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*Madison*

# American Motorcycle, American Fuel

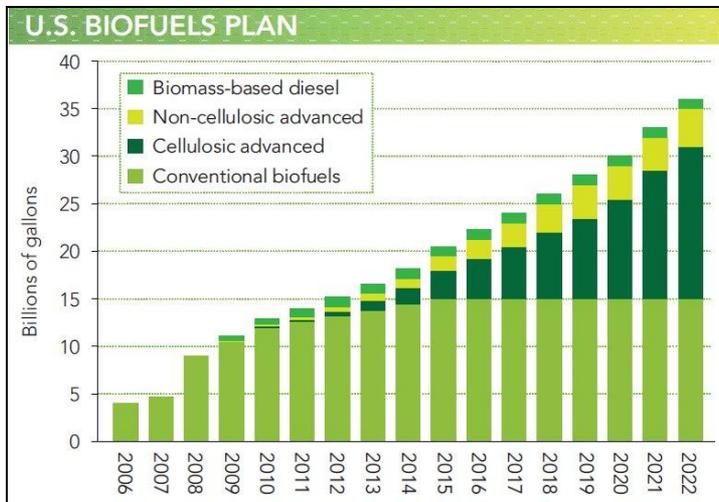
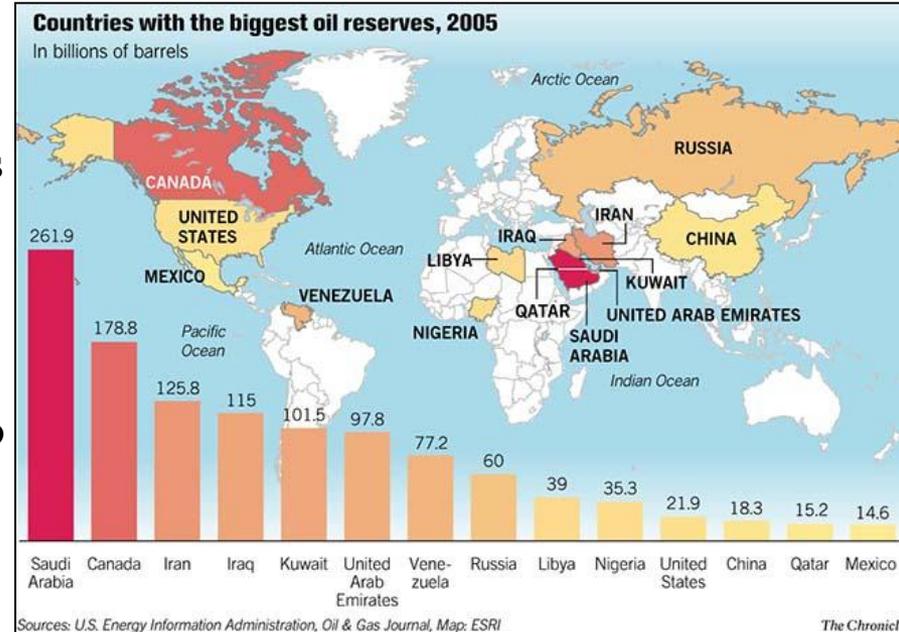
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**James Madison University**

College of Integrated Science and Technology

- The world's demand for oil is increasing at an alarming rate
- The United States has turned to ethanol mandates to help reduce dependence on foreign oil
- Unfortunately, ethanol does not run well in convention spark-fired gasoline engines
- Unless.. the engine is retrofitted with hardware to enable higher compression (14.1:1) and software modifications to retard spark timing (4-8° BTDC)



← 25%

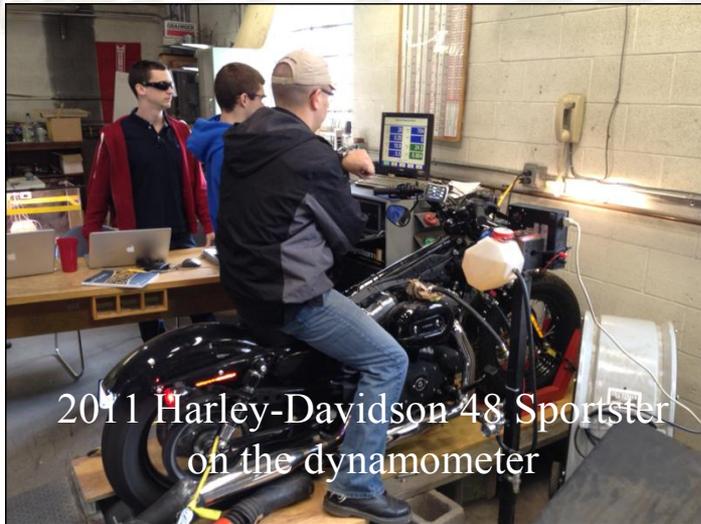
← 11%

Where we are now



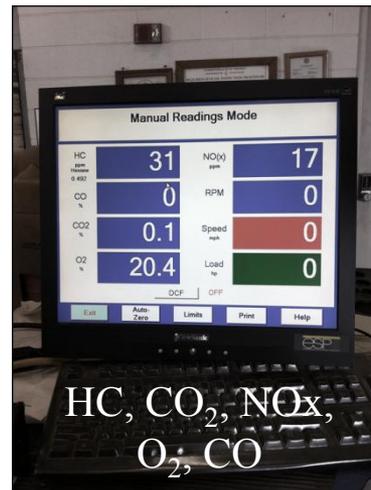
# Methods

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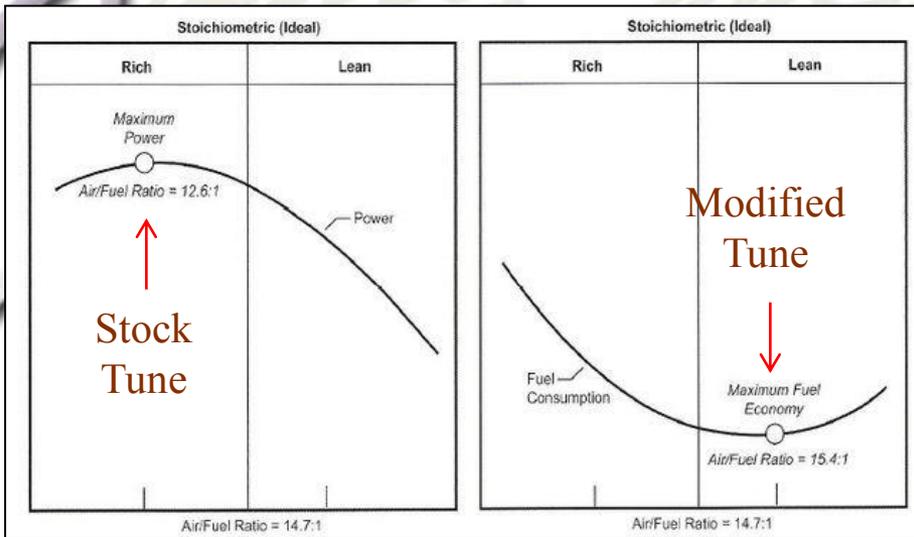
- DynoJet PowerVision (PV) flash tuner
- Tuner used to re-flash Harley electronic control unit (ECU)
- Intended to provide Harley enthusiasts with a way to get more horsepower out of their bikes
- Tuner was used to go in opposite direction: **economy**

- Dynamometer for load and emissions
- E0, E10, E15, and E85 run with stock tunes as baseline, and custom modified tunes made by the group
- Trials included logging data on the PV tuner 10 times per run in 30 second intervals over a ~6 minute period, repeated each fuel and tune
- Emissions data was video recorded from the computer screen



# Methods

- The tuner collects data on the engine (AFR, MPG, **Volumetric Efficiency (VE)**, temperature, RPM, spark timing)
- This data was used to create custom modified tunes by modifying the VE tables and spark timing in WinPV and flashing the tune to the PV unit
- VE modification tricks the engine into introducing more oxygen to the mixture



VE [Front Cyl]  
StockMod3minus12

RPM	Throttle Position (Percent)											
	0	2	5	10	15	20	25	30	40	60	80	100
750	70.5	70.0	74.5	79.0	79.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
1000	74.0	79.0	76.5	76.5	78.0	80.0	78.5	79.5	79.0	76.0	78.0	85.0
1500	73.5	81.0	70.5	69.0	73.0	68.0	69.5	71.0	73.0	73.5	78.0	79.5
2000	71.5	80.5	72.5	71.0	75.0	74.5	75.0	80.0	81.5	86.0	85.5	86.0
2500	73.0	79.5	73.0	76.0	76.5	74.5	71.5	73.0	75.5	80.0	79.5	83.5
3000	73.0	78.0	69.0	75.5	77.0	76.0	70.5	74.5	74.5	78.0	78.5	83.5
3500	72.0	78.0	69.0	77.0	82.0	80.5	73.0	78.0	78.5	80.5	82.5	86.5
4000	73.0	78.0	68.0	77.5	85.0	81.0	74.0	77.5	79.0	80.0	81.5	85.0
4500	73.0	78.0	68.0	73.5	83.5	82.0	75.0	76.0	76.0	77.0	79.5	81.5
5000	77.0	78.0	68.0	72.5	80.5	82.5	74.0	75.5	74.0	75.0	79.0	80.5
5500	80.0	80.0	68.0	69.0	77.5	79.0	74.0	73.0	73.0	72.5	75.5	78.0
6000	83.0	82.0	68.0	72.0	75.5	79.5	75.5	75.5	74.5	72.0	74.5	77.0
6500	83.0	82.0	68.0	72.0	75.5	76.0	75.5	75.5	74.5	73.5	75.0	77.0
7000	83.0	82.0	68.0	72.0	75.5	76.0	75.5	75.5	74.5	73.5	75.0	77.0
7500	83.0	82.0	68.0	72.0	75.5	76.0	75.5	75.5	74.5	73.5	75.0	77.0
8000	83.0	82.0	68.0	72.0	75.5	76.0	75.5	75.5	74.5	73.5	75.0	77.0

- Lambda, the normalized AFR, is usually about 1.0 in conventional engines
- Lambda of 1.12 indicates an increase of AFR, resulting in greater fuel economy and lean burn
- Vehicle manufacturers tune to 1.0 to keep the balance between power and efficiency

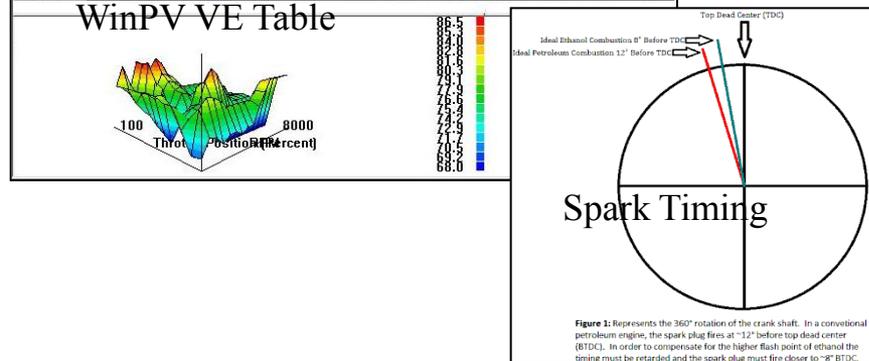
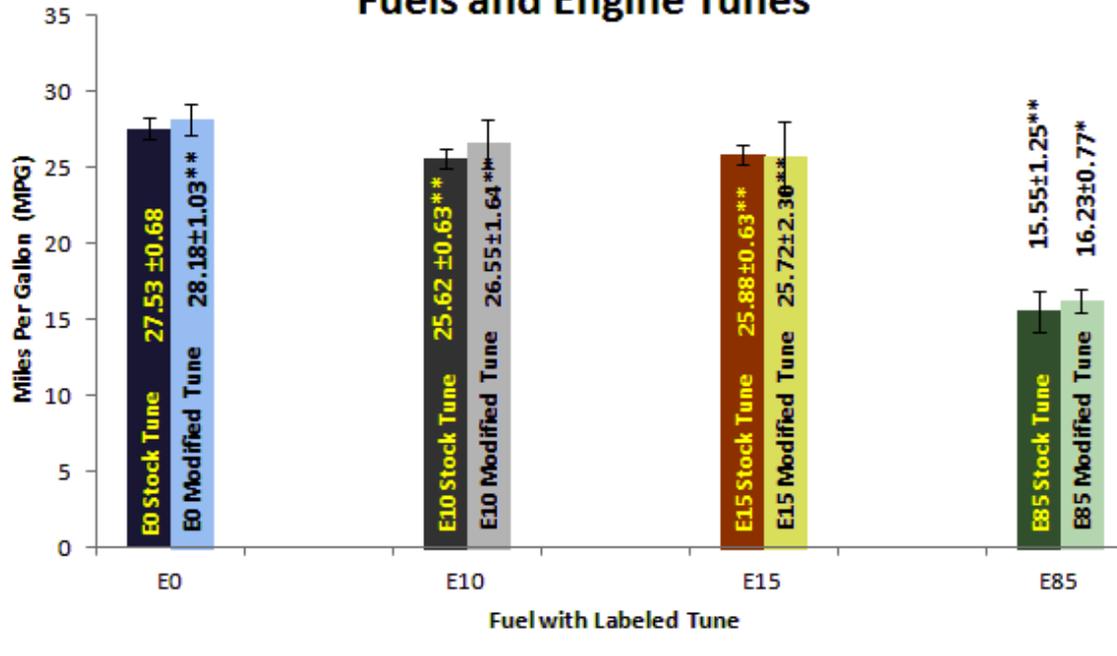


Figure 1: Represents the 360° rotation of the crank shaft. In a conventional petroleum engine, the spark plug fires at "12° before top dead center (BTDC). In order to compensate for the higher flash point of ethanol the timing must be retarded and the spark plug must fire closer to "8° BTDC."

# Results – Miles per Gallon

**MPG Means ± Standard Deviation for Blended Fuels and Engine Tunes**



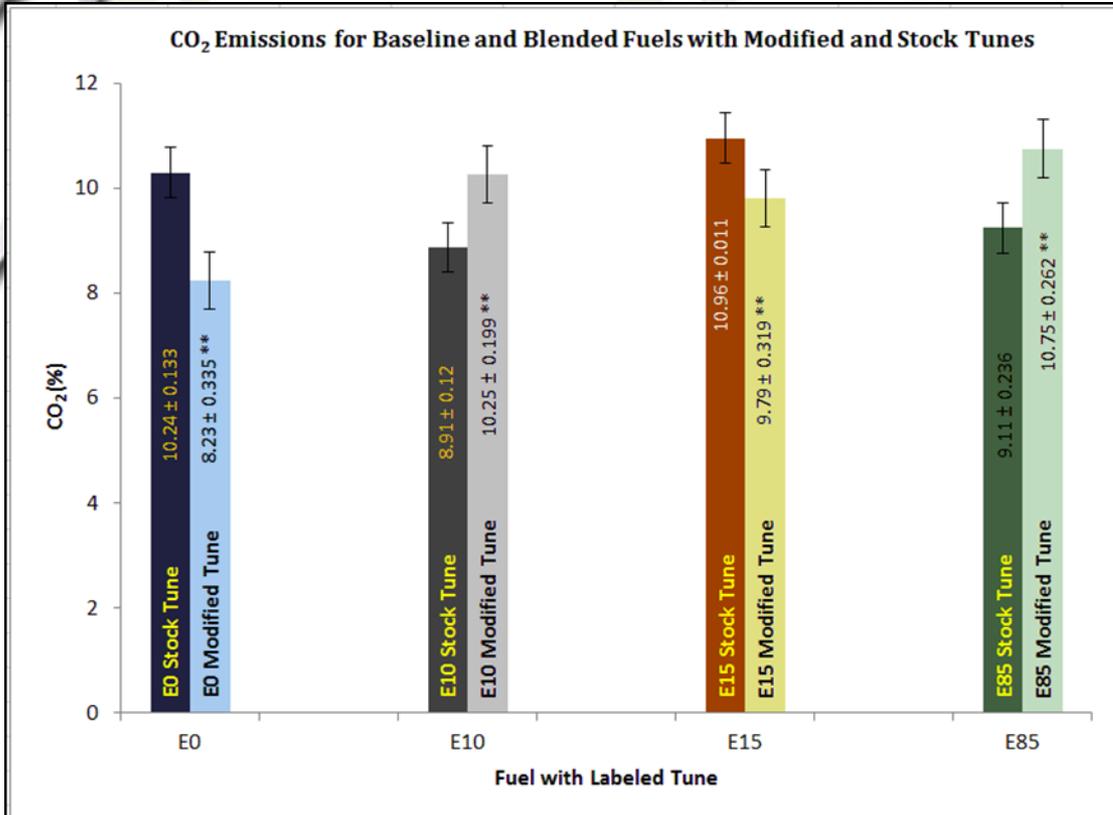
- Miles per gallon increased when the modified tunes were used with E0, E10, and E85
- All changes were statistically significant with P-values < 0.01
- E15 had a slight decrease in fuel economy

Results presented as mean ± standard deviation. N≥1500. \*P≤0.05 \*\*P≤0.01

Modified engine tuning is compared to stock engine tuning for each fuel blend. For increasing ethanol concentration, statistical significance is provided for stock tunes using ethanol blends relative to stock tune for E0 (pure gasoline).

# Results – Miles per Gallon

# Results – CO<sub>2</sub>



Results presented as mean ± standard deviation. N≥120. \*\*P≤0.01. Modified engine tuning is compared to stock engine tuning for each fuel blend. For increasing ethanol concentration, statistical significance is provided for stock tunes using ethanol blends relative to stock tune for E0 (pure gasoline).

- CO<sub>2</sub> emissions decreased with E0 and E15
- All decreases were statistically significant with P-values < 0.01
- 3 percent lower CO<sub>2</sub> emissions indicates a reduction of approximately 100 kg per capita per year

# Results

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Fuel Savings						
Fuel	Tune	Average MPG	Percent Difference	Gallons Used per Year	Fuel Expenditures / Year	Savings
E0	Stock	27.53		544.86	\$2,179.45	
	Modified	28.18	2.4	532.31	\$2,129.25	50.20
E10	Stock	25.62		585.40	\$2,341.60	
	Modified	26.55	3.6	564.93	\$2,259.71	81.89
E15	Stock	25.88		579.60	\$2,318.42	
	Modified	25.72	-0.6	583.28	\$2,333.14	-14.72
E85	Stock	15.55		964.40	\$3,857.61	
	Modified	16.23	4.3	924.34	\$3,697.36	160.25

This table shows annual fuel expenditure savings when using the modified tune over the stock tune. Table made assuming an annual distance traveled of 15,000 miles and \$4 per gallon fuel prices.

Compared to E0	Stock	Modified
E0		2%
E10	7%	4%
E15	6%	7%
E85	44%	41%

Percent change compared to E0 Stock tune. Values in red show percent decrease.

# Conclusion

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The 16 studies above the zero line show that ethanol contains more energy than the fossil-based energy used to produce it. The nine studies below the zero line say that ethanol is a net fossil energy loss.

- One MIT study reports 1 unit of fossil fuel input can yield 1.5 units of ethanol when co-product credit is applied (energy saved from using corn by-product for high quality livestock feed)
- Still, the max energy gain of 50% means that the 10% of gasoline displaced with E10, only half of that return is realized.

# Conclusion

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- Even though E10 costs less per gallon, it cost more per mile than E0
  - The 7% MPG decrease should result in a \$0.28 decrease in price per gallon (just to break even)
    - Unfortunately, the price is reduced only \$0.10. The consumer pays the extra \$0.18 (%4.5 overpay) for less MPG
  - The Modified tune resulted in 4% MPG reduction
    - Reduces customer overpay to \$0.06 (1.5%)
- 
- Greater MPG savings could be realized if...
    - Engine compression ratios are increased
    - Ethanol fuel blends are primarily used where they are produced (Midwest U.S.) to cut down of transportation cost. While the rest of the country tunes engines at or near lambda 1.12

	E0	E10 Stock	E10 Modified
MPG	28	26	27



Financial Analysis	
E0	\$3.99/gallon
E10	\$3.89/gallon
Price Difference	\$0.10
Price % Decrease	3
MPG % Decrease (Stock)	7
MPG % Decrease (Modified)	4

## Pictures

- [http://www.sfgate.com/c/pictures/2005/08/21/bu\\_oil\\_reserves.jpg](http://www.sfgate.com/c/pictures/2005/08/21/bu_oil_reserves.jpg)
- [http://www.theresilientearth.com/files/images/us\\_biofuel\\_plan.jpg](http://www.theresilientearth.com/files/images/us_biofuel_plan.jpg)
- <http://www.transmitmedia.com/golfTDI/Images/b20.jpg>
- <http://www.window.state.tx.us/specialrpt/energy/renewable/images/exhibit13-7.png>
- All other sources and data available upon request