Ohio's First Ethanol-Fueled Light-Duty Fleet

Background

This project is another focus fleet study sponsored by the U.S. Department of Energy (DOE) 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 alternative fuel vehicles (AFVs) and to demonstrate that AFVs can meet the vehicle needs of fleets.

The overall objectives of the study are to assess whether the operational performance and costs of operating AFVs are similar to, better than, or not as good as those of similar gasoline vehicles.

In these studies, we collect and analyze detailed operating and maintenance records and cost data. Project goals are to evaluate the costs of operating AFVs, compared to gasoline vehicles, and to assess the performance and reliability of these vehicles. Additionally, emissions testing of study vehicles may be included in the evaluation effort. The emissions results are used to compare the air quality impacts of these vehicles.

This AFV evaluation project was a cooperative effort supported by the following organizations:

Participants	Role/Responsibility
State of Ohio, Department of Administrative Services; state agencies using study vehicles	Purchased vehicles, served as host fleet for study, and funded emissions testing
Council of Great Lakes Governors	Provided grant to support purchase of vehicles and fuel
Public Utilities Commission of Ohio, Biomass Energy Program	Provided grant to support purchase of vehicles and fuel
U.S. Department of Energy	Provided funding for data collection, analysis, and reporting
Battelle (under contract to NREL and the State of Ohio)	Collected, analyzed, and reported on vehicle performance and operations data; coordinated emissions testing

In this overview, we summarize the study results and experiences of the State of Ohio fleet.

Introduction

In 1996, the State of Ohio established a project to demonstrate the effectiveness of ethanol as an alternative to gasoline in fleet operations. The state purchased and incorporated a number of flexible-fuel vehicles (FFVs) into its fleet. Flexible-fuel vehicles are designed to operate on all gasoline, all E85 (a blend of 85% ethanol and 15% gasoline), or any combination of the two fuels up to 85% ethanol. The key objectives of the state's program were:

- To establish and operate a fleet of ethanol-fueled AFVs
- To use ethanol, as much as possible, in operating these fleet vehicles
- To collect operations, maintenance, and cost data for selected ethanol and gasoline vehicles over 24 months of vehicle operation
- To evaluate and compare the selected E85 and gasoline vehicles based on detailed data collected during 24 months of operation, and make a summary of the fleet's experience available
- To encourage the use of ethanol (DOE and NREL encourage the use of several alternative fuels, including E85).

Vehicle Information

The project study fleet included 10 FFV and 3 gasoline Ford Tauruses, all from the 1996 model year. The vehicles were assigned to individuals or vehicle pools at various state agencies and were generally used for local trips around the Columbus area. The general vehicle specifications for the FFV and the gasoline Taurus are the same (see table below). However, Ford has incorporated a number of design changes into its FFV model to ensure that the vehicles will perform well on ethanol-fuel blends. Some of these changes include alcohol-resistant materials in the fuel system and an alcohol fuel sensor linked to a control module that is calibrated to compensate for varying fuel blends. In addition, the fuel tank is larger on the FFV because it takes slightly more fuel to drive the same distance on E85 as on gasoline (the energy content of E85 is lower than gasoline).

Specifications	E85 Vehicles	Gasoline Vehicles
Number of Vehicles	10	3
Make	Ford	Ford
Model	Taurus	Taurus
Model year	1996	1996
Engine displacement (L)	3.0	3.0
Engine maximum horsepower	140	140
Engine configuration	V-6	V-6
Compression ratio	9.0:1	9.0:1
Fuel tank capacity (gal)	18.4	16
Air conditioning (Y/N)	Y	Y
Axle ratio	3.77:1	3.77:1

Refueling

During the planning process for the project, state administrators decided to set up two E85 refueling sites in the Columbus, Ohio, area to fuel the E85 study vehicles, all of which were generally operated in the metro Columbus area. One site was an existing 500-gallon station, at the Reynoldsburg Department of Agriculture facility, and the other was a new installation, located at the central garage facility of the Ohio Department of Transportation (ODOT), near downtown Columbus. The new facility included a 2,000-gallon storage tank and cost approximately $28,000, including installation. The existing station was in service throughout this project. The new installation was completed and began to operate in March 1997, about six months later than originally planned (the study vehicles went into service between April and August 1996). Issues related to getting the proper permits delayed the opening of the new station several times. The delays in opening the new station affected the E85 usage in four of the FFVs during the early part of the project. The state minimized the use of these FFVs, to limit the number of miles the FFVs were operated only on gasoline, until the new station was up and running.

Data Collected

Five different state agencies purchased the vehicles and agreed to participate in the study, as shown in the table below. Each participating agency agreed to keep and submit fuel usage logs, fuel receipts, and maintenance and repair data and receipts for all study vehicles operating in its fleet. The Department of Administrative Services also gave the project access to centralized state vehicle and service records, which include paper and electronic data collection systems.

Agency	Number of Vehicles FFV	Gasoline
Department of Administrative Services	1	–
Public Utilities Commission	4	–
Department of Agriculture	5	–
Office of Industrial Commission	–	1
Department of Commerce/ Liquor Control	–	2
Total	**10**	**3**

Besides directly collecting operational data, we conducted one series of emissions tests on two of the FFVs and on two of the gasoline-only vehicles. Testing was conducted according to the Federal Test Procedure (FTP), as outlined in the *Code of Federal Regulations*. Finally, several fuel samples were analyzed from each of the fuel stations to confirm the ethanol content and the heating value of the E85 used by the study FFVs.

The Fleet's Experience: Data and Results

Vehicle Usage

Vehicle usage during the study period was about the same for the two vehicle types. On a monthly basis, the ethanol vehicles accumulated an average of 1,121 miles, compared to an average of 1,199 miles for the gasoline-only vehicles. Overall, the study vehicles accumulate approximately 14,000 miles annually, which is typical for light-duty fleet vehicles. The fleet did not experience any problems that could affect vehicle usage, such as significant vehicle downtime.

Fuel Usage

The E85 usage averaged 63% (by volume) for the total study period. During the last 12 months of the study, E85 usage jumped up to 72% (by volume) following the opening of the new fueling station at the ODOT facility. None of the FFVs operated exclusively on E85. During the last year of the study, all the FFVs used E85 at least 50% of the time, and five of them averaged 75% or better use of E85 (by volume). E85 usage was not higher because it was not always convenient to get to one of the E85 stations when fuel was needed.

Fuel Economy

There are different ways to look at fuel economy when comparing alternative fuel and gasoline vehicles. Of most interest to vehicle drivers is the 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. The average fuel economy for the FFVs was just over 23 miles per gallon (mpg), which is lower than the average of 24.6 mpg for the gasoline vehicles. We expect this result because the energy content of E85 is lower than that of gasoline, and the fleet operated its FFVs on E85 a significant amount of the time (see Fuel Usage discussion above).

Vehicle Range

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. Ford opted to ensure that its FFVs and its gasoline Taurus have similar ranges by installing a slightly larger fuel tank in the FFVs (see vehicle specifications table). So although the E85 and gasoline-only fuel economy are somewhat different, the operators did not see a difference in vehicle range.

Maintenance and Repairs

State vehicles are generally maintained or repaired by local auto repair facilities or the local Ford dealer, depending on the nature of the service required. The vehicles operated by the Department of Agriculture were maintained in the department's own shop, with the exception of warranty repairs. All warranty repairs were done at the local Ford

dealership. The FFVs and gasoline-only vehicles followed the maintenance schedule recommended by the manufacturer. In the only major difference in service between the FFVs and gasoline vehicles, the FFVs required special low-ash engine oil. During the course of this project, Ford eliminated the requirement for using the special oil. With Ford's permission, the FFVs in this fleet switched to using standard oil during the last 6 to 12 months of this project. This change in oil usage did not result in any problems with the FFVs.

There were very few occurrences of unscheduled maintenance or repairs for either the FFVs or the gasoline-only vehicles in this study fleet (12 instances for the FFVs and 7 for the gasoline vehicles). A number of these repairs were covered under warranty, and only one of the FFV repairs may have been fuel-related (a spark plug coil problem that affected vehicle power).

Operating Costs

The operating costs we considered in this study included the fuel usage costs and maintenance costs. The fuel usage costs are the cost of the fuel used per mile. Maintenance costs included parts, labor, and other costs. The other costs included items like recycling costs, disposal of parts and engine oil, and other maintenance costs that could not be separated into labor and parts.

The cost of gasoline fluctuated significantly during the study period, ranging from $1.03 per gallon up to $1.33 per gallon. The average price of gasoline throughout the project was $1.23 per gallon. During the last 12 months, the gasoline cost averaged or was $1.18 per gallon. The price of E85 was stable during the study, but did depend on the site at which the fuel was purchased. The Department of Agriculture fuel station was small, which resulted in a higher price of $1.88 per gallon during the study. At the larger fueling station at the ODOT facility, E85 averaged $1.33 per gallon. It became clear from this study that E85 fuel prices could be lower (for the user), if larger quantities of fuel could be purchased.

In evaluating the fuel usage cost for the FFVs, both gasoline and E85 costs had to be taken into account, because these vehicles used both fuels. The fuel cost per gallon for the FFVs, based on the monthly fuel usage and cost data, ranged between $1.20 and $1.63 per gallon of fuel used. The average fuel cost per gallon for the FFVs was $1.50 during the whole study period and $1.52 for the last 12 months.

For comparison purposes, the fuel usage costs for the FFVs and gasoline-only vehicles are presented on a per 1,000 mile basis. As shown in the table on the next page, fuel cost just over $50 per 1,000 miles of operation for the gasoline-only vehicles, and $65.54 per 1,000 miles in the FFVs. Fuel costs were approximately 30% higher for the FFVs, which is consistent with the differences seen in fuel economy, and with the cost of E85. During the last 12 months of the study, the fuel cost difference between the gasoline-only vehicles and the FFVs was even greater, as we would expect with the increased use of E85.

Overall, maintenance costs for this fleet of study vehicles were low. The maintenance costs are presented in the table on a per 1,000 miles of vehicle operation basis (these costs exclude body and tire work). The maintenance costs were nearly 13% higher for the E85 vehicles than for the gasoline-only vehicles. This was due almost entirely

to the requirement to use the expensive special oil in the FFVs. As mentioned above, Ford eliminated the requirement for special oil for the FFVs during the course of this study. Once the need for the special oil was eliminated, this fleet found that the maintenance costs (over similar mileage intervals) were very similar for the FFVs and the gasoline vehicles. We expect that other fleets that choose to operate these FFVs will see little difference in the maintenance and repair costs of FFVs compared to those of similar gasoline vehicles.

Operating Costs	Total ($ per 1000 miles)	
	Gasoline	FFV
Fuel Usage	50.09	65.54
Maintenance	7.69	8.81
Total	**57.78**	**74.35**

The total operating cost for 1,000 miles of vehicle operation was $74.35 for the FFVs and $57.78 for the gasoline-only vehicles. This difference in cost was driven almost entirely by the higher cost of the E85 fuel. This fleet's experience indicates that purchases of larger quantities of E85 fuel can reduce costs per gallon of fuel (in this case, by about 28%). This can help to bring the total costs of operating these FFVs closer to those of operating similar gasoline vehicles. At least for the near future, with E85 production being limited, E85 is expected to continue to cost more than gasoline. Fuel cost will continue to dominate operating cost differences between FFVs and their gasoline counterparts, with the total difference depending on actual per gallon fuel price and level of E85 usage. Based on this fleet's experience, fuel cost differences could be as low as about 8% (based on per gallon cost of fuel).

Emissions Test Results

Emissions testing was conducted on two FFVs and two gasoline-only vehicles at Automotive Testing Laboratories in nearby East Liberty, Ohio. The tests were conducted following the FTP. The gasoline baseline fuel selected for this testing was California Phase 2 Certification gasoline (designated RFG). This clean-burning gasoline provides the best modern gasoline for comparing the FFVs and the gasoline-only vehicles. The E85 used in the testing consisted of 85% ethanol blended with the base RFG fuel. The FFVs were tested on both RFG and E85.

The average emissions results are summarized in the following table. Although the emissions testing in this project was limited, the results followed some trends seen in more extensive test programs, including decreased CO and NO_x for the FFVs compared to the gasoline-only vehicles (Kelly et al., 1996a, 1996b). The differences between emissions results of the FFV and gasoline-only vehicles are a by-product of calibration compromises required to enable the FFV to operate on E85, gasoline, and blends of the two fuels. It is reasonable to expect that differences between E85 and gasoline will decrease as the auto manufacturers continue to improve control technology. It is worthwhile to point out that, regardless of test fuel or vehicle type, all the emissions results from this project were well below the applicable useful life standards.

FFV and Standard Gasoline Vehicles—Average Emissions Results

Type	FFV		Std Gas	EPA
Fuel	E85	RFG	RFG	Tier 1
Regulated Emissions				
NMHC (E) (g/mi)	0.149	0.101	0.114	0.25
THC (E) (g/mi)	0.189	0.117	0.132	0.41
CO (g/mi)	1.33	1.01	1.39	3.4
NO_x (g/mi)	0.09	0.08	0.22	0.4
Greenhouse Gases				
CO_2 (g/mi)	389.8	412.1	407.6	–
Methane (g/mi)	0.046	0.021	0.023	–
Aldehydes				
Formaldehyde (g/mi)	0.00226	0.00099	0.00127	–
Acetaldehyde (g/mi)	0.01302	0.00030	0.00035	–
Fuel Economy				
MPG (actual)	15.8	21.1	21.3	–
MPEG	21.4			

Fleet Feedback

The fleet managers participating in this study were asked to provide feedback on their experiences with the Taurus FFVs compared to similar gasoline-only vehicles in their fleets. Here is a summary of their responses:

- All responding fleet managers said they had few or no problems with the FFVs.
- The FFVs operate essentially the same as their gasoline-only vehicles.
- The range of the FFVs was acceptable.
- Oil changes were expensive because of the special engine oil (although this changed after Ford eliminated this requirement).
- The only major concern identified with this project was the availability of E85.

Conclusions

The State of Ohio has operated the flexible-fuel Taurus in its fleet since 1996. The fleet has discerned no operational difference between it and similar gasoline vehicles. Here is a summary of the major findings of this study:

- The fleet achieved about 72% (by volume) usage of E85 in its FFVs. Fleet managers indicated that fuel availability was an issue, even with the two fueling sites set up for this project.

- The fleet did not experience any difference in the overall performance of the FFVs. With the exception of needing special oil (a requirement eliminated by Ford during the course of this project), these vehicles did not require any different or additional scheduled or unscheduled maintenance or repairs.
- Vehicle operating costs were higher for the FFVs than the gasoline vehicles in this fleet. Both maintenance and fuel costs were higher for the FFVs.
  - The higher maintenance costs resulted mostly from the higher priced special oil. Because that requirement was eliminated, fleets using these FFVs in the future are likely to see little or no difference in maintenance costs.
  - The price per gallon of E85 is higher than that of gasoline. In the near future, if E85 production continues to be limited, users can expect E85 to continue to cost more than gasoline. As a result, fleets should expect higher fuel costs for operating FFVs on E85. A fleet's actual fuel cost will depend on fuel price per gallon and percent usage of E85.
  - Fleets adding this type of FFVshould expect to see higher operating costs, which result almost exclusively from the higher cost of E85 fuel.

Overall, State of Ohio representatives have been pleased with the performance of the Taurus FFVs in the state fleet. The vehicles perform well, and meet the operators' needs. During the course of this study, the state opted to add more FFVs to its fleet—adding 282 in 1997 and 335 in 1998. Clearly, the State of Ohio has made a commitment to continue adding FFVs to its fleet. In addition, the state is continuing to work to expand the E85 fueling infrastructure within Ohio.

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Additional information is also available in the detailed project report titled *Ohio's First Ethanol-Fueled Light-Duty Fleet: Final Study Results,* which is available on the World Wide Web at *http://www.afdc.doe.gov/demoproj/ldv/title.html*

Produced for the U.S. Department of Energy (DOE) by the National Renewable Energy Laboratory, a DOE national laboratory.

NREL/BR-540-25238
December 1998

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste