# Alternative Fuel (E85) Performance/Economics/Quality/Usage

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16. Abstract:
Federal regulations have encouraged the movement for fleet management to embrace environmental concerns and be a part of the solution. MoDOT has proactively taken strides towards being environmentally responsible in the way they do business. The most significant contribution has been the acquisition of flexible fuel vehicles (FFVs). Maximizing the impact of such an investment becomes the challenge of the fleet managers and the goal of leadership. This study provides an overview of the E85 product to reveal performance experience of FFVs fueled with E85 as well as the potential environmental benefits. Applying these findings to the FFV fleet within the Missouri Department of Transportation’s (MoDOT) fleet offers decision makers quantifiable measures to be considered during policy development. The implications of E85 use presented in this study lay the foundation for strategic fleet management. Factors like fuel efficiency estimates, expected engine performance and maintenance, potential to reduce oil consumption, greenhouse gas emissions, fuel cost considerations and E85 fuel accessibility are all available to assist MoDOT in their future efforts to determine the appropriate policies to guide fleet operations. Balancing the cost benefit of using E85 versus gasoline may not be a statewide evaluation but rather a consideration of the individual district FFV fleets or even FFV models. This study offers the tools, including policies and best practices currently in place in other states and best practices, to assist MoDOT in making these decisions.

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## Executive Summary

Federal regulations encourage fleet management to be part of the environmental solution. MoDOT is proactive in business and environmental responsibility, such as use of E85 in their flexible fuel vehicles (FFVs). This study provides an overview of the E85 trends and best practices among other states as well as vehicle performance and the potential environmental benefits of fueling FFVs with E85. Applying these findings to the FFVs of MoDOTs fleet offers decision makers quantifiable factors to consider during policy development. Factors include fuel efficiency estimates, petroleum based fuel consumption, greenhouse gas emissions and fuel cost comparisons. Missouri is fortunate to have the fifth largest number of E85 refueling locations in the country. This level of accessibility makes it is feasible for MoDOT to contemplate E85 for its entire fleet.

E85 is not a one-size-fits-all solution. It makes sense to evaluate not only at the individual district FFV fleets but also each FFV make and model. Each group of vehicles sharing a particular year, make and model has its own combination of fuel efficiency, cost effective breakeven point and environmental contributions. Collectively, this wide range of individual vehicle factors must be assessed locally and balanced statewide to achieve optimal benefits. E85 has tremendous potential, if used appropriately by MoDOTs FFV fleet. The following summarizes the findings throughout the study:

- FFVs experience no loss in power and acceleration when operating on E85. Performance actually improves with a 5-7% increase in engine horsepower.
- Fuel efficiency may be 20-30% fewer MPG when FFVs are fueled with E85, depending on the year/make/model of the vehicle and other factors (e.g. driver habits, traffic conditions).
- Using seasonal E85 blends, as recommended for Missouri by the U.S. Department of Energy, should eliminate E85 cold start problems.
- Maintenance cost differences between E85 FFVs and their gasoline counterparts are negligible and may actually be reduced for FFVs using E85 because it is a cleaner fuel.
- If fueled with E85, MoDOTs current FFV fleet could reduce petroleum consumption by more than 7,600 barrels per year and GHG emissions by nearly 1,300 tons of CO2 per year.
- The service areas of the 98 E85 (as of December 2007) in Missouri provide adequate refueling opportunities should MoDOT choose to require E85 usage in its FFV fleet.
- For most of MoDOTs current FFVs, there is a realistic price spread at which E85 is more cost effective.

## Introduction

The purpose of this research is to relate E85 ethanol use to practical applications in MoDOT. This report provides information for MoDOT employees to make good decisions related to E85. Data was gathered about fuels and the various makes, models, and model years of vehicles in MoDOT's Flexible Fuel Vehicle (FFV) fleet. Based on the data, methods were developed to compare fuel costs and to compare current or future vehicle's efficiency.

## Overview of Alternative Fuels

The Energy Policy Act (EPAct) of 1992 defines the following fuels as alternative fuels:

- Pure methanol, ethanol and other alcohols
- Blends of 85% or more of alcohol with gasoline
- Natural gas and liquid fuels domestically produced from natural gas
- Liquefied petroleum gas (propane)
- Coal-derived liquid fuels; hydrogen
- Electricity
- Pure biodiesel (B100)
- Fuels, other than alcohol, derived from biological materials
- P-Series fuels

In addition, the U.S. Department of Energy (DOE) is authorized to designate other fuels as alternative fuels, provided the fuel is substantially nonpetroleum, yields substantial energy security benefits, and offers substantial environmental benefits.[1] The focus of this study is the alternative fuel E85, which is a nominal 85 percent ethanol and 15 percent gasoline.

E85 requires a factory-modified engine that is essentially the same as a gasoline engine (same parts – different materials), unlike other alternatives that require different engines such as diesel, electric, or fuel cell. Table 1 provides a side-by-side comparison of gasoline and ethanol. Appendix A provides a comparison of all alternative fuels.

[1] http://www.eere.energy.gov/afdc/ethanol/incentives_laws_federal.html?print Retrieved July 30, 2008.

Table 1 – Side-By-Side Comparison of Gasoline and Ethanol

| | Gasoline | Ethanol |
|---|---|---|
| Pump Octane Number | 84-93 | 110 |
| Main Fuel Source | Crude Oil | Corn, grains, or agricultural waste (cellulose) |
| Energy Content (Lower Heating Value) | 116,090 Btu/gal | 76,330 Btu/gal for E100 |
| Energy Content (Higher Heating Value) | 124,340 Btu/gal | 84,530 Btu/gal for E100 |
| Safety Issues (All alternative fuel vehicles must meet today's OEM Safety Standards) | Gasoline is highly flammable, but vehicles have been engineered to reduce risks. Gasoline is not biodegradable, so spills pollute soil and water. | Ethanol is less toxic than gasoline. Ethanol vapors disperse more rapidly than gasoline, lowering concentrations to safe levels more quickly after an accident. |
| Energy Security Impacts | Manufactured using oil, of which nearly is 2/3 imported. | Ethanol is produced domestically. E85 reduces lifecycle petroleum use by 70% and E10 reduces petroleum use by 6.3%. |
| Fuel Availability | Available at all fueling stations. | E85 available at an increasing number of retail stations (nearly 1500 in 43 states). The majority are in the Midwest, with 1/4 of all stations in Minnesota. |
| Maintenance Issues | | Practices are very similar, if not identical, to those for conventionally fueled operations. |
| Energy Comparison (Percent of Gasoline Energy) | 100% | E100 contains 66%, E85 contains 72% to 77% |
| Environmental Impacts of Burning Fuel | Produces harmful emissions; however, gasoline and gasoline vehicles are improving and emissions are being reduced. | E85 vehicles reduce global warming gases. Tests have also shown that E85 reduces NOx and the toxics benzene and 1, 3-butadiene compared to reformulated gasoline, yet increases formaldehyde and acetaldehyde emissions. |

Source: U.S. Department of Energy, *Fuel Comparison Chart* (2008)

## National Trends

While flexible fuel vehicles have been manufactured for over a decade, FFVs are gaining significant attention. E85 vehicles were built primarily to take advantage of Corporate Average Fuel Economy (CAFE) standards that offer benefits for producing vehicles that can use environmentally friendly fuels. Even if most consumers never use their flex-fuel capability, automakers still received a CAFE benefit. Current fuel economy credits have been extended to 2019 by Section 109 of the Energy Independence and Security Act of 2007. Environmental benefits take on a new meaning in terms of national security and reducing dependency on foreign oil. Political issues are part of the renewed interest in FFVs and alternative fuels. The most obvious catalyst is the rising price of gasoline. With current oil prices exceeding $100 per barrel, the time is right for automakers to improve their E85 efficiency, to become more competitive with gasoline. [2]

*Policies*

Effective January 1, 2008, Missouri law requires at least 70 percent of new vehicles purchased for the state vehicle fleet must be FFVs that can operate on fuel blends of 85 percent ethanol (E85). Excess acquisitions of AFVs may be credited towards future biennial goals. If a state agency fails to meet a biennial acquisition goal, then purchases of any non-AFVs are not permitted until the goals are met or an exemption or goal reduction has been granted. In addition, 30% of the fuel purchased annually for use in state fleet vehicles must be alternative fuels[3].

The most recent Federal legislation includes the Energy Independence and Security Act of 2007 (P.L. 110-140, H.R. 6). Table 2 summarizes the most significant sections of the Act where Departments of Transportation have jurisdiction. These sections strive to increase fuel efficiency and encourage alternate fuels. It is noted that many of these sections still require rulings or funding before they can take effect.

Table 2 – Summary of Energy Independence and Security Act of 2007

| Section of EISA and Agency with Jurisdiction | Summary, Timeline, Next Action |
|---|---|
| Section 102 Corporate Average Fuel Economy (CAFE) Increase DOT,DOE | EPA Requires an increase in combined (city and highway) CAFE standard to 35 mph overall by 2020. Implementation begins with model year 2011 and phases up. Also requires a rule by December 2010 for work trucks and commercial medium- and heavy-duty trucks. Phases in starting in model year 2011. Requires rulemaking. |
| Section 105 Consumer Information on the Benefits of Alternative Fuel Vehicles DOT,DOE,EPA | Requires the Department of Transportation (DOT) to develop a new system of rating vehicles that makes it easier for consumers to compare fuel economy and greenhouse gas emissions of vehicles. Requires new labeling for fuel economy information, greenhouse gas emission benefits, and alternative fuel use. Final regulations due 42 months after enactment. Requires rulemaking. |
| Section 107 DOT/NAS Fuel Economy Studies DOT,NAS | DOT must execute an agreement with the National Academy of Sciences (NAS) to develop a report evaluating vehicle fuel economy standards. Subsequent updates of the report are due every five years through 2025. Five years from agreement date. Requires appropriation. |

[2] http://www.thefabricator.com/IndustryTrendsAnalysis/IndustryTrendsAnalysis_Article.cfm?ID=1456 Retrieved July 30, 2008.

[3] Senate Bill 54, 2007 and Missouri Revised Statutes 414.400 and 414.410 as summarized at www.eere.energy.gov/afdc/progs/ind_state_laws.php/MO/BIOD Retrieved July 30, 2008.

| Section of EISA and Agency with Jurisdiction | Summary, Timeline, Next Action |
|---|---|
| Section 108 DOT/NAS Heavy-Duty Fuel Economy Studies DOT,NAS | DOT must execute an agreement with the NAS to develop a report evaluating vehicle fuel economy standards. One year from agreement date. Requires appropriation. |
| Section 109 Extension of FFV Credit Program DOT,NHTSA | Extends the current fuel economy credits for flexible fuel vehicles (FFVs) and dual-fuel alternative fuel vehicles (AFVs) through 2019. Provides B20-capable vehicles with the same level of fuel economy credit as other dual-fuel vehicles. The maximum increase that may result from such vehicles is capped at 1.2 MPG through 2014, after which it declines and expires in 2020. Effective immediately. Code amendment. Rulemaking from NHTSA expected in 2009. |
| Section 225 Flexible Fuel Vehicle E85 Optimization Study DOE,DOT,EPA | Requires DOE to study whether optimizing FFVs to operate on ethanol would increase fuel efficiency. Study due 180 days from enactment. Requires appropriation. |
| Section 227 Study on Optimizing Natural Gas Vehicles for Biogas DOE,DOT,EPA | Requires a study of methods of increasing the fuel efficiency of vehicles using biogas by optimizing natural gas vehicle systems that can operate on biogas, including the advancement of vehicle fuel systems and the combination of hybrid-electric and plug-in hybrid electric drive platforms with natural gas vehicle systems using biogas. 180 days to initiate study. Requires appropriation. |
| Section 241 Prohibition of Franchise Agreement Restrictions Relating to Renewable Fuel Infrastructure TO BE DETERMINED | Amends Title I of the Petroleum Marketing Practices Act (15 U.S.C. 2801 et seq.) to prohibit future franchise agreements from containing any provisions that restricts the ability of stations to sell E85, B20, or renewable diesel, including installing a renewable fuel pump or tank, converting an existing tank or pump for renewable fuel use, advertising the sale of any renewable fuel, selling renewable fuel on the premises, purchasing renewable fuel, listing renewable fuel availability prices, and allowing for payment of renewable fuel with a credit card. Effective immediately. |
| Section 242 Reports on Market Penetration of FFVs and E85 Availability DOE,DOT | Requires annual reports to Congress on the market penetration of FFVs and a related bi-annual report on the feasibility of installing E85 infrastructure in areas where FFV penetration has reached 15%. Annual and bi-annual reporting effective immediately. |
| Section 243 Dedicated Ethanol Pipeline Feasibility Study DOE,DOT | Requires a study to assess the feasibility of ethanol pipelines including economics, market risk, existing or potential barriers, regulatory options to mitigate risk and other factors. 15 months from enactment. Requires appropriation. |
| Section 245 Biofuels Transportation Infrastructure Adequacy DOE,DOT | Requires a study of the adequacy of existing transportation modes for domestically produced biofuels. 180 days from enactment. |
| Section 248 Biofuels Distribution and Advanced Biofuels Infrastructure DOE,DOT,EPA | Authorizes a research, development, and demonstration program to test the physical and chemical properties of biofuels as they relate to existing and new distribution infrastructure. Timeline not specified. Requires appropriation. |
| Section 1131 Increased Federal Share for CMAQ Projects DOT, with state discretion | At the discretion of the state, for funds obligated in FY 2008 or 2009, the state share (20%) for Congestion Mitigation and Air Quality projects may be waived and the federal share may be up to 100% of the project cost. Effective FY2008 and 2009. |

*Source: U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center*

*Best Practices*

MoDOT has shared the spotlight with other DOTs showcased as an EPAct *Success Story* with biodiesel. Likewise for E85, there are strategies and policies from other states that encourage E85 usage in the FFVs, for example:

- All TxDOT employees who must drive to perform their jobs drive an alternative fuel vehicle (AFV) and the percentage of alternative fuel use within a district becomes part of the administrator's annual performance review. This is a strong incentive for the top official to influence individual AFV operators to use alternative fuel to the maximum extent.
- Washington D.C. has not only focused on AFV acquisition but also alternative fuel use. Dedicated AFVs are purchased when possible and a card key fueling system enforces 100% alternative fuel use in its FFVs and bi-fuel vehicles.
- The Illinois Department of Central Management Services gives agencies key tags for FFVs, provides decals for the FFV fuel doors, and distributes flyers with maps showing the locations of the E85 stations throughout the state.
- North Carolina Division of Motor Fleet Management has policy to allow state vehicle purchasers to trade in vehicles for FFVs at any time rather than waiting the standard 90,000 miles. This is only available for state entities committed to refueling with E85 where possible. Purchasing gasoline is only allowed when travelling where E85 is not available. To support this policy, North Carolina is focused on expanding their E85 availability.
- The Northland District of the U.S. Postal Service, which covers Minnesota and part of Wisconsin, reported that a successful alternative fuel program depends on having an accurate fuel tracking system. Managers and staff were educated on E85 goals and procedures to ensure the designated program will be cost effective. All FFVs are refueled with E85 when they return to the main fleet office. This practice is ensured by personnel at the main fleet office. All FFVs have fuel door decals and E85 fueling station maps.
- The state of Oregon has "Green Fleets". "Green Fleets" are a collection of vehicles and equipment and these fleets are managed by an organization that implements policy, programs and practices addressing the procurement, management and operations. The goal of fleet management is to improve energy efficiency and reduce emissions. They employ strategies including rightsizing vehicles to duties, implementing an anti-idling program as well as operating a 'green' maintenance shop.[4]

## Performance Findings

FFVs experience no loss in power and acceleration when operating on E85. Actually, the positive impact of using E85 is a substantially higher octane rating than today's gasoline, which means improved performance by way of greater horsepower. E85 has a 100+ octane rating resulting in a five to seven percent increase in engine horsepower. Switching back and forth between the fuel types presents no adverse effects either.

*Fuel Efficiency*

The Environmental Protection Agency has changed the way it estimates miles per gallon (MPG). Starting in model year 2008, estimates will reflect the effects of:

- Faster Speeds & Acceleration
- Air Conditioner Use
- Colder Outside Temperatures

[4] www.sustainableoregon.net/toolkit/green_fleet.cfm Retrieved July 30, 2008.

Consumer Reports indicates this change will benefit consumers; however, initially these lower numbers might be painful to see on the window stickers at the dealership. They tested a variety of vehicles with model years earlier than 2008 and their analysis showed that 90 percent of these vehicles returned worse MPG than the EPA estimates provided for each vehicle. This new system is closer to the results of Consumer Reports' real-world testing. With these new MPG ratings, overall fuel efficiency realized by drivers will now be better than what the EPA predicts on the stickers for some models. A comparison of the old and new MPG ratings is available at www.fueleconomy.gov.[5]

For this study, the MPG estimates were converted to the new ratings system to help compare the MPG of older and newer cars. Below is a summary of the estimated combined fuel efficiencies for MoDOT FFV fleet. The combined fuel efficiency values were assumed to be ten percent city and 90 percent highway driving. Reviewing MoDOT fleet data for the first three quarters of fiscal year 2007, this combination is the best fit when compared to actual MPG. FFVs may have different MPG estimates for different model years. In these cases, the most recent model year estimate is provided in Table 3 below. However, full details for each FFV year, make, and model are provided in Appendix B.

Table 3 – MoDOT Flex Fuel Vehicle Fleet Fuel Efficiencies as of FY08 (3rd Quarter)

| Vehicle Make | Model | MPG Estimated for E85 ONLY | MPG Estimated for Gasoline ONLY |
|---|---|---|---|
| Chevrolet | Impala | 22 | 30 |
| Chevrolet | Silverado 1500 | 15 | 18 |
| Dodge | Grand Caravan | 15 | 23 |
| Dodge | Ram 1500 | 10 | 14 |
| Dodge | Stratus | 18 | 24 |
| Ford | Explorer | 13 | 17 |
| Ford | Taurus | 18 | 24 |

*Source: MoDOT (2008)*

The reality with MoDOT and other fleets is that most FFVs do not run on one fuel exclusively. This may be due to convenience of fuel availability or driver habit. Some FFVs are operated with only gasoline. This prompts the question – does a FFV get have the same MPG estimate for gasoline as the non-flexible fuel or gasoline-only model of the same make and year?  The answer depends on the year, make and model. A review of the vehicle types currently represented in MoDOTs FFV fleet shows no dominant trends one way or the other. Some makes vary from one year to the next regarding which vehicle, FFV or gasoline-only, is estimated to have higher MPG with gasoline.

MoDOT provided fleet data from the first three quarters of fiscal year 2008.  The data includes the total vehicle miles traveled and the total gallons fuel (both gasoline and E85) recorded for each FFV upon refueling. The data collection method could not provide independent fuel efficiencies realized from E85 use (if any) versus choosing gasoline. Only overall quarterly totals were available rather than mileage between each refueling event noting the fuel choice. Therefore, actual fuel efficiencies could not be calculated for each FFV in this study. Instead, the percent of E85 fuel usage is calculated to show the impact of E85 fuel on MPG for each FFV in the fleet. Some vehicles were omitted

[5] www.consumerreports.org Retrieved July 30, 2008.

from the data set used for this analysis because they showed unrealistic fuel efficiencies (e.g. over 50 MPG). This was most likely caused by errors recording or inputting the data. However, these omissions account for well below ten percent of the total FFVs provided by MoDOT.

There are more than 330 FFVs included in this evaluation; therefore, the table providing the fuel efficiency calculations is provided in Appendix C. The fuel efficiencies calculated reflect the reality that E85 yields lower MPG. For example, an Impala in the fleet using just over 90 percent E85 got 23 MPG; however, another Impala that only fueled with gasoline got 31 MPG. The results in Appendix C illustrate how much fuel efficiency fluctuates. It is important to note that these fluctuations are NOT caused only by the fuel usage but there are other contributing factors like driving habits, traffic conditions, etc. In the first three quarters of fiscal year 2007, MoDOTs FFVs averaged approximately 20 MPG. At the low end, one Silverado 1500 achieved 8 MPG with 54% of its fuel being E85. At the high end, one Stratus achieved 35 MPG with 15% of its fuel being E85.

Because a gallon of ethanol contains 72 to 77 percent less energy than a gallon of gasoline, FFVs may get 20 to 30 percent fewer miles per gallon with E85[6]. This is confirmed with the combined fuel efficiency estimates for MoDOTs FFVs in Appendix C where the EPA MPG estimates for E85 and gasoline are shown for each FFV year, make and model. Fewer miles per gallon with E85 means more stops to refuel as compared to fueling with gasoline. Some E85 fuel efficiency loss is the result of automobile manufacturers optimizing performance for gasoline, even in FFVs. An increase in MPG with E85 could be realized if that was the goal of the automaker.

For future vehicle acquisitions, MoDOT may consult the U.S. Department of Energy's annual Fuel Economy Guide for MPG ratings on all FFVs each new model year. The preliminary version of the *2009 Fuel Economy Guide* is available at www.fueleconomy.gov/fed/download.shtml.

*Cold Starts*

In Colorado, cold start tests were performed on the early models of the flex-fueled and the standard gasoline Taurus. Manufacturers recommended practices were followed for the vehicles. A winter grade blend of the ethanol fuel was used – E70 (70% ethanol with 30% gasoline). Both the FFV and conventional Taurus started at -20°F when tested with gasoline. When the FFV Taurus was fueled with ethanol, it did not start at -20° or -15°F, but was successful at -10°F. Though this vehicle was equipped with an engine block heater, it was not in use for these tests. It was expected that using the heater would have resulted in successful starts at the colder temperatures.

In addition, the ethanol fueled Taurus out-performed the standard gasoline test vehicles at -10°F. It was observed that the FFV with E70 actually had a lower crank time (4 seconds) and a better idle rating (7 on a scale from 1 to 9 with 1 being the lowest rating) as compared to both the FFV with gasoline (9 seconds; idle rating 5) and the conventional model (8 seconds; idle rating 4.5). [7]

Operating ethanol powered vehicles in regions with seasonal climate shifts require different blends of the ethanol product. This is why states have labeling laws to display stickers as required by the Federal Trade Commission for E85 fuel that indicates 'Minimum 70% Ethanol'. Cars or trucks to be considered an alternative fuel vehicle (for tax incentives) must be able to operate on <u>up to</u> 85 percent ethanol. The ethanol fuel is seasonally adjusted for cold

[6] http://www.fueleconomy.gov/feg/flextech.shtml Retrieved July 30, 2008.

[7] http://www.nrel.gov/docs/fy99osti/26578.pdf This fact sheet was prepared by the National Renewable Energy Laboratory, a U.S. Department of Energy Laboratory operated by Midwest Research Institute • Battelle • Bechtel June 1999

weather to a blend less than 85 percent ethanol.[8] The more hydrocarbons in the fuel mean the lower the flash point to ignite the fuel when starting. A minimum of 70% by volume of alcohol is permitted in the winter blend by the ASTM fuel standard.[9]

Geography and season indicate the appropriate blend for FFVs. There are three volatility classes for ethanol (designated 1, 2, and 3). Class 1 is summertime E85, and needs to have a minimum of 79 percent ethanol (so even E85 doesn't have to be E85). Class 2's ethanol minimum is 74 and Class 3, wintertime ethanol, is 70 percent. In some parts of the country, Wyoming, for example, Class 3 is sold from October through May and Class 1 is sold only in July and August.[10] The Department of Energy's "Handbook for Handling, Storing and Dispensing E85" indicates the following volatility classes for Missouri as shown in the following table:

Table 4 – Volatility Class by Month for the Geographic Fuel-Marketing Region: Missouri

| Month | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class | 3 | 3 | 3 | 3/2 | 2/1 | 1 | 1 | 1 | 1/2 | 2/3 | 3 | 3 |

*Source: U.S. Department of Energy, Handbook for Handling, Storing, and Dispensing E85 (2006)*

“This seasonal blending from 15% to 30% gasoline limits concerns about winter cold starting and are similar to seasonal adjustments of volatility (vapor pressure) used in gasoline blending throughout the United States." [11] In addition, the Colorado vehicle tests provided a worst case frame of reference for winter temperatures and were performed with Taurus' – a vehicle commonly used in MoDOTs fleet. Missouri does not typically experience sustained winter temperatures below -10°F as was the case in Colorado. It can be deduced that Missouri should not have concerns for cold starts as long as the appropriate ethanol blend is used as indicated in Table 4.

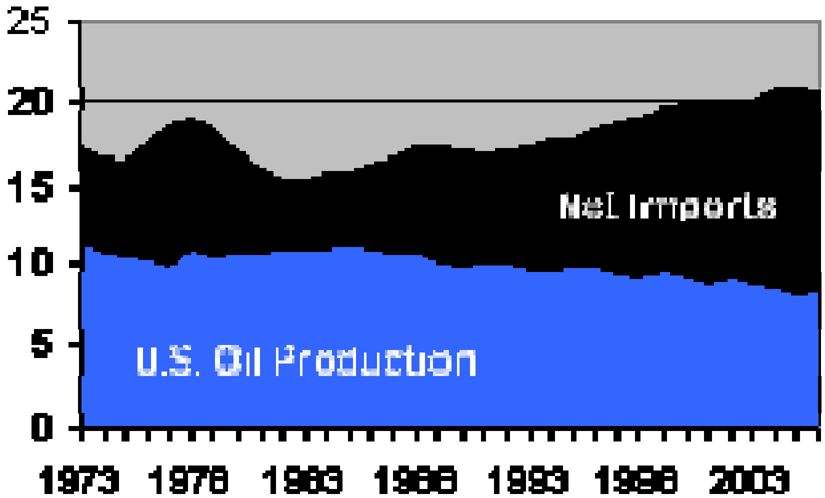
For MoDOT facilities with on-site storage tanks, it is important that the fuel supplier have proper test equipment and the ability to convert summer/winter blend automatically. If a fuel supplier delivers a summer-blended fuel in late fall, this could be the cause for slow starting in some of the FFVs[12]. The U.S. Department of Energy's *Handbook for Handling, Storing, and Dispensing E85* includes helpful guidelines and recommendations including E85 Specifications & Standards and Quality Assurance. Some quality checks may be performed on-site by MoDOT, but others may require laboratory services. The handbook and testing procedures may be found online in the E85 Fleet Toolkit at www.eere.energy.gov/afdc/e85toolkit/guidelines.html

[8] http://alternativefuels.about.com/od/ethanole85/a/flexfuelvehicle.htm Retrieved July 30, 2008.
[9] http://www.autobloggreen.com/2007/02/27/when-is-e85-not-85-percent-ethanol-when-its-e70-with-an-e85-st/ Retrieved July 30, 2008.
[10] http://www.autobloggreen.com/2007/02/27/when-is-e85-not-85-percent-ethanol-when-its-e70-with-an-e85-st/ Retrieved July 30, 2008.
[11] http://www.autobloggreen.com/2007/02/27/when-is-e85-not-85-percent-ethanol-when-its-e70-with-an-e85-st/ Retrieved July 30, 2008.
[12] http://www.eere.energy.gov/afdc/e85toolkit/lessons.html Retrieved July 30, 2008.

*Energy Impact*

Reducing the consumption of petroleum-based fuels is a goal for fleets across the country, not just in Missouri. As a policy decision, the use of E85 in fleet vehicles can reduce dependence on foreign oil. The U.S. Department of Energy reports that the U.S. consumes more than 20 million barrels of oil each day, 60 percent of which is imported. More relevant is the fact that is it is estimated that 68 percent of that petroleum fuel is used for transportation. This imported oil costs approximately $270 billion annually. Figure 1 shows the history of U.S. oil consumption:

Figure 1 – United States Petroleum Use from 1973 to 2006 (Million Barrels/Day)




*Source: EIA, Monthly Energy Review, July 2007*

The following graphic illustrates the effect of a single vehicle's consumption of petroleum-based fuel. This represents an average petroleum consumption for trucks and suvs used in MoDOTs fleet. By choosing to run a vehicle on alternative fuels the impact is real.


An Energy Impact Score depicts the number of barrels of petroleum that a given vehicle will likely consume each year[13]. Approximately 28 gallons of ethanol is one less barrel of oil, reducing demand for imported oil by almost 100,000 barrels per day. This reduces the U.S. trade deficit by billions. Renewable energy helps extend our fuel supply by adding volume to the fuel market[14].

Based on 10 percent city and 90 percent highway fuel efficiency estimates for each vehicle in the MoDOT FFV fleet, MoDOT vehicles have a potential to reduce annual petroleum consumption by more than 7,600 barrels/year. (See Appendix D for reductions contributed by each MoDOT FFV.) This was calculated by using the DOE Energy Impact

[13] U.S. Department of Energy, GREET Model, Argonne National Laboratory and U.S. petroleum statistics: U.S. DOE, Energy Information Administration (EIA). *Monthly Energy Review*, July 2007.

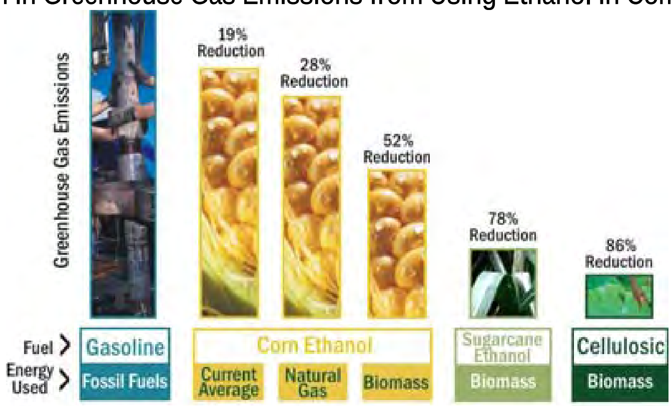
[14] http://www.iowacornethanol.com/1b.html Retrieved July 30, 2008.

Scores for each FFV year, make and model and multiplying by the number of that type of vehicle currently in the fleet. Individual Energy Impact Scores are in Appendix B.

*Greenhouse Gas Emissions (GHG)*

E85 has the highest oxygen content of all available fuels, so it burns more fully. In addition to the benefits of a cleaner burning fuel, the GHG emissions from the total life cycle of ethanol fuel are much less than those from gasoline. Today, on a life cycle basis, ethanol produced from corn results in about a 20 percent reduction in GHG emissions relative to gasoline. With improved efficiency and use of renewable energy, this reduction could be as much as 52 percent. In the future, ethanol produced from cellulose has the potential to cut life cycle GHG emissions by up to 86 percent relative to gasoline[15] as illustrated in Figure 2 below:

Figure 2 – Reduction in Greenhouse Gas Emissions from Using Ethanol in Comparison to Gasoline




Source: Wang et al, *Environmental Research Letters*, Vol. 2, 024001, May 22, 2007

The current MoDOT FFV fleet has the potential to reduce its carbon footprint by nearly 1,300 tons of CO2 by using E85 fuel rather than gasoline. (See Appendix D for reductions by FFV.) Ethanol blended fuels currently in the market meet stringent tailpipe emission standards. In addition, ethanol readily biodegrades without harm to the environment, and is a safe, high-performance replacement for fuel additives such as MTBE.

The U.S. Department of Energy dispels the myth that more energy goes into producing ethanol than it delivers as fuel. "In terms of fossil energy, each gallon of ethanol produced from corn today delivers one third or more energy than is used to produce it. Ethanol has a positive energy balance – that is, the energy content of ethanol is greater than the fossil energy used to produce it – and this balance is constantly improving with new technologies."

[15] http://www.doe.gov/media/biofuels_greenhouse_gases_myth_and_facts.pdf Retrieved July 30, 2008.

## Application to MoDOT's Fleet

The Missouri Energy Task Force provided recommendations in August 2006 for promoting the development of alternative fuel sources. Prior to that publication, MoDOT was reported as the lead state agency in the use of alternative fuels. MoDOT has been doing their part to support the proposed efforts to conserve energy, reduce dependence on foreign energy sources, and support Missouri agriculture.

Based on fleet data provided by MoDOT for fiscal year 2007, MoDOT had 6,446 vehicles. Of those, 715 or 11 percent were flexible fuel vehicles. Only 15 percent of the fuel consumed by FFVs was alternative fuel as shown in Table 5:

Table 5 – MoDOT Fleet Using Alternative Fuels

| Fuel Type | Gallons |
|---|---|
| Biodiesel | 5,365 |
| Ethanol | 36,226 |
| Other | 11,262 |
| Alternative Fuel Total | 52,853 |
| Diesel | 2,912 |
| Gasoline | 308,293 |
| Total Fuel FY07 | 364,058 |
| Percent Alternative Fuels | 15% |

*Source: MoDOT, 2007*

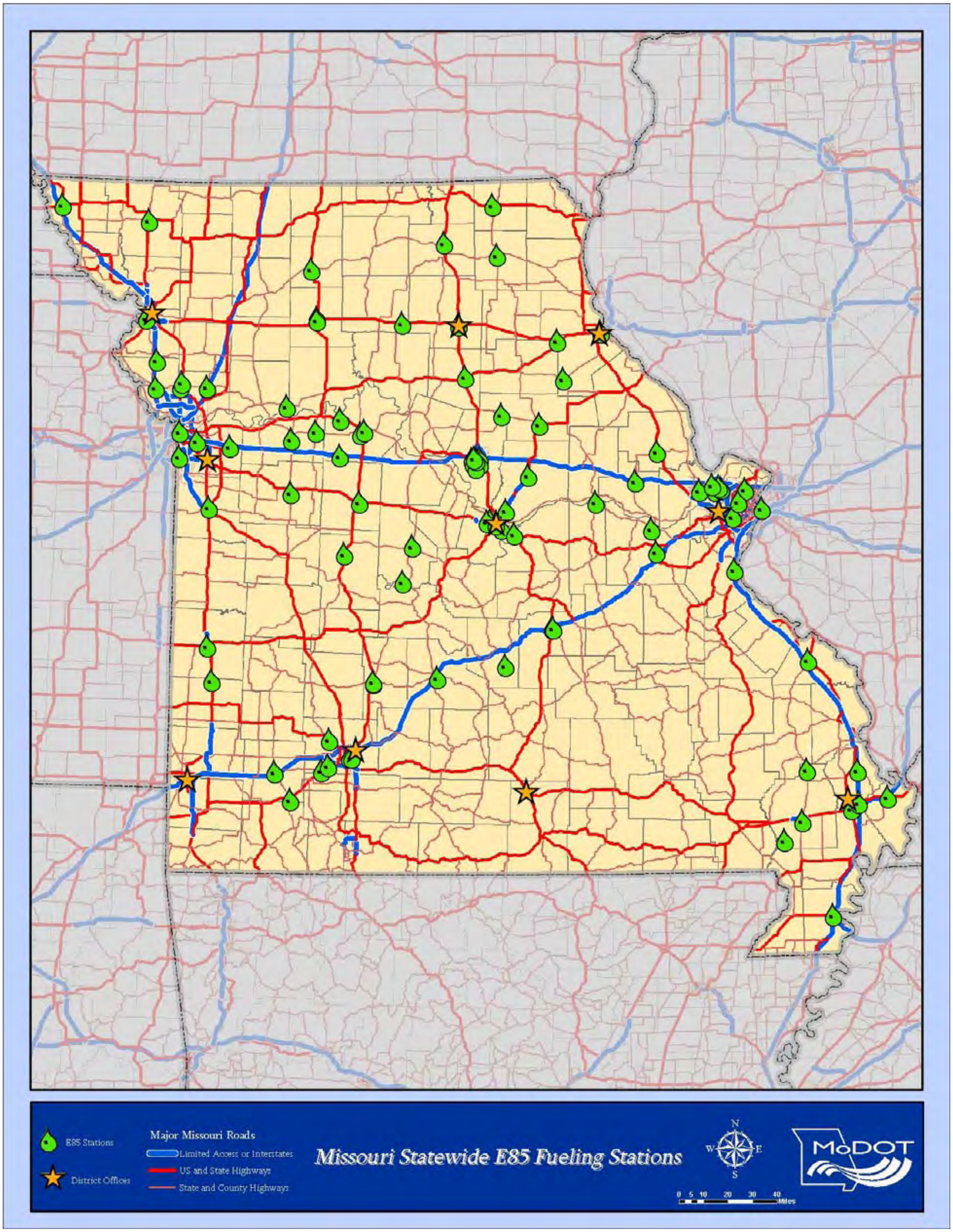
The caveat to the usage of E85 is typically whether or not such fuel is commercially available. One purpose of this research project is to relate availability of the fuel across the state, which is critical in determining the feasibility of serving the fleet within and traveling between all ten Districts and Headquarters.

### Access to E85

As of the close of the 2007 calendar year, there are 98 E85 station locations throughout Missouri with more than a half a dozen locations planned and not yet accessible[16]. Minnesota is nearing 400 locations ranking it number one for number of E85 stations; Missouri is fifth. Missouri's station locations have been mapped in conjunction with MoDOT facility locations on Figure 3.

[16] http://www.mocorn.org/Ethanol/e85.htm#fuelingLocations Retrieved July 30, 2008.

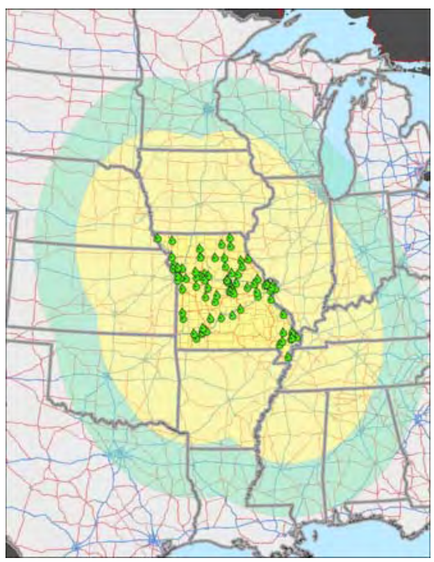
Figure 3 – E85 Station Locations



As shown in Figure 3, District 9 is located in an area with the fewest E85 stations. This is reflected by the few FFVs based there. However, travel from any district office or maintenance facility does not exceed minimum service range from current E85 stations. Access to E85 in Missouri is based on fuel efficiencies realized by MoDOT in the first three quarters of fiscal year 2008, as discussed earlier and documented in Appendix C. The fuel efficiencies (MPG) assumed ten percent city and 90 percent highway driving; multiplying the MPG by the vehicles fuel capacity (gallons) provided mileage per tank of fuel for each FFV. The minimum and maximum values provide the range of travel for MoDOTs fleet.

The Dodge Ram 1500 afforded the shortest range of 260 miles per tank of E85. Though the tank capacity is 26 gallons, the largest tank size, the combined fuel efficiency is only ten miles per gallon (MPG) with E85. 390 miles is the farthest distance provided by the Chevrolet Silverado 1500. The Silverado also carries 26 gallons of fuel capacity in its tank; however, its combined fuel efficiency is 15 MPG with E85. These minimum and maximum service ranges are shown in Figure 4:

Figure 4 – Maximum and Minimum Service Areas from Missouri's E85 Stations



As shown in Figure 4, the state of Missouri does have adequate E85 refueling opportunities should MoDOT choose to operate its fleet on E85 as a policy. Though it is geographically feasible at this time, the distribution of refueling opportunities still does not provide convenience. Trip planning is required to identify routes with access to E85 stations. There are station locators powered by Google that allow a driver to select one or more fuel types and enter their origin and destination such as http://www.eere.energy.gov/afdc/stations/find_route.php This route may not be the most efficient in terms of overall mileage. Additional miles travelled means additional gallons of fuel consumed.

Considerations for additional on-site E85 refueling locations are more involved than cost benefit calculations used in the private sector. Policy decisions for the use of E85 within the fleet will affect the benefit received from investing in bulk storage. For example, District 9 has the least conveniently accessible refueling opportunities; however, there may be a low return from their FFVs, based on fuel price and efficiency comparisons, as will be discussed later in this study—depending on the make and model of the FFVs in their fleet. In that case, the contribution of the District 9 fleet from an environmental perspective may not offer enough merit to investing in bulk storage. Other perspectives, such as policy requirements, may still justify development.

Education about, acceptance of and accessibility to E85 are key to the success of its use by MoDOT employees. MoDOT already provides E85 at some of its facilities. There is also a nationwide push for more gas stations to provide better public access. MoDOT use of public stations would increase demand for them. There may be opportunities for MoDOT to partner with the private sector or even other agencies as part of statewide expansion. E85 infrastructure projects can be daunting but the U.S. Department of Energy, Energy Efficiency and Renewable Energy suggests: [17]

- Contacting other fleet managers to compare lessons learned from operations similar to MoDOT. Appendix E contains a summary of fleet case studies and success stories as well as contact information for fleet managers.
- It is critical to any fueling station's success to have a dependable fuel supplier and a certified contractor familiar with E85. Although ethanol fuels are in wide use today, many old misconceptions remain. Contact Clean Cities coalitions (St. Louis and Kansas City) and the National Ethanol Vehicle Coalition for industry contacts familiar with E85, E85 suppliers, and partnership opportunities.
- Seek potential partners (public or private) that can share the expense of providing access to E85 fuel. A near-by fleet may also be interested in evaluating E85 fueling possibilities. A centrally located station, or a station at another fleet site to share fueling resources, is an option to consider at a fraction of the cost of providing fuel independently.

➨ Maintenance & Operations

Of vital importance before setting policy for alternative fuel use is the consideration of the long-term effects of such a decision on maintenance and operations. The current MoDOT fleet includes the following FFVs that offer the opportunity to use E85 fuel:

Table 6 – MoDOT Flex Fuel Vehicle Fleet as of FY08 (3rd Quarter)

| Model Years | Vehicle Make | Model |
|---|---|---|
| 2006,2007 | Chevrolet | Impala |
| 2003, 2004, 2005,2006 | Chevrolet | Silverado 1500 |
| 2001, 2002, 2003, 2006 | Dodge | Grand Caravan |
| 2004 | Dodge | Ram 1500 |
| 2003, 2004 | Dodge | Stratus |
| 2003, 2004, 2005 | Ford | Explorer |
| 1997,1998, 1999, 2000, 2001, 2002, 2004, 2005 | Ford | Taurus |

*Source: MoDOT (2008)*

[17] http://www.eere.energy.gov/afdc/e85toolkit/partnering.html Retrieved July 30, 2008.

E85 FFVs are engineered to run on blends of gasoline and ethanol in any percentage up to 85 percent in a single tank. Special onboard diagnostics "read" the fuel blend, so there are no switches to flip, no mixing or blending. The Powertrain Control Module automatically adjusts fuel injection and ignition timing to compensate for the different fuel mixtures. This makes using E85 “transparent” to the driver.

The fuel sensor that detects the ethanol/gasoline ratio is the only major additional part included on flex-fueled vehicles. A number of other parts on FFVs fuel delivery systems—fuel tank, fuel lines, fuel injectors, computer system, anti-siphon device, and dashboard gauges—are slightly modified so they are ethanol compatible. Because alcohols are corrosive the parts in contact with ethanol have been upgraded, like stainless steel fuel tanks and Teflon lined fuel hoses.

Data gathered by other states report negligible differences in general maintenance costs between E85 vehicles and gasoline counterparts. Studies indicate maintenance costs may be reduced for FFVs because of the way E85’s cleaner exhaust emission impacts engine operation and performance. [18]

### Cost Comparison

Annual fuel costs to operate the MoDOT FFVs are included in Appendix B. These were based on the assumptions of ten percent city and 90 percent highway driving, 15,000 annual miles and recent fuel prices of $3.89 per gallon of gasoline and $3.05 per gallon of E85. These annual fuel costs are a single snap shot of a scenario with multiple variables that change at different rates. While these values could be used as a benchmark for operating costs, a more practical measure is one that may be applied by each driver when faced with a decision at the pump.

MoDOT FFVs are fueled from zero to 100 percent with E85 fuel depending on the vehicle. As mentioned previously, the ratio of E85 to gasoline impacts the fuel efficiency of any given vehicle in addition to the variations from one make and model to the next. Changes between individual driver habits and vehicle use in the field can yield MPG far greater or less than those estimated for the vehicle. Tank capacity is not consistent throughout the fleet, which also contributes to the inability to accurately average annual fuel costs for the entire fleet. Each vehicle must be evaluated separately.

The most obvious and significant variable in these calculations is the dynamic nature of fuel prices. E85 and gasoline do not inflate at the same rate. Table 7 notes recent fuel prices in the state of Missouri during 2008 (January through July). This sampling of actual fuel costs reported by consumers may include more than one report on a single date from a different location in the state. Table 7 illustrates the variation in the costs per gallon of E85 as compared to gasoline as well as the price spread ranging from six to 26 percent:

[18] http://www.constructionbusinessowner.com/topics/environment-and-compliance/consider-energy-and-environmental-costs-when-making-fleet-decisions.html Retrieved July 30, 2008.

Table 7 – Price Spreads Reported between E85 and Gasoline Costs per Gallon

| E85 Price | Gas Price | Price Spread | Date Reported | E85 Price | Gas Price | Price Spread | Date Reported | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $2.34 | $2.99 | 22% | 5-Jan | $3.09 | $3.79 | 18% | 23-May | $3.21 | $3.79 | 15% | 28-Jun |
| $2.44 | $2.99 | 18% | 7-Jan | $3.08 | $3.76 | 18% | 23-May | $3.09 | $3.92 | 21% | 30-Jun |
| $2.34 | $2.89 | 19% | 23-Jan | $3.15 | $3.75 | 16% | 23-May | $3.19 | $3.89 | 18% | 30-Jun |
| $2.47 | $2.80 | 12% | 1-Feb | $3.08 | $3.76 | 18% | 24-May | $3.19 | $3.97 | 20% | 2-Jul |
| $2.44 | $2.89 | 16% | 28-Feb | $3.17 | $3.79 | 16% | 26-May | $3.37 | $3.95 | 15% | 2-Jul |
| $2.44 | $2.99 | 18% | 29-Feb | $3.17 | $3.75 | 15% | 26-May | $3.09 | $3.88 | 20% | 3-Jul |
| $2.52 | $3.04 | 17% | 18-Mar | $3.17 | $3.72 | 15% | 30-May | $3.15 | $3.93 | 20% | 3-Jul |
| $2.49 | $3.09 | 19% | 21-Mar | $3.11 | $3.87 | 20% | 31-May | $3.26 | $3.92 | 17% | 3-Jul |
| $2.49 | $3.09 | 19% | 24-Mar | $3.39 | $3.89 | 13% | 31-May | $3.21 | $3.79 | 15% | 4-Jul |
| $2.79 | $3.14 | 11% | 3-Apr | $3.11 | $3.87 | 20% | 1-Jun | $3.09 | $3.98 | 22% | 6-Jul |
| $2.64 | $3.29 | 20% | 19-Apr | $3.15 | $3.89 | 19% | 2-Jun | $3.27 | $3.97 | 18% | 6-Jul |
| $2.74 | $3.39 | 19% | 21-Apr | $3.09 | $3.72 | 17% | 2-Jun | $3.39 | $3.83 | 11% | 6-Jul |
| $2.99 | $3.48 | 14% | 22-Apr | $3.07 | $3.75 | 18% | 4-Jun | $3.62 | $3.98 | 9% | 7-Jul |
| $2.69 | $3.37 | 20% | 24-Apr | $2.99 | $3.72 | 20% | 5-Jun | $3.09 | $3.95 | 22% | 8-Jul |
| $3.12 | $3.47 | 10% | 25-Apr | $3.09 | $3.90 | 21% | 6-Jun | $3.39 | $3.95 | 14% | 8-Jul |
| $2.99 | $3.59 | 17% | 26-Apr | $3.05 | $3.89 | 22% | 10-Jun | $3.09 | $3.92 | 21% | 9-Jul |
| $2.79 | $3.49 | 20% | 28-Apr | $3.06 | $3.90 | 22% | 12-Jun | $3.50 | $3.93 | 11% | 9-Jul |
| $2.99 | $3.53 | 15% | 4-May | $3.06 | $3.89 | 21% | 12-Jun | $3.15 | $3.88 | 19% | 11-Jul |
| $3.11 | $3.31 | 6% | 5-May | $3.31 | $3.93 | 16% | 12-Jun | $3.19 | $3.98 | 20% | 12-Jul |
| $3.15 | $3.35 | 6% | 5-May | $3.23 | $3.83 | 16% | 13-Jun | $3.21 | $3.79 | 15% | 12-Jul |
| $2.69 | $3.63 | 26% | 8-May | $3.16 | $3.78 | 16% | 13-Jun | $3.39 | $3.99 | 15% | 12-Jul |
| $3.08 | $3.54 | 13% | 8-May | $2.99 | $3.85 | 22% | 14-Jun | $3.63 | $3.99 | 9% | 12-Jul |
| $3.29 | $3.62 | 9% | 8-May | $3.09 | $3.86 | 20% | 17-Jun | $3.15 | $3.92 | 20% | 14-Jul |
| $2.89 | $3.69 | 22% | 9-May | $3.27 | $3.87 | 16% | 18-Jun | $3.39 | $3.98 | 15% | 15-Jul |
| $2.89 | $3.62 | 20% | 13-May | $3.09 | $3.99 | 23% | 19-Jun | $3.19 | $3.90 | 18% | 16-Jul |
| $2.99 | $3.69 | 19% | 13-May | $3.09 | $3.84 | 20% | 21-Jun | $3.27 | $3.87 | 16% | 16-Jul |
| $2.69 | $3.56 | 24% | 17-May | 3.09 | $3.84 | 20% | 22-Jun | $3.39 | $3.96 | 14% | 17-Jul |
| $3.14 | $3.68 | 15% | 19-May | $3.49 | $3.92 | 11% | 24-Jun | $3.16 | $3.88 | 19% | 18-Jul |
| $3.09 | $3.69 | 16% | 20-May | $3.09 | $3.86 | 20% | 25-Jun | $3.37 | $3.95 | 15% | 2-Jul |
| $3.09 | $3.79 | 18% | 21-May | $3.09 | $3.84 | 20% | 27-Jun | $3.09 | $3.88 | 20% | 3-Jul |
| $3.30 | $3.69 | 11% | 21-May | $3.19 | $3.88 | 18% | 28-Jun | $3.15 | $3.93 | 20% | 3-Jul |

*Source: http://e85prices.com/missouri.html*

E85 costs less but yields fewer miles per gallon compared to gasoline. The following analysis determines the breakeven point at which E85 becomes cost effective for each FFV. (A sample of FFV types with corresponding fuel tank capacity and estimated MPG is evaluated at a range of price points to determine the percent spread between costs per gallon. This analysis accounts for the specifications of each fleet vehicle.) Table 8 summarizes the findings for vehicle sample:

Table 8 – Price Spread for E85 to be the Economical Choice

| Year | Make | Model | MPG Estimated for E85 ONLY | MPG Estimated for Gasoline ONLY | MPG Difference | **Price Spread** |
|---|---|---|---|---|---|---|
| 2006 | Chevrolet | Impala | 20 | 27 | 7 | 26% |
| 2007 | Chevrolet | Impala | 22 | 30 | 8 | 27% |
| 2004 | Chevrolet | Silverado 1500 | 13 | 17 | 4 | 23% |
| 2005 | Chevrolet | Silverado 1500 | 12 | 16 | 4 | 25% |
| 2003 | Chevrolet | Silverado 1500 | 13 | 17 | 4 | 23% |
| 2005/2006 | Chevrolet | Silverado 1500 | 15 | 18 | 3 | 17% |
| 2001/2002 | Dodge | Grand Caravan | 15 | 21 | 6 | 29% |
| 2003/2006 | Dodge | Grand Caravan | 15 | 23 | 8 | 35% |
| 2004 | Dodge | Ram 1500 | 10 | 14 | 4 | 28% |
| 2003/2004 | Dodge | Stratus | 18 | 24 | 6 | 25% |
| 2004 | Ford | Explorer | 14 | 18 | 4 | 22% |
| 2005 | Ford | Explorer | 13 | 17 | 4 | 23% |
| 2000-05 | Ford | Taurus | 18 | 24 | 6 | 25% |
| 2000 | Ford | Taurus SE | 18 | 25 | 7 | 28% |

*Source: TranSystems*

Multiple model years for the same FFV make and model are included in Table 8 to show how slight changes to MPG impact the percent difference in cost of E85 as compared to gasoline. Comparing the spread to the history illustrated in Table 7, the actual price spread varied from six to 24 percent thus far in 2008. This indicates it is likely that prices will vary such that it may be more cost effective to fuel the majority of the fleet with E85. The newer Silverado 1500s only require a 17 price spread to be fueled most cost effectively with E85. There are some vehicles that require a cost differential that has yet to be achieved. The worst case is the Dodge Grand Caravan. This FFV would require a price spread greater than 35 percent for E85 to be a cost effective choice; this is unlikely. That is not to say that changes in demand and industry production won't impact pricing such that these greater spreads could be realized in the future. This analysis presents the feasibility of considering cost effectiveness of E85 a viable factor for fleet fueling policies. These values strive for the optimal breakeven point based purely on the cost of fuel per mile driven; however, lesser price comparisons may be desired and achievable.

Drivers can make cost effective decision at the pump if educated on these price spread requirements. Data specific to the vehicle's year/make/model may be provided in each FFV to be used as a quick reference to determine the best fuel choice whenever refueling. The most user friendly option would function similar to a tip calculator used by restaurant patrons. A matrix could provide a cross reference for potential gasoline prices per gallon to determine the E85 price per gallon threshold for a cost effective purchase. Local decision makers can use this information when setting policy for E85 use in FFVs.

This analysis considers the cost effectiveness of fueling MoDOT's fleet with E85; however, this can be just one element of a total fueling policy that balances the goals to conserve energy, reduce dependence on foreign energy sources, lower greenhouse gas emissions and support Missouri agriculture with the annual costs of operations. Using the District 9 example; their fleet consists of Stratus and Taurus FFVs, which require a spread of at least 25 percent. This is just beyond the highest price spread experienced thus far. Consideration of the reality of experiencing that cost spread and the environmental impact potential of E85 use for their size of fleet, relative to the entire MoDOT FFV fleet, may not be enough to justify on-site tanks to facilitate any policies for predominant E85 use. District specific decisions can account for the net positive impact of an E85 strategy to determine the best fit.

## Summary of Findings

Having access to E85 fuel across the state makes it possible for decision makers to consider environmentally friendly policies in Missouri with measurable results. E85 presents the challenge of balancing the tremendous environmental benefits against fuel efficiency loss. Realizing lesser MPG in the FFVs fueled by E85 diminishes the return perceived from a lower price per gallon at the pump as compared to gasoline. Cost effective fleet operations are in mind when the study evaluates the breakeven point that considers both fuel efficiency and cost per gallon. Given the feasibility of operating FFVs on E85 in Missouri, decision makers may start by evaluating the cost comparisons and then incorporate environmental considerations to set policy. Make and model analysis illustrates vast differences to be considered in future vehicle purchases. For example, consider what has been presented for the Chevy Silverado 1500 versus the Dodge Grand Caravan. The Silverado 1500 can be cost effectively fueled with E85 with a price spread of only 17%; however, gasoline would be the preferred fuel for the Dodge Grand Caravan based on the same cost comparison analysis. Fueling the Grand Caravan exclusively with gasoline would not offer a reduction in GHG or oil consumption; however, there are less than 10 of these FFVs in MoDOTs fleet. Meanwhile there are over 250 Silverado 1500 FFVs in the fleet that are currently being fueled predominantly with gasoline. Not only would fueling the 1500s with E85 be more cost effective at today's prices but the environmental impacts realized from the reduction in the carbon footprint (>660 tons of $CO_2$) and the consumption of oil (>3,500 barrels/year) are significant. This would clearly offset the potential loss of choosing the less environmentally friendly option to operate the Grand Caravan on gasoline. The Grand Caravan FFVs collectively would have only contributed a reduction of < 8 tons of $CO_2$ and < 83 barrels/year. This analysis suggests that policy may not be applicable for the entire fleet but rather a consideration for each make and model and its comparative contribution as a fraction of the entire fleet. In addition, there may be policy determinations by district based on their FFV fleet composition (e.g. makes and models), trip planning requirement for refueling and district contribution to the overall environmental goals for the state. State and District leadership may consider the impact of district level policies on overall fleet operations and policy may affect strategic decisions like FFV district assignments or considerations for additional on-site bulk storage of E85.

The following summarizes the general E85 findings and the potential implications of E85 use by MoDOTs FFV fleet:

- FFVs experience no loss in power and acceleration when operating on E85. Performance actually improves with a 5-7% increase in engine horsepower.
- Fuel efficiency may be 20-30% fewer MPG when FFVs are fueled with E85, depending on the year/make/model of the vehicle and other factors (e.g. driver habits, traffic conditions).
- Using seasonal E85 blends, as recommended for Missouri by the U.S. Department of Energy, should eliminate E85 cold start problems.
- Maintenance cost differences between E85 FFVs and their gasoline counterparts are negligible and may actually be reduced for FFVs using E85 because it is a cleaner fuel.
- If fueled with E85, MoDOTs current FFV fleet could reduce petroleum consumption by more than 7,600 barrels per year and GHG emissions by nearly 1,300 tons of $CO_2$ per year.
- The service areas of the 98 E85 (as of December 2007) in Missouri provide adequate refueling opportunities should MoDOT choose to require E85 usage in its FFV fleet.
- For most of MoDOTs current FFVs, there is a realistic price spread at which E85 is more cost effective.

# Side-By-Side Comparison of Alternative Fuels

Provided by

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Alternative Fuels & Advanced Data Center

http://www.eere.energy.gov/afdc/progs/fuel_compare.php

Table 1 (Continued) – Side-By-Side Comparison of Alternative Fuels

| | Gasoline | No. 2 Diesel | Biodiesel | Compressed Natural Gas(CNG) | Electricity | Ethanol | Hydrogen | Liquefied Natural Gas (LNG) | Liquefied Petroleum Gas (LPG) | Methanol |
|---|---|---|---|---|---|---|---|---|---|---|
| Pump Octane Number | 84-93 | N/A | N/A | 120+ | N/A | 110 | 130+ | 120+ | 105 | 112 |
| Main Fuel Source | Crude Oil | Crude Oil | Fats and oils from sources such as soy beans, waste cooking oil, animal fats, and rapeseed | Underground reserves | Coal, nuclear, natural gas, hydroelectric, and small percentages of wind and solar. | Corn, grains, or agricultural waste (cellulose) | Natural gas, methanol, and electrolysis of water. | Underground reserves | A by-product of petroleum refining or natural gas processing | Natural gas, coal, or, woody biomass |
| Energy Content (Lower Heating Value) | 116,090 Btu/gal | 128,450 Btu/gal | 119,550 Btu/gal for B100 | 20,268 Btu/lb | 3,414 Btu/kWh | 76,330 Btu/gal for E100 | 51,585 Btu/lb | 74,720 Btu/gal | 84,950 Btu/gal | 57,250 Btu/gal |
| Energy Content (Higher Heating Value) | 124,340 Btu/gal | 137,380 Btu/gal | 127,960 Btu/gal for B100 | 22,453 Btu/lb | 3,414 Btu/kWh | 84,530 Btu/gal for E100 | 61,013 Btu/lb | 84,820 Btu/gal | 91,410 Btu/gal | 65,200 Btu/gal |
| Energy Comparison (Percent of Gasoline Energy) | 100% | 111% | B100 has 103% the energy of gasoline or 93% of diesel. B20 has 109% of gasoline or 99% of diesel | 1 lb CNG has 17.5% the energy of 1 gal gasoline. | 1 kWh electricity contains 3% of the energy in 1 gal gas | E100 contains 66%, E85 contains 72% to 77% | 1lb H2 has 44.4% the energy in one gallon gasoline | 64% | 73% | 49% |
| Environmental Impacts of Burning Fuel | Produces harmful emissions; however, gasoline and gasoline vehicles are improving and emissions are being reduced. | Diesel vehicles have been engineered to reduce risks. Diesel is not biodegradable, so spills pollute soil and water. | Reduces hydrocarbons, toxic compounds, CO, particulate matter, and global warming gases. Has uncertain impact on NOx. | Compared to reformulated gasoline, CNG emits less (and less reactive) ozone-forming pollutants, hydrocarbons (including potency-weighted toxics), CO, formaldehyde, and acetaldehyde. Only methane emissions were increased by the use of CNG. | EVs have zero tailpipe emissions; however, most electricity production emits pollution. | E85 vehicles reduce global warming gases. Tests have also shown that E85 reduces NOx and the toxics benzene and 1, 3-butadiene compared to reformulated gasoline, yet increases formaldehyde and acetaldehyde emissions. | Zero regulated tailpipe emissions for fuel cell vehicles, however, pollutants are emitted from hydrogen production. | Considered similar to CNG--compared to reformulated gasoline, it emits less (and less reactive) ozone-forming pollutants, hydrocarbons (including potency-weighted toxics), CO, formaldehyde, and acetaldehyde. Only methane emissions were increased by the use of LNG. | Compared to gasoline, LPG reduces CO by 20%, total hydrocarbons by 40%, and NOx by 30%. | When compared to reformulated gasoline, M85 emitted fewer (and less reactive) ozone forming pollutants, hydrocarbons, and potency-weighted toxics (including acetaldehyde, benzene, 1, 3-butadiene.) However, it also emitted more NOx and formaldehyde. |

Table 1 (Continued) – Side-By-Side Comparison of Alternative Fuels

| | Gasoline | No. 2 Diesel | Biodiesel | Compressed Natural Gas(CNG) | Electricity | Ethanol | Hydrogen | Liquefied Natural Gas (LNG) | Liquefied Petroleum Gas (LPG) | Methanol |
|---|---|---|---|---|---|---|---|---|---|---|
| Energy Security Impacts | Manufactured using oil, of which nearly is 2/3 imported. | Manufactured using oil, of which nearly is 2/3 imported. | Biodiesel is domestically produced, renewable, and reduces petroleum use 95% throughout its lifecycle. | CNG is domestically produced. The United States has vast natural gas reserves. | Electricity is generated mainly through coal fired power plants. Coal is the United States' most plentiful and price-stable fossil energy resource. | Ethanol is produced domestically. E85 reduces lifecycle petroleum use by 70% and E10 reduces petroleum use by 6.3%. | Hydrogen is produced domestically and can be produced from renewable sources. | LNG is domestically produced. | Approximately half of the LPG in the U.S. is derived from oil, but no oil is imported specifically for LPG production. | Methanol is domestically produced, sometimes from renewable resources. |
| Fuel Availability | Available at all fueling stations. | Available at many fueling stations. | Available at an increasing number of retail stations. Nearly 653 stations in 45 states offer blends of at least 20% biodiesel. Also available in bulk from an increasing number of suppliers. | Available at an increasing number of retail stations (784 in 45 states). Home refueling appliances also available. | Most buildings have adequate electrical capacity for charging, but special hookup or upgrades may be required. Decreasing numbers of electrical charging stations are available in 14 states. | E85 available at an increasing number of retail stations (nearly 1500 in 43 states). The majority are in the Midwest, with 1/4 of all stations in Minnesota. | There are only 37 hydrogen stations across the country. Most are in California and available for private use only. | Public LNG stations are limited (only 47 nationally), LNG is also available through several suppliers of cryogenic liquids. | LPG/Propane is the most accessible alternative fuel in the U.S. There are more than 2,240 stations nationwide. | Methanol remains a qualified alternative fuel as defined by EPAct, but it is not commonly used or easily available. |
| Maintenance Issues | | | Hoses and seals may be affected by higher-percent blends; lubricity is improved over that of conventional diesel fuel. | High-pressure tanks require periodic inspection and certification. | Service requirements are less than with gasoline or diesel. No tune-ups, oil changes, timing belts, water pumps, radiators, or fuel injectors are required. However, it is likely that the battery will need replacement before the vehicle is retired. | Practices are very similar, if not identical, to those for conventionally fueled operations. | When hydrogen is used in fuel cell applications, maintenance should be very minimal. | High-pressure tanks require periodic inspection and certification. | Some fleets report service lives that are 2-3 years longer, as well as extended intervals between required maintenance. | Special lubricants must be used as directed by the supplier and M-85-compatible replacement parts must be used. |
| Safety Issues (All alternative fuel vehicles must meet today's OEM Safety Standards) | Gasoline is highly flammable, but vehicles have been engineered to reduce risks. Gasoline is not biodegradable, so spills pollute soil and water. | Diesel is a relatively safe fuel since people have learned to use it safely. Diesel is not biodegradable though, so a spill could pollute soil and water. | B100 is non-toxic and biodegradable. Furthermore, it doesn't ignite as easily as diesel fuel. | Pressurized tanks have been designed to withstand severe impact and high external temperatures. Leakage can present a hazard, but can usually be detected because an odorant is added to CNG. | OEM EVs meet all the same vehicle safety standards as conventional vehicles. However, under FMVSS 500, neighborhood electric vehicles (NEV) are exempt from safety crash testing and the airbag requirements. | Ethanol is less toxic than gasoline. Ethanol vapors disperse more rapidly than gasoline, lowering concentrations to safe levels more quickly after an accident. | Hydrogen has an excellent industrial safety record; codes and standards have now been developed for fuel cell vehicle systems and components to reduce risks. | Cryogenic fuels require special handling procedures and equipment to properly store and dispense. Leak detectors must be used because odorants cannot be added to LNG. | Adequate ventilation is important for fueling an LPG-fueled vehicle due to increased flammability of LPG. LPG tanks are 20 times more puncture resistant than gasoline tanks. | Methanol is extremely toxic. Exposure can occur through inhalation of vapors or through skin contact. |

# Fleet Vehicle Data Sheets

Provided by

U.S. Department of Energy
Energy Efficiency and Renewable Energy
&
U.S. Environmental Protection Agency

http://www.fueleconomy.gov/feg/

# 2000 Ford Taurus

**Flex-fuel Vehicle**
Use Your Gas Prices & Annual Miles

Switch to Metric units

*Compare side-by-side*

## Estimated New EPA MPG

MPG ratings for this vehicle have been revised

| | E85 | | | Gasoline | |
|---|---|---|---|---|---|
| 12 | 18 Combined | 19 | 17 | 25 Combined | 26 |
| City | | Hwy | City | | Hwy |

Compare to Official EPA Window Sticker MPG

## MPG Estimates from Drivers Like You

Learn more about "Your MPG"

**Average based on 8 vehicles.**

**21.1**

Lo **17** → Hi **25**

View Individual Estimates

Disclaimer

## Fuel Economics

| | E85 | Gasoline |
|---|---|---|
| **Cost to Drive 25 Miles** | **$4.24** | **$3.89** |
| **Fuel to Drive 25 Miles** | 1.39 gal | 1.00 gal |
| **Annual Fuel Cost*** | $2542 | $2334 |

Based on 90% highway, 10% city driving, 15000 annual miles and a fuel price of $ 3.89 per gallon of gasoline and $3.05 per gallon of E85 . Use Your Gas Prices & Annual Miles

## Energy Impact Score

| | E85 | Gasoline |
|---|---|---|
| **Annual Petroleum Consumption** (1 barrel=42 gallons) | 4.4 barrels/year | 13.7 barrels/year |

## Carbon Footprint

| | E85 | Gasoline |
|---|---|---|
| **Annual Tons of $CO_2$ Emitted** | 6.2 | 7.3 |

Personalize Annual Miles

3.2 14.3 3.2 14.3

## EPA Air Pollution Score

**Air Pollution Score** Not Available

# 2007 Chevrolet Impala

**Flex-fuel Vehicle**
Use Your Gas Prices & Annual Miles

Switch to Metric units

*Compare side-by-side*

## Estimated New EPA MPG

MPG ratings for this vehicle have been revised

| E85 City | E85 Combined | E85 Hwy | Gasoline City | Gasoline Combined | Gasoline Hwy |
|---|---|---|---|---|---|
| 14 | 20 | 21 | 18 | 27 | 28 |

## Official EPA Window Sticker MPG

| E85 City | E85 Combined | E85 Hwy | Gasoline City | Gasoline Combined | Gasoline Hwy |
|---|---|---|---|---|---|
| 16 | 22 | 23 | 21 | 30 | 31 |

## MPG Estimates from Drivers Like You

Learn more about "Your MPG"

Average based on 7 vehicles.

**25.6**

Lo 21 → Hi 35

View Individual Estimates

Disclaimer

## Fuel Economics

| | E85 | Gasoline |
|---|---|---|
| Cost to Drive 25 Miles | $3.81 | $3.60 |
| Fuel to Drive 25 Miles | 1.25 gal | 0.93 gal |
| Cost of a Fill-up | $46.66 | $59.52 |
| Miles on a Tank | 306 miles | 413 miles |
| Tank Size | 17.0 gal | 17.0 gal |
| Annual Fuel Cost* | $2288 | $2161 |

Based on 90% highway, 10% city driving, 15000 annual miles and a fuel price of $ 3.89 per gallon of gasoline and $3.05 per gallon of E85 . Use Your Gas Prices & Annual Miles

## Energy Impact Score

**Annual Petroleum Consumption** (1 barrel=42 gallons)

| | E85 | Gasoline |
|---|---|---|
| Annual Petroleum Consumption |  4.0 barrels/year |  12.7 barrels/year |

## Carbon Footprint

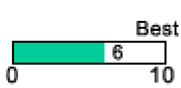
| | E85 | Gasoline |
|---|---|---|
| Annual Tons of $CO_2$ Emitted | 5.6 | 6.8 |

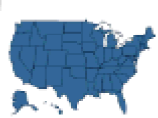
Personalize Annual Miles



## EPA Air Pollution Score

Air Pollution Score



# 1997 Ford Taurus

Use Your Gas Prices & Annual Miles

Switch to Metric units

Compare side-by-side

## Estimated New EPA MPG

**REGULAR GASOLINE**

| City | Combined | Hwy |
|---|---|---|
| 17 | 24 | 26 |

**MPG ratings for this vehicle have been revised**

**Compare to Official EPA Window Sticker MPG**

## MPG Estimates from Drivers Like You

**Average based on 4 vehicles.**

**24.2**

Lo **22** → Hi **26**

View Individual Estimates

**Learn more about "Your MPG"**

Disclaimer

## Fuel Economics

| | |
|---|---|
| **Cost to Drive 25 Miles** | **$4.05** |
| **Fuel to Drive 25 Miles** | 1.04 gal |
| **Annual Fuel Cost*** | $2431 |

Based on 90% highway, 10% city driving, 15000 annual miles and a fuel price of $ 3.89 per gallon . Use Your Gas Prices & Annual Miles

## Energy Impact Score

**Annual Petroleum Consumption**
(1 barrel=42 gallons)

**14.3 barrels/year**

## Carbon Footprint

**Annual Tons of $CO_2$ Emitted** 7.7

Personalize Annual Miles

3.2 — 14.3

## EPA Air Pollution Score

**Air Pollution Score** Not Available

## 1998 Ford Taurus

Use Your Gas Prices & Annual Miles

Switch to Metric units

*Compare side-by-side*

### Estimated New EPA MPG

**REGULAR GASOLINE**

**MPG ratings for this vehicle have been revised**

**23** Combined

**17** City

**24** Hwy

**Compare to Official EPA Window Sticker MPG**

### MPG Estimates from Drivers Like You

User MPG estimates are not yet available for this vehicle.

**Learn more about "Your MPG"**

### Fuel Economics

| | |
|---|---|
| **Cost to Drive 25 Miles** | **$4.23** |
| **Fuel to Drive 25 Miles** | 1.09 gal |
| **Annual Fuel Cost*** | $2537 |

Based on 90% highway, 10% city driving, 15000 annual miles and a fuel price of $ 3.89 per gallon . Use Your Gas Prices & Annual Miles

### Energy Impact Score

**Annual Petroleum Consumption**
(1 barrel=42 gallons)

**14.9 barrels/year**

### Carbon Footprint

**Annual Tons of $CO_2$ Emitted**

8.0

Personalize Annual Miles


### EPA Air Pollution Score

**Air Pollution Score**

Not Available