

**A Report on the Evaluation and  
Comparison Fuel Economy of High  
Performance Clean Diesel (HPCD) as  
Produced by  
EcoChem Alternative Fuels, LLC**

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## Background

The goal of this HPCD validation project is to compare various attributes of two diesel fuels, conventional #2 Ultra Low Sulfur Diesel (ULSD) and High Performance Clean Diesel (HPCD) as produced by EAF. The subjects of the two fuels are trash trucks and recycling trucks operated by the City of Marion.

## Experimental Design

The experiment compares the two fuels used in 9 trucks: first, operate on ULSD then secondly, on HPCD. Then, after a suitable length of time measure the various attributes of interest for each truck. This would lead to independent samples for which it is expected to find certain variability among the trucks - they all have different baseline fuel economy depending on age, maintenance history and other factors.

It was observed that a problem arises if this variability is large in that it could completely hide an important difference in the fuel economy between the two fuels. Uncorrected data observed a variability range to more than 100% in some cases. It was also observed that most of the drivers did not follow fueling protocol.

When we took a closer look at the data, we were able to identify “outliers” in the data sets. To eliminate these outliers we used a density grouping technique that identified the highest density of data points excluding “peak and valley” outliers. The “corrected” data was then compared and a consistent improvement was observed.

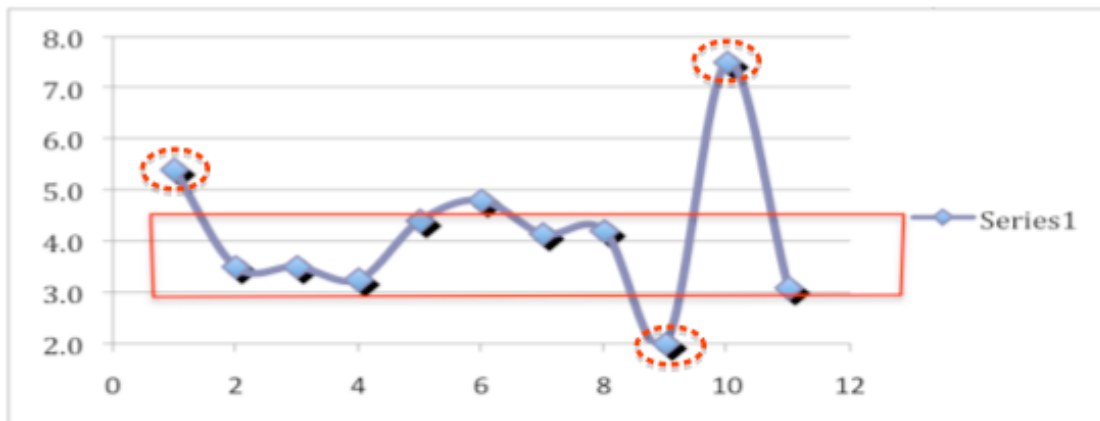


Chart 1, Density Grouping

In the City of Dublin, Ohio study, a paired design was used to remove some of this variability from the analysis so it is possible to more clearly see any difference in fuel economy of the fuels studied. We applied the seasonal variation to this study as a standard for all test vehicles.

## Subject Vehicles

There were 9 trucks owned and operated by The City of Marion (COM) that were utilized in this evaluation project. The same trucks were used throughout. The trucks were selected to be representative of the COM fleet including low mileage, medium mileage and large mileage trucks. The trucks all were used in normal day to day operations by the COM.

## **Data Management**

All data was collected had to adhere to a strict protocol designed and agreed to in a formal Validation Project Plan (VPP) before the evaluation process began. Important features of the data collection include:

1. All trucks were fueled and topped off by the driver of said truck
2. All data was recorded on log sheets by driver and forwarded by email to EcoChem for input to database and statistical analysis. A sample log sheet is shown in Appendix A.
3. Photographs were taken at the beginning of phase 2, 3 and 4 of each truck showing the odometer reading so that data could be verified. A sample photograph is shown in Appendix B.

## **The Periods of the Experiment**

As indicated previously, with the paired design the evaluation started with 9 trucks operating on both fuels. EAF disclosed that in their opinion it was likely that the trucks would show a reduced fuel economy for a period of time following the introduction of the HPCD. The theory behind this is that the HPCD does a “scrubbing” of engine parts and during that time frame it is possible that many particles will be released through the fuel, combustion and exhaust system thereby actually reducing performance. The length of this Cleansing phase was estimated to be about 3-4 weeks.

Therefore, the project was broken into 3 distinct periods: Baseline, Cleansing and Validation. In addition to allow for the cleansing period, this approach allowed for the determination of seasonal adjustment factors. This is shown in the table on the following page.

## **Period Primary Purpose Calendar Seasonal Adjustment**

Baseline performance: August 29 – September 25

Cleansing of fuel system and engine: September 26 – October 23

Validation comparative to baseline: October 24 – December 4

## **Data Collected and Calculations**

For each and every day a truck was fueled, data was recorded on a truck-specific log sheet with respect to:

- Date Vehicle ID
- Type of fuel pumped
- Gallons of fuel pumped (with a requirement that the tank be topped off)
- Odometer reading

All of the data was delivered to EcoChem and then entered on a weekly basis into an MS Excel database. The initial date of the project, August 29, 2011 was used to top off all the bus fuel tanks and record the initial mileage. Thereafter, the miles per gallon statistic (MPG) were calculated by dividing the difference between fuel filling stops by the gallons of fuel pumped. The descriptive statistics for the raw uncorrected MPG data are shown in Appendix B.

## Conclusions

When corrected for seasonal variations of 0.167 MPG, the HPCD fueled truck showed an average 0.25-0.84 or a 0.47 net improvement in fuel economy. On a percentage basis, this equates to 11%. These results are shown in table 1 below. The bottom section of each bar is the average MPG for each bus operating with ULSD. Although individual buses varied, in every case, the HPCD showed an improvement in fuel economy.

**The expected average increase in MPG by using HPCD in this fleet rather than conventional ULSD is 11%.**

Period	Baseline	Validation	
Truck #	ULSD	HPCD (Corrected)	% Difference
#1	4.0	4.8	+19.17%
#4	3.3	3.9	+13.36%
#14	1.9	2.2	+7.82%
#15	2.0	2.2	+6.54%
#16	1.6	1.9	+8.66%
#17	1.8	2.1	+6.61%
RC3	4.1	4.5	+7.02%
RC4	4.3	4.9	+11.72%
RC5	3.9	4.6	+18.11%

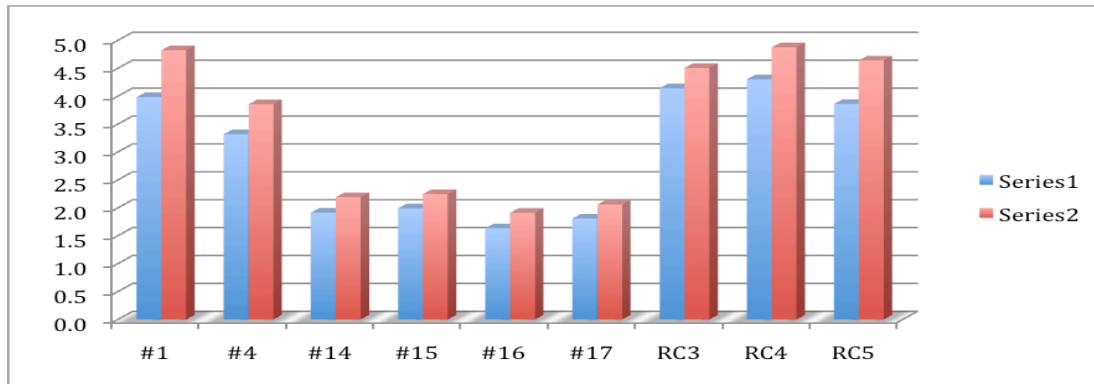
**Table 1, Corrected Results of Fuel Economy (MPG)**

Disclaimer: The results and conclusions contained herein are the opinions of EcoChem Alternative Fuels and not necessarily the City of Marion, Ohio.

## APPENDIX A

### Statistical Analysis and Results

Chart 2 shown below is the average MPG for each bus for each period of the project. These are for the 9 trucks that changed from operating on ULSD to HPCD. By inspection it can be seen that for every bus the fuel efficiency as measured by MPG using the HPCD was higher than the ULSD. It should be noted that the data in this chart has been corrected for seasonal variation by adding 0.167 MPG to each data point in the Validation period.



**Chart 2, Fuel Economy (MPG) by truck**

The results of the calculated MPG were then subjected to a series of statistical analysis including calculation of descriptive statistics and testing the difference between two means (the ULSD and HPCD) for paired data. The seasonally corrected means of the descriptive statistics were used to create the Table 2 below. In addition to looking at the original data, a new quantity can be calculated for each bus: the difference between the mean of the two fuels. Both confidence intervals and tests for paired analyses use this difference.

Period	Baseline	Validation	
Truck #	ULSD	HPCD (Corrected)	% Difference
#1	4.0	4.8	<b>+19.17%</b>
#4	3.3	3.9	<b>+13.36%</b>
#14	1.9	2.2	<b>+7.82%</b>
#15	2.0	2.2	<b>+6.54%</b>
#16	1.6	1.9	<b>+8.66%</b>
#17	1.8	2.1	<b>+6.61%</b>
RC3	4.1	4.5	<b>+7.02%</b>
RC4	4.3	4.9	<b>+11.72%</b>
RC5	3.9	4.6	<b>+18.11%</b>

**Table 2, Seasonally Corrected Means to Economies (MPG)**

## APPENDIX B

### Descriptive Statistics: MPG

The following tables show the descriptive statistics from the collected (uncorrected) baseline and the validation data excluding anomalies. A separate table is displayed for each truck. For the two evaluation periods (Base and Validation) the sample size (N), Mean, and Standard Deviation (StDev) are shown. The sample size relates to the number of distinct fueling dates for each period throughout the evaluation. There were between 15 and 30 data points for each truck. A scatterplot of the uncorrected means of the data is shown in Chart 3 below.

#### Truck #1

Period	N	Mean	St Dev
Base	8	3.984	0.345
Validation	9	4.648	0.322

#### Truck #4

Period	N	Mean	St Dev
Base	7	3.319	0.314
Validation	14	3.679	0.288

#### Truck #1

Period	N	Mean	St Dev
Base	12	1.914	0.102
Validation	18	2.016	0.107

#### Truck #15

Period	N	Mean	St Dev
Base	8	1.991	0.172
Validation	7	2.071	0.189

#### Truck #16

Period	N	Mean	St Dev
Base	13	1.634	0.141
Validation	19	1.735	0.143

#### Truck #17

Period	N	Mean	St Dev
Base	15	1.808	0.131
Validation	16	1.883	0.153

#### Truck #RC3

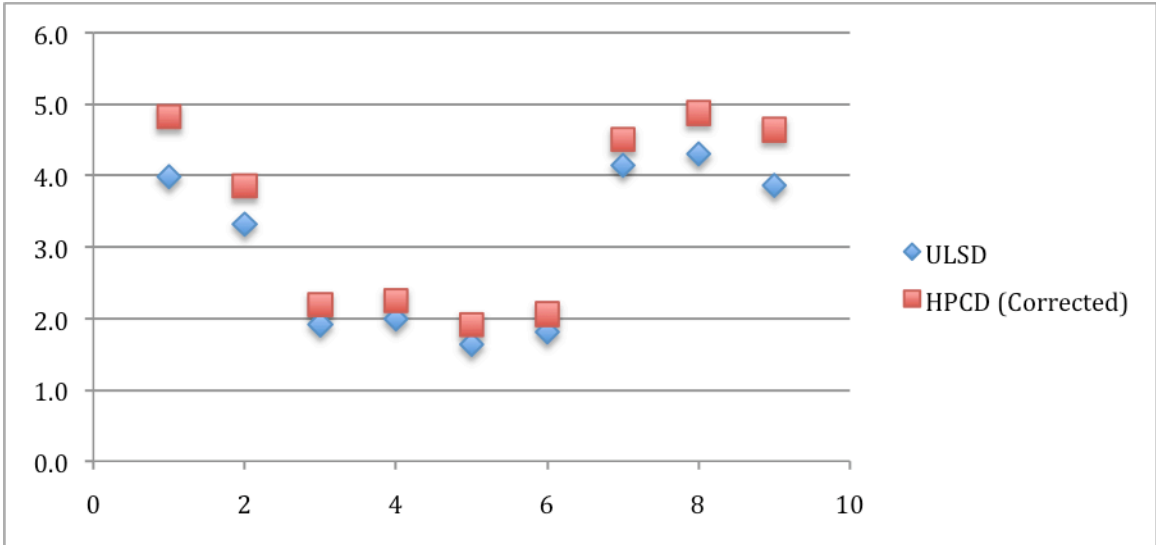
Period	N	Mean	St Dev
Base	8	4.142	0.342
Validation	17	4.329	0.295

#### Truck #RC4

Period	N	Mean	St Dev
Base	6	4.303	0.273
Validation	17	4.699	0.385

#### Truck #RC5

Period	N	Mean	St Dev
Base	8	3.862	0.607
Validation	9	4.464	0.794



**Chart 3 Scatter plot of trucks, ULSD vs HPCD**

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