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IS THE GASOLINE GALLON EQUIVALENT AN ACCURATE MEASURE OF MILEAGE FOR ETHANOL AND METHANOL FUEL BLENDS?

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Abstract

This study investigated whether or not the gasoline gallon equivalent (GGE), a unit that compares fuel-economy based solely on the fuel energy content, is an accurate measure of the fuel economy of ethanol and methanol fuel blends. Data was collated from several separate reports that tested 2011 flex fuel vehicles (FFV), 2007-2009 vehicles that had their engine control modules (ECMs) optimized to run on alcohol fuels by tuning their software, and a 2012 non-FFV Chevrolet Traverse that was also optimized for alcohol fuels. In all cases no other physical changes were made to the engine or fuel injection system. All alcohol fuel blends in optimized vehicles consistently achieved better miles per gallon than estimated by the GGE. While further testing is needed, these results lead us to believe that the GGE undervalues the fuel economy of alcohol fuels in optimized vehicles even when using existing engine technology. **The significance of these findings is that current well-to-wheel emissions models, such as GREET, significantly overstate the emissions and greenhouse gas implications of alcohol fuels compared with well-to-wheel emissions of gasoline.**

Contents

Introduction

The gasoline gallon equivalent (GGE) is a primary measure for comparing fuel economy of vehicles running on alternative fuels with the fuel economy of vehicles running on regular gasoline (Gable). GGE is determined by calculating the ratio of British Thermal Units (BTU) per unit in gasoline (114,100 BTUs/unit) with alternative fuels such as ethanol (76,100 BTUs/unit) and methanol (56,800 BTUs/unit) (Gable). GGE can also be calculated for blends of the fuels — such as E85 or M60 — with the percentage of the alternative fuel being represented by the number following the E or M (E85 would be 85% ethanol and 15% gasoline, while M60 would be 60% methanol and 40% gasoline).

This accounts for the energy content of the fuel, but doesn't consider the octane of the fuels and their combustion characteristics in modern fuel injection engines. A presentation composed by Henry Joseph Jr. — the Product Technology Emissions Laboratory & Engine Test manager of Volkswagen Brazil — for the Brazilian Vehicles Manufacturers Association claims that ethanol performance in Brazilian vehicles is nine percent higher than predicted by energy content (Brazilian Vehicles Manufacturers Association). Meanwhile, a study conducted by the University of Riverside claims despite a lower energy content, higher efficiency is obtained from ethanol in optimized engines (Lucon, Alvares Jr., and Coehlo, pg. 6).

This study was designed to measure the differences between projected mileage based on the GGE and the actual mileage obtained. We pulled from reports that looked at alcohol fuels in newer flex fuel vehicles (FFVs) from 2011, a newer non-FFV from 2012 which was tuned for alcohol fuel use, and older vehicles from 2007 that were also tuned to burn alcohol fuels more efficiently.

All the modifications that were done to the vehicles to optimize them to run on alcohol fuels were only performed by modifying the relevant tables in the car computer (ECM) via a process called "reflashing." With the exception of replacing O-rings and seals with ones that are compatible with methanol, there were no other physical changes made to the engine or the fuel injection system. There was also no attempt to take advantage of the high octane of the alcohol fuels to increase engine compression.

GHG emissions models such as GREET and regulatory agencies such as the Environmental Protection Agency (EPA) employ the GGE to help measure and compare difference in emissions among different fuels. Such models look at the entire lifecycle of the fuel from well to wheel. Emissions during the creation and transportation of each fuel (a.k.a. upstream emissions) are multiplied by the GGE factor. If burning of 1.5 gallons of ethanol (2.01 gallons of methanol) is necessary to propel a vehicle the same distance it would go on 1.0 gallon of gasoline, the upstream emissions per gallon should be multiplied by these two factors (1.5 for ethanol and 2.01 for methanol). By demonstrating that the GGE understates the actual MPG modern cars can achieve on alcohol fuels, we can show that the total GHG emissions of such fuels are significantly lower compared to acceptable models. For example, if instead of 2.01 GGE for methanol fuel, the actual achievable factor is 1.6 GGE, it means a significant 20% reduction in total GHG emissions vs acceptable models.

Methods

Data Collection

Three different research reports with varying methods were used in this study:

Report 1: Using Alternative Fuels in Non-Flexible Fuel Vehicles: An Emission and Mileage Study

Researcher: Dr. Robert Zubrin and John Brackett

Five different fuel types — E10, E85, E100, M60, and M100 — were tested in a 2009 Chevrolet HHR and a 2007 Chevrolet Cobalt. Both vehicles ran on a 2.2L General Motors Ecotec engine and sported an updated engine control module (ECM) designed to burn alternative fuels in a more efficient manner. The Viton o-rings in the fuel pump were replaced with Buna-N o-rings to allow for the use of methanol. During the test, the vehicles were driven 120.4 miles through elevations changes over 2,000 feet. A FuelTestKits.com kit was used to measure the alcohol content of the fuel (Brackett).

Report 2: Law Enforcement Vehicle Test and Evaluation Program: Vehicle Model Year 2011

Researcher: Leroy D. Baca

Two different fuel types — E10 and E85 — were tested in six different vehicles. E10 was tested in a Chevrolet Impala 3.9 liter V6, a Chevrolet Tahoe 5.3 liter V8, and Chevrolet Caprice 6.0 liter V8. E85 was tested in flex fuel capable models of the same vehicles. The vehicles were driven on closed courses as well as city streets and highways by law enforcement employees. The safety, comfort, and performance of the vehicles were measured alongside the mileage results (Baca).

Report 3: Are newer model GM vehicles flexible fuel capable with the flick of a switch?

Researcher: Dr. Robert Zubrin and John Brackett

A 2012 Chevrolet Traverse LT 3.6 L V6 (non-FFV) was tested. FF was enabled for all testing, and the vehicle’s tune was optimized for ethanol fuel blends. The enabled and optimized Traverse was tested twice with E10 (we used the average for our report) and once with E87. (Bracket, “Are newer model”)

Data Collation

Once the data from these sources was collected, the GGE ratios for the fuels used were calculated and laid out in Table 1 (“Flex-fuel Vehicles”).

Fuel	GGE Ratio
E0	1.000
E10	0.9667
E15	0.9500
E70	0.7667
E76	0.7467
E85	0.7167
E87	0.7103
E100	0.6667
M60	0.6985
M100	0.4975

TABLE 1: GGE Ratios by fuel blend

These numbers were then used to determine the projected miles per gallon according to the GGE by multiplying the E0 results by the ratio of the fuel blend used. If no E0 results were available, E0 was calculated by taking the smallest E## value available and extrapolating the E0 value with the GGE ratio.

Once all the actual and projected values were accounted for, the percent change between each value was computed with the following formula: [(ActualMPG)/(GGEProjectedMPG)-1]*100.

Results

The results for all vehicles and fuels are shown in Table 2. On average, there was an 18.3 percent gain in fuel economy for actual MPG when compared to the GGE Projected MPG for both ethanol and methanol blends across the range of vehicles we tested.

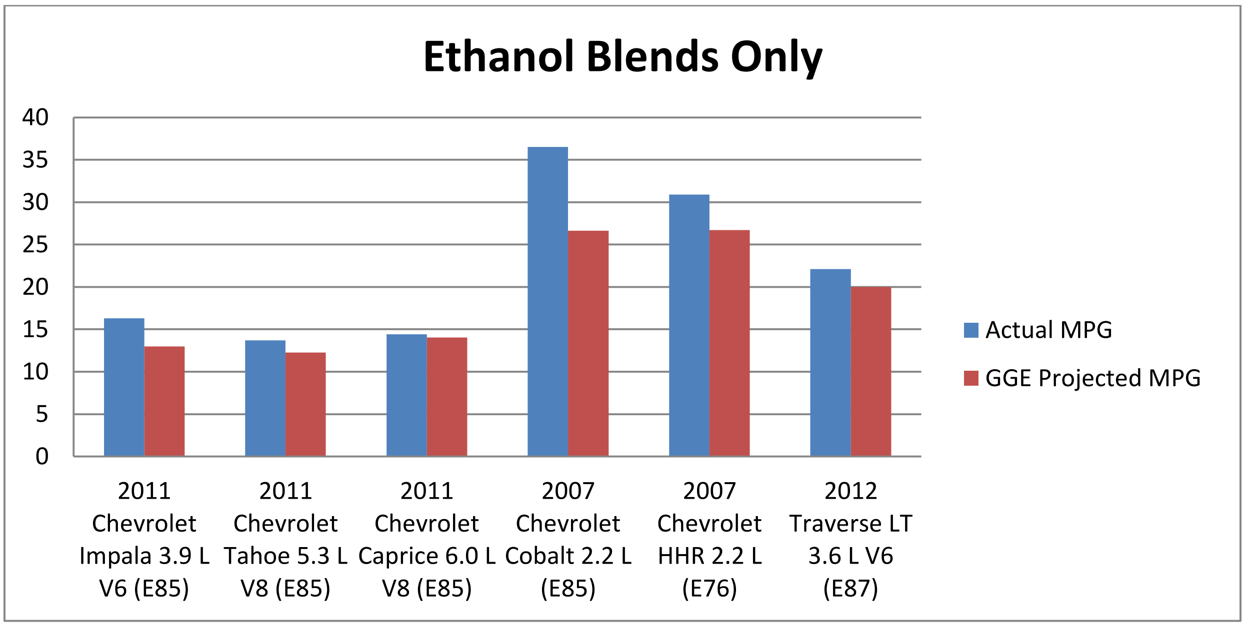
	Tune	Actual MPG	GGE Projected MPG	Percent Difference from Projected to Actual
Vehicle (Fuel)				
2011 Chevrolet Impala 3.9 L V6 (E0)			18.1	
2011 Chevrolet Impala 3.9 L V6 (E10)	Optimize Police	17.5		
2011 Chevrolet Impala 3.9 L V6 (E85)	Optimize Police	16.3	13.0	25.7%
2011 Chevrolet Tahoe 5.3 L V8 (E0)			17.1	
2011 Chevrolet Tahoe 5.3 L V8 (E10)	Stock	16.5		
2011 Chevrolet Tahoe 5.3 L V8 (E85)	Stock	13.7	12.3	11.8%
2011 Chevrolet Caprice 6.0 L V8 (E0)			19.6	
2011 Chevrolet Caprice 6.0 L V8 (E10)	Stock	18.9		
2011 Chevrolet Caprice 6.0 L V8 (E85)	Stock	14.4	14.0	2.5%
2007 Chevrolet Cobalt 2.2 L (E0)			37.1	
2007 Chevrolet Cobalt 2.2 L (E10)	Stock	35.9		
2007 Chevrolet Cobalt 2.2 L (E85)	Optimized	36.5	26.6	37.1%
2007 Chevrolet Cobalt 2.2 L (M60)	Optimized	31.9	25.9	23.0%
2007 Chevrolet Cobalt 2.2 L (M100)	Optimized	24.4	18.5	32.1%
2007 Chevrolet HHR 2.2 L (E0)			35.8	
2007 Chevrolet HHR 2.2 L (E15)	Stock	34.0		
2007 Chevrolet HHR 2.2 L (E76)	Optimized	30.9	26.7	15.6%
2007 Chevrolet HHR 2.2 L (M60)	Optimized	27.7	25.0	10.8%
2007 Chevrolet HHR 2.2 L (M100)	Optimized	20.3	17.8	14.0%
2012 Traverse LT 3.6 L V6 (E0)			28.1	
2012 Traverse LT 3.6 L V6 (E10)	Stock	27.2		
2012 Traverse LT 3.6 L V6 (E87)	Optimized	22.1	20.0	10.7%
Average				**18.3**

TABLE 2: Actual MPG, GGE Projected MPG, and Percent Change for all tested fuels

Table 3 and Graph 1 show the results for the vehicles tested with ethanol fuel blends. On average, there was a 17.2 percent gain in fuel economy for actual MPG when compared to the GGE Projected MPG for ethanol fuel blends.

Ethanol Blends Only	Actual MPG	GGE Projected MPG	Percent Difference from Projected to Actual
Vehicle (Fuel)			
2011 Chevrolet Impala 3.9 L V6 (E85)	16.3	13.0	25.7%
2011 Chevrolet Tahoe 5.3 L V8 (E85)	13.7	12.3	11.8%
2011 Chevrolet Caprice 6.0 L V8 (E85)	14.4	14.0	2.5%
2007 Chevrolet Cobalt 2.2 L (E85)	36.5	26.6	37.1%
2007 Chevrolet HHR 2.2 L (E76)	30.9	26.7	15.6%
2012 Traverse LT 3.6 L V6 (E87)	22.1	20.0	10.7%
Average:			**17.2**

TABLE 3: Actual MPG, GGE Projected MPG, and Percent Change for all ethanol blends

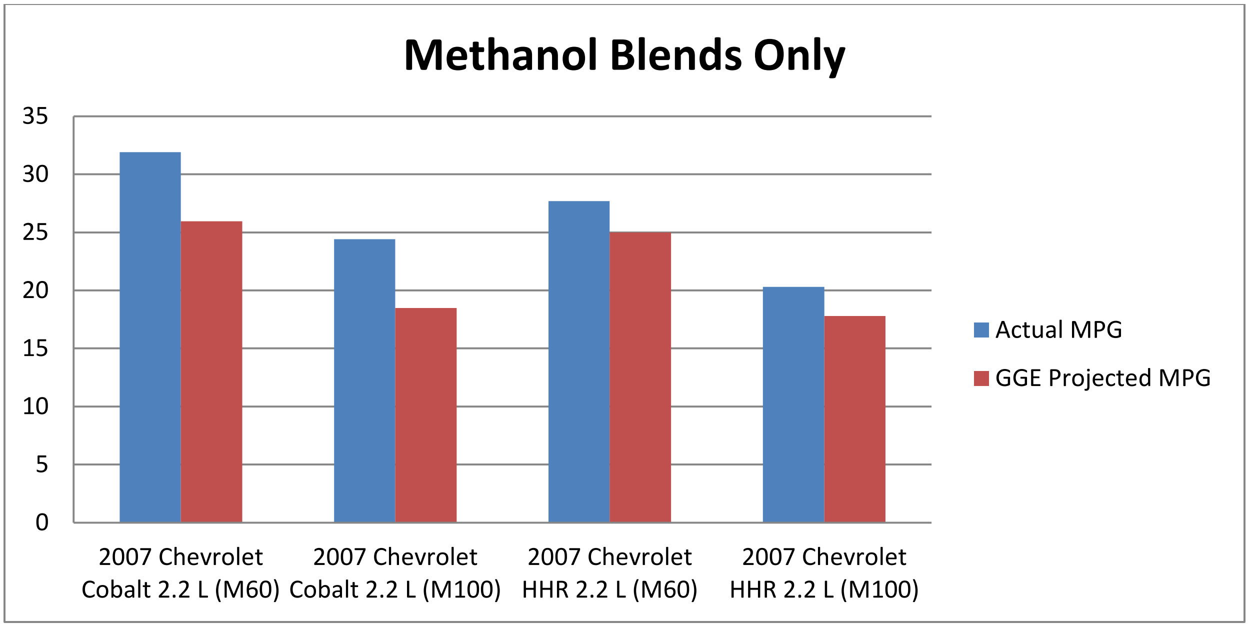


Graph 1: Actual MPG vs. GGE Projected MPG for Ethanol fuel blends

Table 4 and graph 2 show the results for the vehicles tested with methanol fuel blends. On average, there was a 20.0 percent gain in fuel economy for actual MPG when compared to the GGE projected MPG for methanol fuel blends.

Methanol Blends Only	Actual MPG	GGE Projected MPG	Percent Difference from Projected to Actual
2007 Chevrolet Cobalt 2.2 L (M60)	31.9	25.9	23.0%
2007 Chevrolet Cobalt 2.2 L (M100)	24.4	18.5	32.1%
2007 Chevrolet HHR 2.2 L (M60)	27.7	25.0	10.8%
2007 Chevrolet HHR 2.2 L (M100)	20.3	17.8	14.0%
Average:			**20.0**

TABLE 4: Actual MPG, GGE Projected MPG, and Percent Change for methanol blends



Graph 2: Actual MPG vs. GGE Projected MPG for Methanol fuel blends

Conclusion

While more comprehensive and controlled testing is needed to solidify the hypothesis that the GGE undervalues the fuel economy of alcohol fuels, this study raises many questions as to the legitimacy of the current GGE values.

Again, even though the BTU content of the respective fuels is correct, the GGE does not factor in octane differences and the combustion characteristics of alcohol fuels. Stock tunes that come with flexible fuel vehicles sometime fail to take advantage of the characteristics of the fuel resulting in large variations in observed MPG. However, for vehicles that were either designed by the original equipment manufacturers (OEMs) to be FFVs or programmed aftermarket that were tuned to combust alcohol fuels more efficiently, the GGE underestimated their fuel mileage on ethanol (by 17.2%) and methanol (by 20.0%).

Moving forward, future studies should look at broader ranges of vehicles optimized for alternative fuel use to determine whether or not the GGE system is an effective way to measure the efficiency of alternative fuels in properly tuned FFVs.

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