intended only to illustrate approaches that organizations could use in adopting AFVs into their fleets. The data cited here, although representing real experience for the fleet discussed in this study, may not be replicated for other fleets.

The Office of Energy Efficiency and Renewable Energy

Sponsored by the U.S. Department of Energy
Energy Efficiency and Renewable Energy Office of Transportation Technologies

Prepared by the National Renewable Energy Laboratory (NREL)
NREL is a U.S. Department of Energy National Laboratory
Operated by Midwest Research Institute • Battelle • Bechtel

NREL/FS-540-24226
May 1999
Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste