American Coalition for Ethanol

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FUEL ECONOMY STUDY

Comparing Performance and Cost of Various Ethanol Blends and Standard Unleaded Gasoline

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Mileage and Cost comparison using Unleaded, E10, E20, and E30

PURPOSE OF THE STUDY

As ethanol production and use has expanded from coast to coast in the United States, increased public discussion and media attention has focused on various properties of those blends versus standard unleaded gasoline. Among the most frequent matters for debate has been the matter of fuel efficiency and the resulting effect on cost of vehicle operation.

Quite often, opinion stated as fact has made its way into the public arena, in forms as varied as Letters to the Editor claiming mileage losses of 15% or more, to an unscientific test performed by a television station that showed a ten percent blend of ethanol performed worse than unleaded, but provided more miles per gallon than premium. While letters to the editor do evoke a certain amount of skepticism from readers, traditional media reports often carry more weight. In the TV segment mentioned, the station clearly stated that the test was unscientific. But the viewer was clearly left with the impression that it was more costly to use ethanol-blended gasoline.

In a more subtle manner, ethanol's efficiency has been brought into question as representatives of the automotive and oil industries have stated at various times that a ten percent blend of ethanol provides 3% less fuel efficiency. These comments were based on the fact that a ten percent blend of ethanol has a BTU content 3% lower than gasoline, and the assumption that the lower BTU content would result in 1-to-1 reduction in mileage per gallon.

The ethanol industry has traditionally held the belief that ethanol's properties as an oxygenate would provide more complete burning of the base fuel, and offset some of the BTU loss. Furthermore, since ethanol blends are traditionally less expensive than straight gasoline, it stands to reason that if MPG of both types of fuel were similar, the ethanol blend would be the better value in terms of cost per mile of operation.

When ACE responded to negative media accounts regarding ethanol blend fuel economy, reporters typically asked for documentation of our statements. There appeared to be very little information available. It was decided that ACE should commission a pilot study, to determine whether there were variances in MPG between ethanol blends in gasoline.

Prior to ordering this pilot study, ACE was able to locate only one study on fuel economy variances between ethanol-blended and non-ethanol-blended gasoline. A 1996 study by the University of Wisconsin-Milwaukee compared several types of oxygenated reformulated gasoline to conventional unleaded. The sample also used only 5.7% ethanol as opposed to the more common 10% blend, and several of the ethanol fuel samples used had wide variations in BTU content. The study used vehicles manufactured from 1979 to 1994, and the sample vehicles and drivers showed some very wide deviations from expected results. Even so, the overall variance in those tests showed that ethanol-blended RFG provided 98% of the MPG performance of conventional unleaded gasoline.

CHOICE OF FUELS TO BE TESTED

In addition to questions about E10's efficiency versus conventional gasoline, an effort was underway in the State of Minnesota to pass legislation that would require 20% of the state's fuel be ethanol by 2010. While an E20 blend was not the target of the legislation, a decision was made to test an E20 blend (20% ethanol, 80% gasoline) to gather information that could be relevant to that legislative effort. The fuel would be tested in the same unmodified, non-flexible fuel vehicle, with special attention paid to any operational variations in the engine performance ("trouble" indicator lights, hesitation, etc.) in addition to mileage differences.

Also, due to past studies that showed some differences between ethanol blends and conventional gasoline were reduced as ethanol percentage approached 25 to 30%, an E30 blend (30% ethanol, 70% gasoline) was also tested. As was the case with E10 and E20, the fuel would be tested in the same unmodified, non-flex-fuel vehicle, with special attention paid to any operational variations in the engine performance ("trouble" indicator lights, hesitation, etc.) in addition to mileage differences.

Finally, in earlier meetings regarding the possible project, Allen Kasperson (the individual contracted to perform the test) mentioned that he had denatured fuel with soy diesel and isopentane, and that the original tests of Reid vapor pressure (RVP) had shown lower RVP in blends made with ethanol denatured in that fashion. This fuel blend was added to the list of fuels to be tested.

TEST PARAMETERS

At their January 18, 2005 meeting, the ACE board of directors approved a motion meeting to fund a small-scale study that would test the efficiency of five fuel blends in three different unmodified vehicles. The five fuel blends were:

- Unleaded gasoline (NL)
- Unleaded with 10% standard ethanol (E10)
- Unleaded with 20% standard ethanol (E20)
- Unleaded with 30% standard ethanol (E30)
- Unleaded with 10% ethanol denatured with iso-pentane and bio-diesel (E10AK)

Three late-model vehicles were to be used in the test, one each from:

- General Motors
- Ford
- Toyota or Honda

Allen Kasperson, a Fuel Research Specialist with over 30 years of training automobile and truck technicians as an instructor at Lake Area Vocational Technical School in Watertown, South Dakota, was selected to conduct the study.

Care was taken to eliminate any of the variations or "human inputs" that have rendered other "tests" unscientific.

Data Logger – The EASE Diagnostics FV-12-CAN Vehicle Interface was used to record data directly from the engine's computer into a laptop computer. The "data logger monitored fuel consumption, driveability, and any significant variances in performance as each vehicle is operated on three 100-mile trips. Care was taken to reduce all environmental factors affecting mileage. The computer monitored and recorded fuel economy instantaneous and average, acceleration, calculated load, air flow rate, warning lights, coolant temperature, vehicle speed, and long term fuel trim.

Fuel - Composition of gasoline varies significantly from season to season, and to a smaller extent, from station to station and truckload load to truckload. To eliminate statistical variations that could be caused by variations in fuel, with the exception of the ethanol in the final sample, all ethanol and gasoline used in the test were taken from a common supply source. Each vehicle was parked in the same location for fueling and fuel removal, to eliminate the possibility that parking on an incline or decline could cause more or less fuel to be pumped out of the tank during fuel removal. Initially, fuel was removed from each car using the car's in-tank electric fuel pump. Five gallons of fuel, measured in a graduated cylinder was placed in the tank before each 100-mile trip. At the end of each 100-mile trip, fuel was pumped out of the tank, into a graduated cylinder, again using the automobile's in-tank electric fuel pump.

Vehicles – The vehicles used in this test were a 2005 Chevrolet Impala with a 3.4-liter engine, a 2005 Ford Taurus with a 3.0-liter engine, and a 2005 Toyota Camry with a 4-cylinder engine. All cars had the oil changed within less than 500 miles of the test. Tire pressure was checked before every trip. The only accessories used in the vehicle during tests were the car's heater and the power used to run the data logger and laptop computer. The researcher was the only passenger on all trips. The car was driven 70 miles per hour. Miles traveled were calculated using the automobile's odometer. All three vehicles showed the same mileage on the interstate loop, and that mileage matched the mileage indicated by state mile markers on the highway.

Terrain and Weather – To eliminate variances in terrain, all cars were driven on 100-mile loop on Interstate 29 in South Dakota, from Interstate 29 Exit 177 near Watertown SD, to Interstate 29 Exit 127, south of Brookings, SD. All tests were performed on days that had no precipitation, on dry roads. Temperatures were within a small range for each vehicle. Vehicle 1 tests were performed when temperatures were +24F to +30F, Vehicle 2 tests were performed when temperatures were +32F to +49F, Vehicle 3 tests were performed when temperatures were +61F to +68F most days, with one day, April 18, just over +80F. Winds were normally in the 10 to 15 mph range, with the exception of two days, April 14 & 18. Those days, winds were approximately 25 MPH.

Fuel Costs – since fuel costs vary widely, for purposes of this study, OPIS average rack price for gasoline and ethanol at the Sioux Falls SD Magellan terminal at the beginning of the study were used. Actual prices paid for iso-pentane and bio-diesel were used. Ethanol and bio-diesel were priced net of the federal blender's tax credit. Federal tax of 18.4 cents per gallon and state tax of 20 cents were assumed. Using the miles per gallon figures obtained, prices from any date or location could be entered

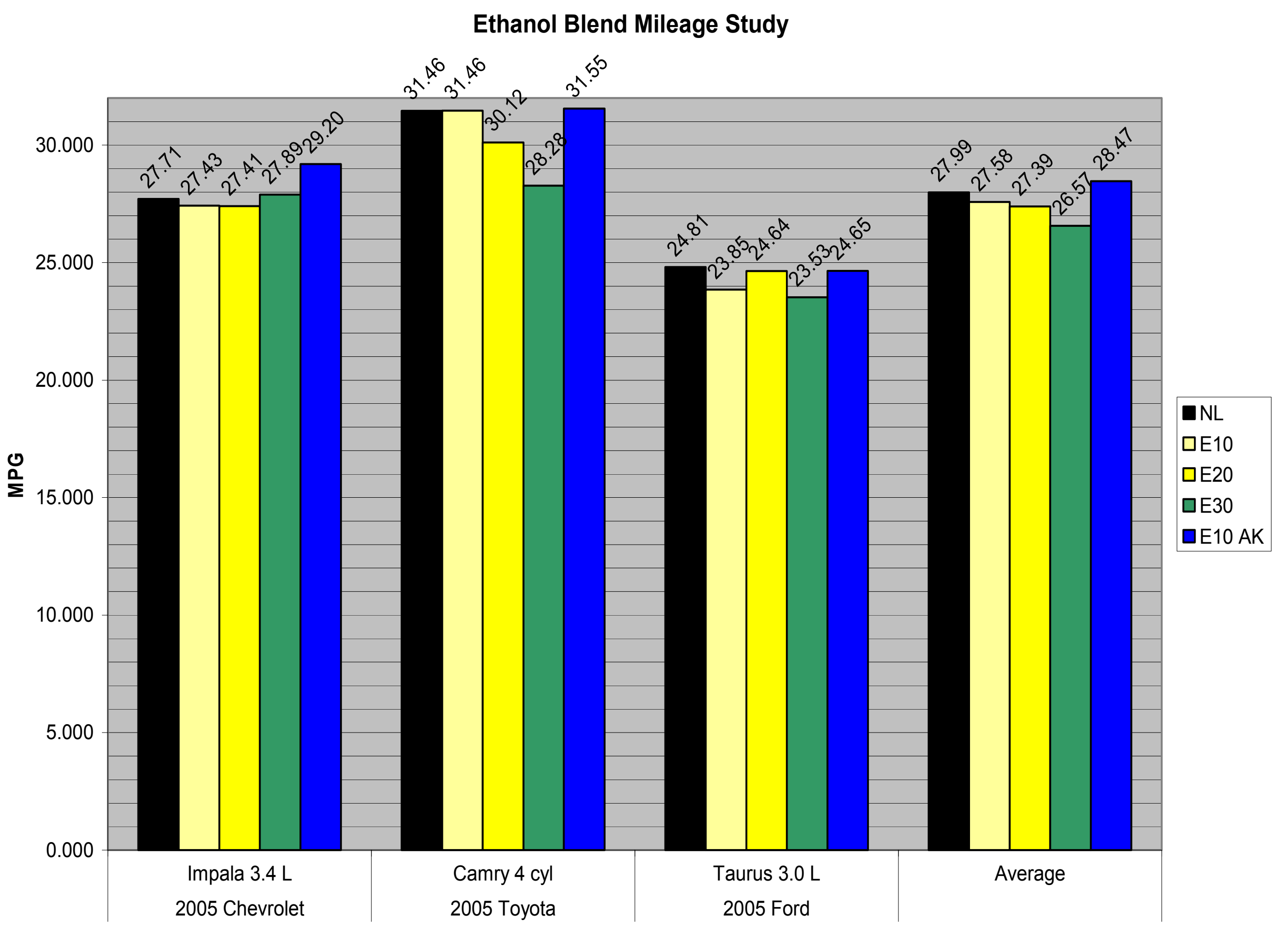
RESULTS

1) The three vehicles averaged 1.5% lower mileage with E10, 2.2% lower mileage with E20, 5.1% lower mileage with E30, and miles per gallon actually increased by an average of 1.7% when using E10AK made with the specially denatured ethanol. E10AK was the highest mileage fuel in two of three cars.

One vehicle – the Toyota Camry – showed virtually no variance between unleaded and either of the E10 blends, and both E10 blends actually performed better than straight unleaded. That car also took the largest drops on fuel efficiency when using E20 and E30. Kasperson suggested that the vehicle's "tight" tolerances for optimizing efficiency of standard fuels like unleaded and E10 would possibly also result in larger variances in non-standard fuels.

The Chevrolet Impala showed just over 1% lower MPG on E10 and E20, but gained .6% MPG operating on E30, and over 5% on the E10AK blend

The two lowest MPG rates during the test were recorded by the Taurus on days when wind speeds were highest – approximately 10 mph higher than other test days, and in the case of the E30, during the warmest weather of the test. E10 provided almost 4% less MPG than unleaded; E30 was nearly 5% lower. The Taurus was the only car that showed an MPG loss on E10AK, and it performed best on E20 – only .7% lower than unleaded.

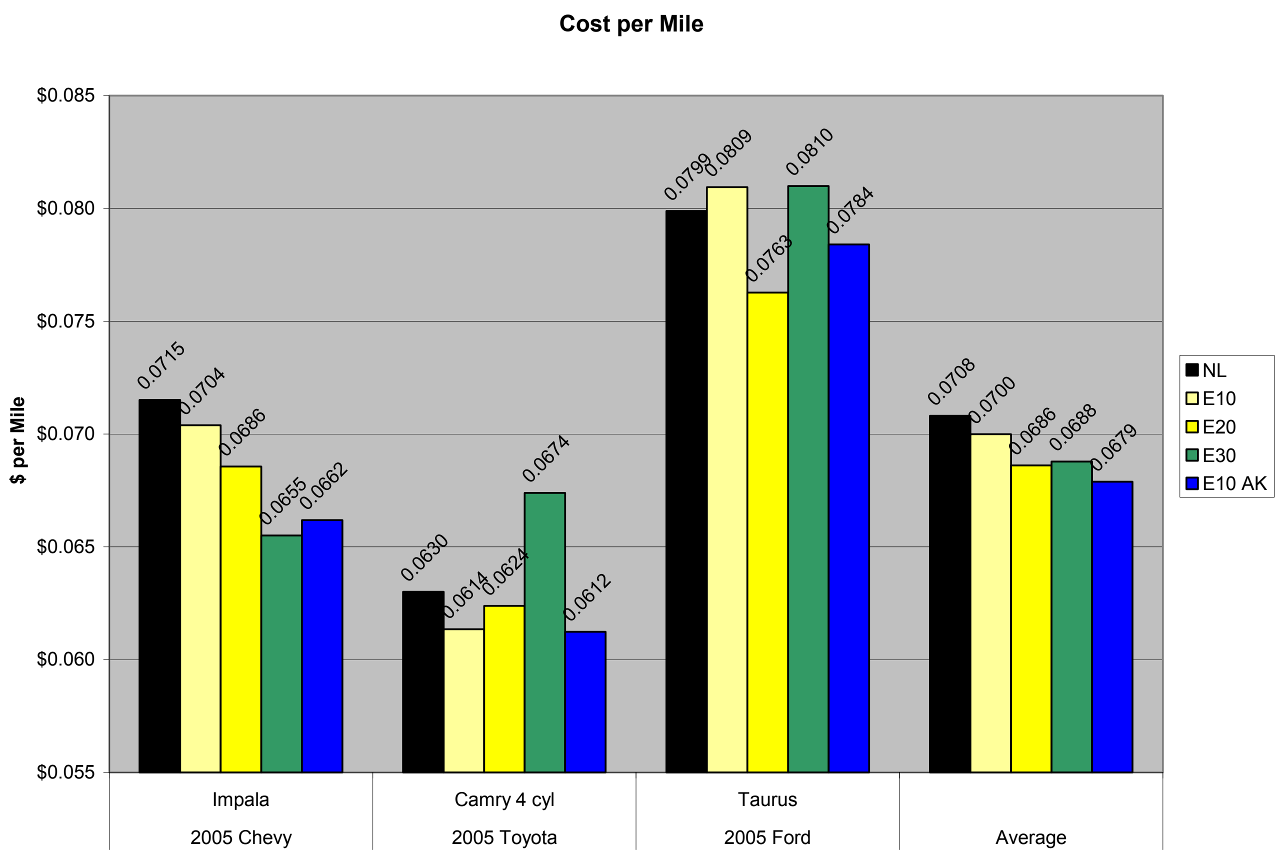


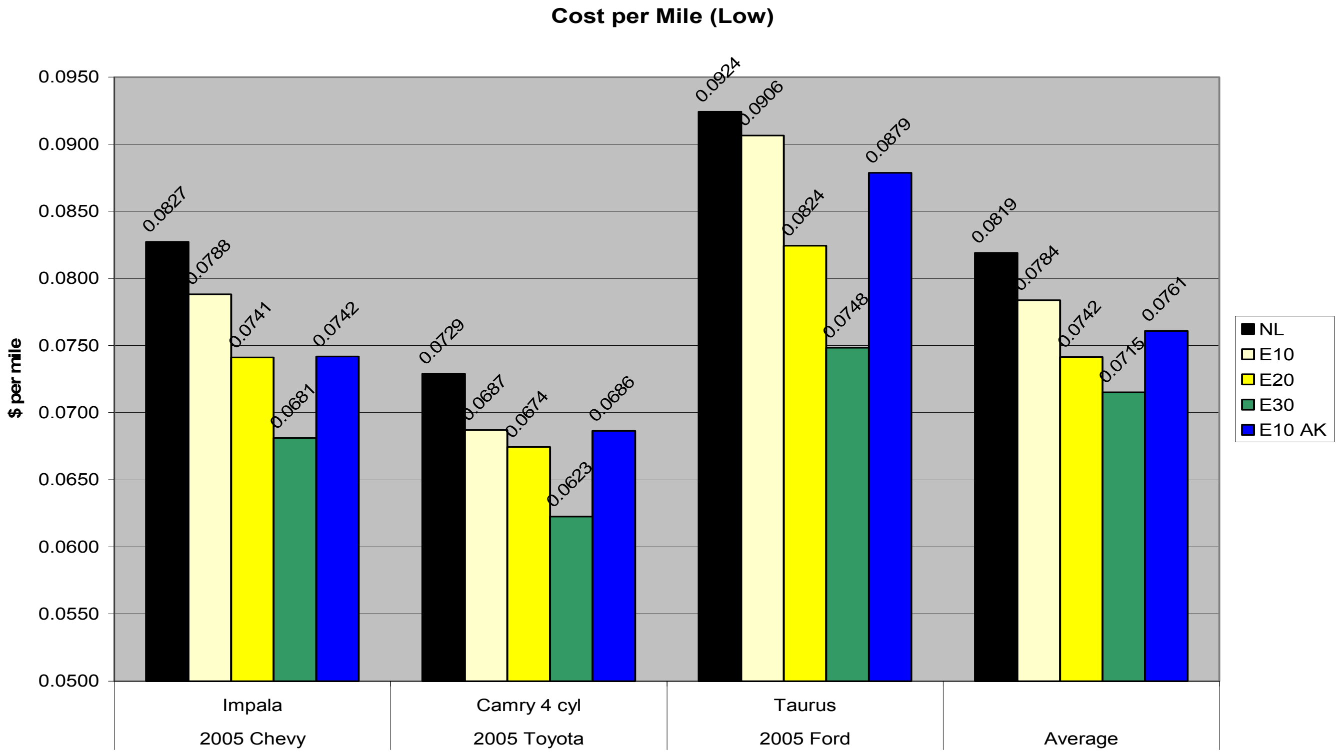
2) Because the cost of ethanol was lower than the cost of gasoline, although MPG of ethanol blends were slightly lower, cost per mile of operation was generally lower when using ethanol blends. The only ethanol blend that tested at a higher cost per mile than unleaded gasoline was E30 in the Toyota Camry and the E10 and E30 in the Taurus.

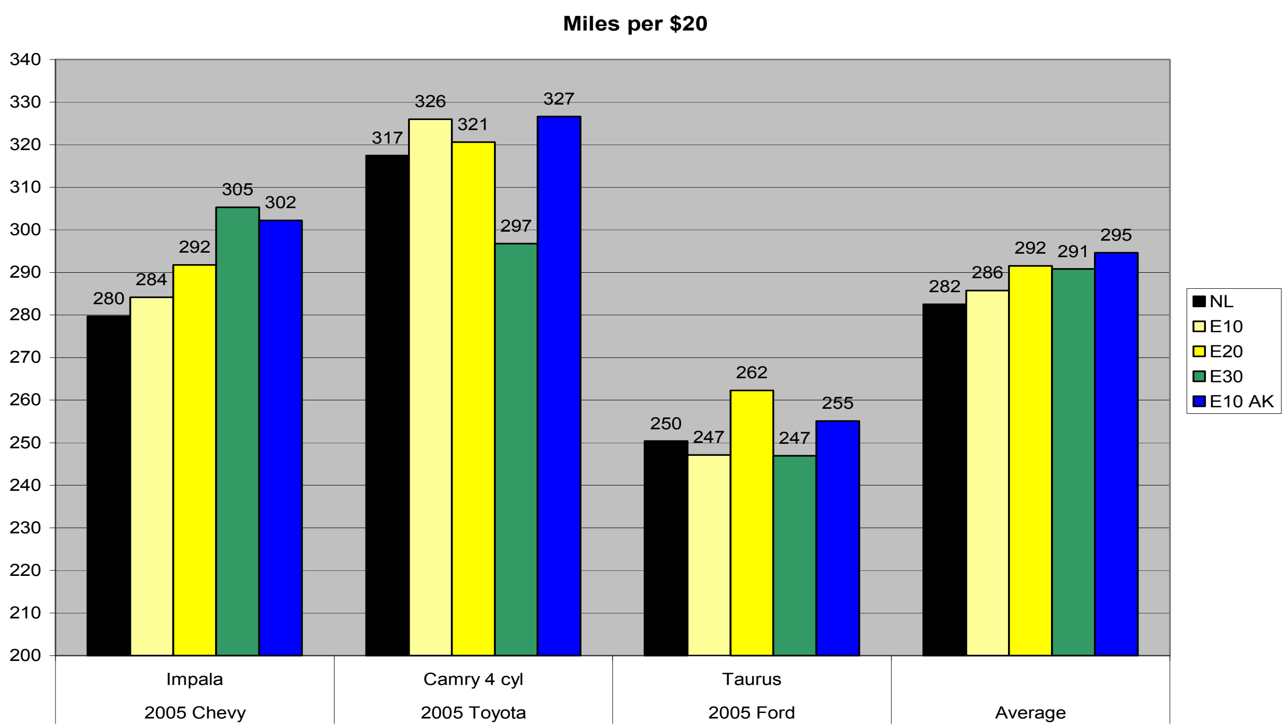
In general, the more ethanol used, the lower the cost per mile. At the start of the study (when fuel was obtained) costs of ethanol and unleaded gasoline were both just under $1.60 per gallon. Using average MPG, E10 is a less expensive fuel than unleaded until ethanol's cost is nearly 30 cents above unleaded. At one point during the test, prices of gasoline and ethanol were far enough apart that E10 was 4% less expensive, and E20 was almost 13% less expensive (see chart – "Cost per Mile (low)").

It should be noted that E10AK appears to offer less savings in the low ethanol price chart, however, the price is skewed by the fact that iso-pentane and soy diesel were not available in larger quantities. Should the fuel be made on a more consistent basis, costs should moderate from economies of scale.

Finally, a third chart (below) was created, combining the MPG and fuel costs to illustrate the number of miles one would be able to travel on a $20 fill-up.




Cost per Mile (Low)
$ per mile
0.0950
0.0900
0.0850
0.0800
0.0750
0.0700
0.0650
0.0600
0.0550
0.0500
0.0827
0.0788
0.0741
0.0681
0.0742
0.0729
0.0687
0.0674
0.0623
0.0686
0.0924
0.0906
0.0824
0.0748
0.0879
0.0819
0.0784
0.0742
0.0715
0.0761
Impala
2005 Chevy
Camry 4 cyl
2005 Toyota
Taurus
2005 Ford
Average
NL
E10
E20
E30
E10 AK


Miles per $20
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
280
284
292
305
302
317
326
321
297
327
250
247
262
247
255
282
286
292
291
295
Impala
2005 Chevy
Camry 4 cyl
2005 Toyota
Taurus
2005 Ford
Average
NL
E10
E20
E30
E10 AK

3) Contrary to statements commonly made by vehicle manufacturers and technicians, no warning lights were displayed at any time while operating on any of the blends of fuel. The data logging computer monitors all warning light systems, and did not record any malfunction indicator lights (MIL), diagnostic trouble code (DTC) lights, or emissions DTCs.

4) Another area that was of interest in the data logging computer's recording was the short-term and long-term fuel trim. The car's computer has the ability to adjust the air/fuel ratio based on a too rich or too lean mixture. In older model vehicles, it was assumed that the oxygen sensor caused a MIL to be displayed when fuel with too much ethanol was used, as the oxygen sensor did not recognize fuel with a much higher oxygen content. In all vehicles used, the long and short-term fuel trim adjusted the air fuel ratios normally, and recorded all operation on all fuel blends as being within a "normal" range.

5) Because of the short duration of the test, there was no investigation of whether there was less engine wear due to using a lower BTU (cooler) fuel. An ACE member, who has been operating a non-flex fuel vehicle on E85 since its purchase, has promised to allow the organization to investigate that vehicle's engine when it reaches 100,000 miles – possibly later this year.

CONCLUSION

While vehicles using concentrations of ethanol higher than 10% operated normally during this test, the American Coalition for Ethanol cannot recommend using ethanol blends with higher concentrations of ethanol than those recommended by the vehicle's manufacturer. It should be noted that each vehicle in this test ran only 600 of its 1500 miles on E20 or E30, and while the short-term results were good, more study is needed to determine if there are any long-term consequences.

This pilot study appears to confirm that BTU content is not a direct indication of the amount of work a vehicle can do with a given quantity of fuel. Other properties of ethanol seem to minimize the effects of lower BTU content. Admittedly, the test used a very small sample, but the results suggest that a larger and more detailed study be completed in the near future.

Given the differences found between BTU and mileage in this test, a study of the differences in fuel economy between unleaded and E85 in flexible fuel vehicles should also be investigated. Currently, mileage is assumed to be almost 30% lower when using E85, while anecdotal evidence indicates that actual MPG performance of E85 is much better than that estimate.

TEST DATA RECAP

	2005 CHEVROLET IMPALA 3.4 L	2004 TOYOTA 2AZ-FE 4 CYL.	2005 FORD TAURUS 3.0L
FUEL	Unleaded	Unleaded	Unleaded
DATE	2/21/05	3/2/05	4/13/05
WIND/TEMP	SW>10mph/+24	SE10-15mph/+32	SE10mph/+64
MILES	329.8	323.7	320.4
FUEL USED	11.900	10.418	12.914
MPG	27.714	31.455	24.810
FUEL	10% Ethanol	10% Ethanol	10% Ethanol
DATE	2/22/05	3/3/05	4/14/05
WIND/TEMP	N10-15mph/+28	S10-15mph/+43	S15-25mph/+68
MILES	330.0	318.0	319.2
FUEL USED	12.032	10.110	13.383
MPG	27.426	31.464	23.851
FUEL	20% Ethanol	20% Ethanol	20% Ethanol
DATE	2/23/05	3/4/05	4/15/05
WIND/TEMP	S10-15mph/+30	S10-15mph/+43	NW10-15mph/+67
MILES	339.7	318.0	318.8
FUEL USED	12.395	10.559	12.941
MPG	27.406	30.116	24.635
FUEL	30% Ethanol	30% Ethanol	30% Ethanol
DATE	2/25/05	3/5/05	4/17/05
WIND/TEMP	N10-15mph/+28	W10-15mph/+44	S15-25mph/+81
MILES	317.1	318.1	324.6
FUEL USED	11.368	11.25	13.797
MPG	27.894	28.275	23.527
FUEL	10% AK Ethanol	10% AK Ethanol	10% AK Ethanol
DATE	2/26/05	3/6/05	4/19/05
WIND/TEMP	SE10-15mph/+30	NW10mph/+49	NE15-25mph/+68
MILES	317.2	318.0	318.8
FUEL USED	10.864	10.078	12.93
MPG	29.197	31.554	24.648

	2005 Chevrolet	2005 Toyota	2005 Ford		Variance		
	Impala 3.4 L	Camry 4 cyl	Taurus 3.0 L	Average			
NL	27.714	31.455	24.810	27.993			
E10	27.426	31.464	23.851	27.580	-0.015		
E20	27.406	30.116	24.635	27.386	-0.022		
E30	27.894	28.275	23.527	26.565	-0.051		
E10 AK	29.197	31.554	24.648	28.466	0.017		
		Cost per Mile					
	2005 Chevy	2005 Toyota	2005 Ford	Average	Variance		
	Impala	Camry 4 cyl	Taurus				
NL	0.0715	0.0630	0.0799	0.0708			
E10	0.0704	0.0614	0.0809	0.0700	-0.011		
E20	0.0686	0.0624	0.0763	0.0686	-0.031		
E30	0.0655	0.0674	0.0810	0.0688	-0.029		
E10 AK	0.0662	0.0612	0.0784	0.0679	-0.041		
		Miles per $20					
	2005 Chevy	2005 Toyota	2005 Ford	Average			
	Impala	Camry 4 cyl	Taurus			Fuel	*Net Cost
NL	280	317	250	282		ETH	1.082
E10	284	326	247	286		UNL	1.598
E20	292	321	262	292		ISO	1.710
E30	305	297	247	291		SOY	1.460
E10 AK	302	327	255	295		AKE	1.102

**net cost of ethanol and soy biodiesel include blenders tax credit of .51 and 1.00 respectively*