NORTH CAROLINA DEPARTMENT OF PUBLIC INSTRUCTION

Division of Safe and Healthy Schools Support

Transportation Services

Propane School Bus Pilot Project

DRAFT - February, 2014

NORTH CAROLINA DEPARTMENT OF PUBLIC INSTRUCTION

Propane School Bus Pilot Project

DRAFT - February, 2014

EXECUTIVE SUMMARY

Introduction

Gregory Poole Equipment Company, the servicing and sales dealer for Blue Bird school buses, approached DPI Transportation Services about a pilot project to test the implementation of propane-powered school buses in North Carolina. They provided two school buses powered by a Ford 6.8L engine with the ROUSH CleanTech Liquid Propane Autogas Fuel System for use in North Carolina Local Education Agencies (LEAs). The LEAs were responsible for the cost of fuel. DPI provided guidance on the structure of the pilot project and compiled the information for this report. The first LEAs to test these vehicles were Brunswick (Bus #1001) and Union (Bus #1000). The buses then went to Nash-Rocky Mount schools and Chapel Hill-Carrboro City schools respectively.

Propane As a Fuel For School Buses

Propane is a by-product of natural gas processing and petroleum refining. It is produced domestically, which helps to reduce dependence on foreign oil. Propane usually costs significantly less than diesel, although more propane is required to travel the same distance as diesel as it contains less energy per gallon than diesel. Propane engines and today's clean diesel engines are both environmentally friendly. While each has pros and cons, there is not a clear benefit to one over the other from an emissions perspective.

Propane is also much closer to diesel than to Compressed Natural Gas (CNG) in logistical characteristics. Roush lists a system pressure of up to 312 psi, as opposed to CNG at 3600 psi, and thus is much more manageable from a dispensing standpoint. Propane buses can be refueled from mobile fuel trucks as well as underground and above ground tanks much like diesel. The massive compressor and space investments in CNG solutions are not necessary for a propane solution.

Test Results and Findings

Cost. In 2013 there was a 50 cent per gallon excise tax credit available to school districts. Because propane costs less than diesel on a per-gallon basis and more gallons of propane are required to travel the same number of miles as a diesel school bus, this tax credit is very significant. In terms of fuel, the propane bus was cheaper to operate than the diesel bus if the tax credit is considered. In terms of fuel, the diesel bus was cheaper to operate in the absence of a tax credit. Calculations based on average results are shown as follows. Further, a brief historical analysis indicates that the uncertainty and variability experienced with diesel costs are still present with propane. (NOTE: at this writing, propane costs have spiked and there is essentially no difference in price per gallon between the two fuels, except for the tax credit.)

Diesel $/gal	Propane $/gal (no Credit)	Propane $/gal (w/Tax Credit)	Propane Fuel Use Compared to Diesel	$/100 Miles - @ 7 mpg diesel	$/100 miles – propane (no credit)	$/100 miles – propane w/credit
$3.105	$1.951	$1.451	81.2% More Fuel	$44.36	$50.50	$37.56

Fueling Time. Operationally, the single biggest difference is in the time required for refueling. The refueling time was 3 or more times longer for propane than for an equivalent number of gallons of diesel. When compounded by the additional amount of fuel used, total man-hours required for refueling the propane bus to travel the same number of miles was 5 or more times that of the diesel bus. If the dispensing time issue can be solved, the sheer increased volume of fuel required points to additional man-hours.

OTHER OBSERVATIONS. Drivers and technical staff had a number of positive comments about the performance of the propane school bus.

- Cold Starts Easier / Engine warms up quicker
- Responsive acceleration
- Electronic automatic start is a nice feature
- The bus runs quietly
- There can be a smell in passenger compartment after refueling
- Fuel tank can only be filled ¾

Project Results and Findings

The results of the study are presented in the categories of Cost, Operational Observations, Maintenance Considerations and Environmental Issues. The cost of operations and the fueling operations are specific to North Carolina implementation of propane-powered school buses.

A. Cost of Fuel

Through December of 2013, propane had a $0.50 per gallon refundable federal excise tax credit available to consumers, including local education agencies (LEAs). As of February 2014, none of the counties involved has reported successfully receiving the credit for the fuel. One was rejected due to not completing the process correctly and at least one other chose not to apply for the credit because the cost of the time invested would be greater than the refund potential for such a small amount of fuel.

	Diesel $/gal Purchase Average	Propane $/gal (w/o Credit)	Propane $/gal (w/Credit)	Propane Fuel Use Compared to Diesel. Average Percentage
1. Union	3.089	1.807	1.307	91.19% More Fuel
2. Brunswick	3.157	2.039	1.539	79.33% More Fuel
3. Chapel Hill	3.070	2.006	1.506	85.51% More Fuel
Average (1-3)	**3.105**	**1.951**	**1.451**	
4. Nash*	3.076	1.664*	1.664*	68.87% More Fuel

*Nash likely ineligible for the credit as they did not dispense their own fuel

The first three LEAs all had "skid style" tanks dropped off at the transportation facility. The primary difference in cost between Union, Brunswick, and Chapel Hill was the timing of the purchases. Union ran the bus more, and purchased more fuel over the summer when prices were lower. Brunswick ran the bus much less, and made its primary outlay fairly late when the tank was picked up and when prices were much higher. In contrast, Nash contracted with a propane supplier to do remote fueling of the vehicles. Details of the cost and use for each LEA are shown below.

A.1 – Nash County Costs

Nash county received additional service as a company dispensed the fuel into their vehicle for them. According to documentation from Ferrell AutoGas regarding IRS regulations, "The credit can only be claimed by the entity that 'delivers the fuel into the fuel supply tank' of the motor vehicle." Because of this difference, the Nash cost data is excluded from the average pricing. (Reference 4)

A.2 - Cost Analysis

The average price of propane for Union, Brunswick, and Chapel Hill was $1.951 or $1.451 with the credit.

The average percentage (including Nash) of *additional* gallons of propane needed was 81.225%. That is, for every 100 gallons of diesel required, 181.225 gallons of propane were required to travel the same distance.

Cost comparison without a tax credit. The average break-even price of diesel would be $3.536 per gallon of diesel without the propane tax credit. Assuming a propane price of $1.951 per gallon as seen during the pilot project and a diesel price of $3.536 there would be no difference in fuel cost. The actual price of diesel during the test period was $3.10 per gallon. At those pricing levels, there is a savings of $0.436 per gallon of diesel used by operating diesel rather than propane. Cost advantage: Diesel

Cost comparison WITH a tax credit. The average break-even price of diesel, considering a $0.50 per gallon credit on the cost of propane would be $2.630 per gallon. Assuming a subsidized price of $1.451 per gallon for propane as seen during the pilot project and a diesel price of $2.63 there would be no difference in fuel cost. However, the actual cost of $3.10 per gallon of diesel points to a savings of $0.47 per gallon of diesel (if the diesel bus was run instead of the tax-credited propane). Cost advantage: Propane

Note: DEF (Diesel Exhaust Fluid) is a fluid necessary in modern diesel engines to reduce emissions. The fluid is expended at a rate of 2-3% of the diesel fuel usage and can be purchased (as of December 2013) for around $1.81 per gallon. That translates into a cost of 3.6 – 5.4 cents per gallon of diesel fuel. This impact was not wrapped into the fuel use calculations. The impact cost wise is only around 10% of either of the margins above.

A.3 – Impact of the Tax Credit

The large disparity over a 50 cent credit is due to the larger volume of propane used. From a fuel cost perspective in these LEAs, the cost effectiveness of diesel versus propane as a fuel was contingent on receipt of the tax credit.

Although the tax credit expired December 31, 2013, it has been renewed in the past, sometimes even retroactively, but that does not eliminate the risk of including a temporary tax credit in the calculations. In evaluating this risk, LEAs must consider the 250,000 mile, 20 year life cycle on school buses. The credit, even if renewed retroactively to cover 2014, has not yet existed for 10 years.

Further analysis about infrastructure costs is necessary to know whether an investment in infrastructure would make propane more cost effective for LEAs. A full analysis is beyond the scope of this test, but savings significant enough to replace much of the tax credit (or supplement it), on a per gallon basis, appear possible. From there it is a matter of return on investment when purchasing and maintaining a second type of fueling infrastructure.

A.4 – National Pricing

North Carolina LEAs have experienced major variances in the price of diesel fuel in recent years. That is a definite negative to a reliance on diesel fuel. Changing to propane as an alternative fuel, however, may not eliminate that uncertainty and variation.

Propane Texas spot pricing was up 52.15% January 2013 to December 2013. More surprising is that there were only two months of decline (-0.75% in May and -7.4% in June), and that from June to December the price was up 48.84%. Meanwhile, diesel fuel prices are down 1.87% over the same time period (-0.058 per gallon lower NY Harbor ULSD Futures). (Reference 5)

The North Carolina test LEAs saw variation in diesel between $2.89 and $3.32 (~14.9% spread up from the lowest) during the propane test period, 5/14/2013 through 12/31/2013, while in that same period propane purchased in those LEAs was between $1.61 and $2.24 (~39.1% spread up from the lower). Across all LEAs, over the whole 2013 calendar year, diesel varied up and down and landed at about the same price that it started.

Also of note is that the price of propane differs wildly across the country depending on proximity to producers, storage, and pipelines. While propane as of February 3, 2014 was $1.54/gal in Mont Belvieu Texas, the US Energy Information Administration has the cost of wholesale propane from terminals in NC at $2.951/gal and residential propane at $4.067/gal. The New York State Energy Research and Development Authority (NYSERDA) on February 4 showed a statewide price to residential customers of $3.714 a gallon ranging from $3.295 in the west to $4.14 in the north. A 25.6% higher price must be paid just by moving from west to north in the same state. (References 6 and 7)

A.5 – Historical Pricing

Currently we are coming off historic low propane prices and propane-to-diesel pricing ratios. According to information from the US Energy Information Administration, over the last 20 years the pricing ratio has been around 0.43 to 0.58 which means that, historically, propane has cost 43-58% as much per gallon as diesel if you get them both from the terminals with no transport costs. It is important to note that this is not the type of pricing and ratios NC LEAs see for delivered propane, it is only for historical comparative purposes. (Reference 5)

Since Mid-2012 the ratio has been much lower, around the 0.28 to 0.32 range, which makes propane fuel look much more attractive, compared to diesel. However, since July of 2013 the ratio has been headed steadily upward. In December the ratio was back to 0.42. (Reference 5)

While too soon to be certain the ratios will continue to rise, guidance on propane markets from the Propane Education and Research Council (PERC) suggests that it is likely. In the 2013 market outlook presented by PERC it is suggested that while structural changes in the market might keep the U.S. below historic price levels (as the U.S. becomes a net exporter), prices are not expected to remain as low as they have been during the transition period. (Reference 1)

Where propane prices stabilize after U.S. production and export capacity ramps up over the next two years will give a more complete picture of the cost effectiveness of using propane as a fuel.

B. Operational Observations

A primary concern of the LEAs involved thus far has been related to refueling. The statewide method of fueling school buses for decades has been to store diesel fuel (previously gasoline) centrally and then transport it to school bus parking locations (often at multiple schools in the district) during the day. A single individual operates the fuel truck, dispensing fuel to one bus after another, in an efficient manner. School bus drivers are not required to fuel their own buses and LEAs do not pay drivers for the additional time that this would require. This method of fueling raises some issues, as described below.

1. The LEAs do not currently have the ability of mobile refueling of propane. This is an issue which could be addressed via the purchase of propane dispensing fuel trucks.
2. Refueling when the engine, the fuel system, or the atmospheric temperatures are high takes longer. It was enough of a problem in the pilot test that one LEA substantially restricted the miles traveled by the test bus and another LEA eliminated normal mid-day refueling in favor of before-route morning refueling. Neither of these solutions is feasible as a multi-vehicle fleet solution.
3. Refueling was estimated to take significantly longer for each gallon of propane versus each gallon of diesel. Union suggested refueling took three times as long and had to be done twice as often. Nash reported 12 minutes for 35-40 gallons (by bobtail), and Chapel Hill reported approximately 15 minutes

for 30-35 gallons. Documentation from Blue Bird and Roush indicates a refueling rate of 5-7 gallons per minute which is higher than the LEAs have reported. (Reference 8)
The state's current fuel trucks are rated to dispense diesel to buses at 45 gallons per minute. Buses are required to accept at least 25 gallons per minute up to 80% capacity when tilted towards the inlet 5 degrees without cutting off. This documentation seems to confirm the observations seen in the field.

4. Fuel usage was approximately 68-100% higher in the propane bus. This meant refueling every day as opposed to every other day in most cases.

*Items 3 and 4 combine to make a significant manpower and infrastructure issue. For each propane bus in a fleet it would take 5 or more times the amount of man hours to refuel the bus to cover the same number of miles each day. Given the current refueling time constraints (while the buses are parked at school), it could mean additional refueling nozzles/trucks and the addition of fueling shifts before and/or after school. Of course, implementing a small number of propane school buses could likely be absorbed, but as the fleet expands, changes would definitely be required.

*All LEAs in the pilot reported extremely slow refueling (even the one refueling by bobtail). The rates seen were far below the potential fill rates of the pumps. However, at the time of this writing one of the new pilot LEAs who is having the bus refueled by an experienced propane refueling company is reporting a rate of 18-20 gallons per minute by propane tank-wagon truck (bobtail) with a 65 gallon per minute (gpm) pump. They also report a second truck with a lower gpm rated pump refilled proportionally slower. While not representative of the pilot counties' experiences this is a major area of concern logistically that looks like it could be remedied by improved infrastructure. That said, they have also reported only being able to refill to ¾ full on the fuel gauge and have not yet found a remedy. Since this is a different bus than this problem was reported on previously, there is still an unresolved issue with refueling and refueling rates.

Additional research suggests that the fuel fill tube diameter, pump rate potential, and tank pressure differentials are factors in determining fill rate. Since the pumps aren't living up to their potential fill rates there may be some restriction in the bus refueling system that could be remedied. If the propane buses could be fueled at a similar gpm rate as diesel, then 1.7-2 times as long for refueling for the same number of miles would seem much more reasonable than 5 or more times. If, as suggested by Gregory Poole and United Energy, the propane bus could theoretically be refueled at an even greater speed than diesel vehicles, then that further serves to eliminate this concern. As of this writing however, that has not been the experience of NC LEAs.

C. Maintenance Observations

As there are only two vehicles involved, both under warranty, this test is not able to ascertain maintenance costs of these vehicles.

In contrast to the newest diesel school buses being operated in North Carolina, propane vehicles do not have:

EGR (Exhaust Gas Recirculation) systems
DEF (Diesel Exhaust Fluid)
DPFs (Diesel Particulate Filters)

Also, on the preventive maintenance side, propane school buses offer the following advantages:

Smaller oil reservoir (7 quarts versus 17-20 in the current ISB 6.7L diesel engine)
Less expensive oil filters
Less expensive fuel filters and less frequent fuel filter changes

The above imply simpler and less expensive maintenance. However they have an engine, transmission, and associated components with which North Carolina LEAs have no experience. NC LEAs also have limited experience with the long term maintenance of the comparative diesel vehicles as 2010 emissions buses are still under warranty. As the propane buses have new engines, transmissions, and fuel systems, training to provide this new maintenance knowledge must be acquired.

Argonne National Labs' AFLEET tool for estimating costs and emissions on various vehicle types shows the maintenance and repair costs per mile of diesel and propane buses to be equivalent. (Reference 9)

Unfortunately a full assessment of a 2.5-year-old propane system (July 2011) for long term maintenance costs is not realistic.

C.1 - Longevity of the Bus and Major Components

North Carolina law requires buses to be on the road 20 years and 150,000 miles before replacement. Early replacement based on mileage is allowed if a bus reaches 250,000 miles between 15 and 19 years of age, or if a bus reaches 300,000 total miles at any age.

Many comparisons are made between gasoline and propane engines because they are of similar design and function. Comparisons regarding the lifespan of propane buses to diesel buses are not readily available, other than the EPA certification data which only lists useful life by engine class.

It seems plausible that propane engines fall somewhere between gasoline and diesel in longevity. This plausibility is based on the following: a similar combustion method to gasoline, hardened valves and valve seats for enhanced durability, and a cleaner burning fuel type.

Information from the generator industry says that diesel generators have a significantly greater useful life than propane generators.

At this point in time, there is insufficient data to draw fair conclusions about the longevity of the propane school bus and its power train, and whether it can meet the legislative requirements under the operational characteristics in North Carolina. This is a risk inherent in any new engine design, but it is a risk increased by the other new components and the new fuel type.

C.2 - Observations from the Pilot Project

The following are observations from the maintenance staff and bus drivers in the various LEAs participating in the pilot project.

- Cold starts were easier and the engine warms up quicker.
- The electronic automatic start was a nice feature (same feature which exists in cars where you turn the key or press a button and the computer takes care of the ignition sequence)
- Fumes can invade the passenger compartment after refueling (The driver is most likely noticing the smell of the ethyl mercaptan additive)
- The fuel tank can only be filled to ¾ full. When the tank is cold it will hold more fuel.
- The bus runs much quieter
- The bus has responsive acceleration, but when utilizing the performance, additional fuel consumption is very noticeable. "Need to be a conservative driver"
- One driver reported slower take-off and hill climbs than in a Blue Bird Diesel.
- Training on refueling indicates you need heavy gloves and a full face mask.

C.3 - Observations from Gloucester County Virginia

Gloucester County Public Schools in Virginia is the source of school bus maintenance and repair costs for diesel and propane school buses in the AFLEET tool. The director of transportation there made a number of observations.

- Fuel costs have risen and are, though perhaps temporarily, equal to diesel (Feb. 2014)
- The fuel credit is fairly simple to acquire from the federal government once registered, but the credit has now expired and is an unknown for budgeting
- Gloucester gets about half the fuel economy in propane buses (~4 MPG propane / ~8 MPG diesel)
- Tank capacity and refueling rate have caused Gloucester to keep the routes for the propane buses on the shorter side
- Maintenance and repair costs on propane buses are not lower and may be higher per mile
- Propane buses have been in operation there for five years, but not long enough to speak to longevity

This experience is similar to the NC LEA testing and provides some additional confirmable insights into longer term maintenance and repair costs.

D - Environmental Analysis:

The following table shows AFLEET results based on 10,000 miles using North Carolina data - 6.5 MPG diesel and 81.225% greater fuel use for propane. (Reference 9)

Fuel Type	Green House Gases (GHG) (short tons)	Vehicle Operation Air Pollutant Emissions (lb)							
		CO	NOx	PM10	PM10 (TBW)	PM2.5	PM2.5 (TBW)	VOC	VOC (Evap)
Diesel	22.3	59.1	18.1	0.3	1.7	0.3	0.4	2.1	0.0
Propane	22.6	1,668.1	46.3	0.2	1.1	0.2	0.3	28.2	1.9

EPA engine certification emissions levels, normalized for horsepower differences, yield results in grams per hour of operation. This figure is used rather than grams/bHP-hr since the propane engine has 360 HP to provide similar characteristics to the ISB 6.7L diesel at 220 HP. (Reference 3)

Manufacturer	Engine Family	OMNMHCE (Organic Material Non-Methane Hydrocarbon Equivalent) (g/hr)	CO (g/hr)	NOx (g/hr)
Cummins Inc. (Diesel) 220 HP	DCEXH0408BAP	4.4 (0.02 * 220 HP)	22	41.8
ROUSH (Propane) 360 HP	DRIIE06.8BW5	25.2 (0.07 * 360 HP)	792	28.8
		Propane 5.7 times greater	Propane 36 times greater	Diesel 1.45 times greater

Also, new engine certification includes deterioration factors. That is, how much worse the engines perform emissions-wise as they age. Below are the deteriorated emissions values. (Reference 5)

Manufacturer	Engine Family	OMNMHCE (Organic Material Non-Methane Hydrocarbon Equivalent) (g/hr)	CO (g/hr)	NOx (g/hr)
Cummins Inc. (Diesel) 220 HP	DCEXH0408BAP	7.26	31.9	48.66
ROUSH (Propane) 360 HP	DRIIE06.8BW5	47.88	1267.2	37.44
		Propane 6.6 times greater	Propane 39.7 times greater	Diesel 1.3 times greater

Note that the AFLEET tool draws the conclusion that propane produces more NOx than diesel. However, the EPA certification levels indicate that diesel produces more NOx than propane. It may result from the AFLEET tool being generic 2013 diesel and propane school buses while the EPA certifications are specific to the engine model.

Clearly the largest disparity between the engines is in CO output. Propane buses, while still within 2010 certification limits, are vastly higher than diesel CO output. Also of note is that emissions deterioration appears to be greater in the propane engine as it ages when compared with a diesel engine.

Further, the following data table was put out in 2009 by PERC based on 2010 emissions standards, the GREET model and the ANTARES Group study “Economic Analysis of Alternative Fuel School Buses”. (Reference 2)

Energy End-Use and Climate Change Comparison	Energy Use (MMBtu per bus per year)	Annual Life-cycle GHG Emissions per bus (kgCO2 equivalent per bus per year)		
Unit		**Upstream**	**End-use**	**Total**
Diesel	189	3,440	13,800	17,300
Propane	240	2,900	15,100	18,000
CNG	252	4,460	14,000	18,500
Gasoline	240	4,770	17,000	21,800

Even given that the figures above are based on 5.2 MPG on propane and 6.6 MPG on diesel which amounts to a difference of only 27% more fuel usage in propane, the results put out show that diesel does less environmental damage overall. If these numbers were refigured based on the actual fuel consumption disparity seen in this pilot project (over 80% more propane use compared to diesel) that the picture would appear to be even further in favor of diesel.

APPENDIX A - Individual Testing Results

The initial pilot test was conducted in four LEAs: Union County Public Schools, Brunswick County Schools, Chapel Hill – Carrboro City Schools and Nash-Rocky Mount Schools. Other LEAs have had some limited experience, running a test bus for shorter periods of time. (At this writing, Lincoln, Davidson and Alexander County Schools are preparing for a multi-week pilot test.) Results from these four tests were presented in Section II of this report. The information below provides a little more detail on the individual tests. In most situations there are more diesel miles than propane miles. This is because there is a much longer time period from which to extract diesel MPG data. For example, the propane bus might have run 2 weeks on a given route, but to reduce variability 4 weeks of diesel data on the same route was used.

LEAs were asked to conduct their test in accordance with procedures outlined in Appendix B. In all cases the driver remained the same, the driver used the propane bus instead of the diesel to run the same route for a period of time. The route did not change unless otherwise noted.

A. Test #1 – Union County Bus Number 1000

a. Time Periods

5/29/13 through 6/10/13 - Bus #1000 was put in service to run Route #443. The propane bus was put on this route as soon as it was ready to be placed in service, for the last few days of the regular school year. Route #443 was shortened substantially from previous weeks as early college ended.
The bus was also run during summer school June 17-27th and on a different summer school route July 8-10th – While useful for getting a feel for the vehicle, there was no diesel comparison available.

8/26/2013 through 9/5/2013 – Propane Bus runs in place of bus #443. Bus #207 runs its regular route.

9/9/2013 through 9/24/2013 – Propane Bus runs in place of bus #207. Bus #443 returns to its regular route. Diesel results documented for one month 9/16 – 10/15.

b. Results

i. **2012-13 Route #443 – Bus #1000 (Propane) / Bus #443 (2013 Thomas ISB 6.7L)**
Note: A portion of the route was eliminated by the time the propane bus started running as noted above.

	Miles	Gallons	MPG
Propane	324	92	3.522
Diesel	1324	192	6.896

The propane bus used 95.81% more fuel per mile.

ii. **2013-14 Route #443 – Bus #1000 (Propane) / Bus #443 (2013 Thomas ISB 6.7L)**

	Miles	Gallons	MPG
Propane	1015	292.30	3.472
Diesel	2508	355.00	7.064

The propane bus used 103% more fuel per mile.

iii. 2013-14 Route #207 – Bus #1000 (Propane) / Bus #207 (2013 Blue Bird ISB 6.7L)

	Miles	Gallons	MPG
Propane	1908	443.80	4.299
Diesel	3509	467.00	7.514

The propane bus used 74.77% more fuel per mile.

B. Test #2 – Brunswick County Bus Number #1001

a. Time Periods

5/27/13 through 5/31/13 - The period here is very short, but it ran in place of bus #325.

6/3/13 through 6/10/13 – The period here is very short, but it ran in place of bus #333.

Summer School July 29th through August 2nd – While useful for getting a feel for the vehicle, the time periods and variability do not allow for a diesel comparison.

9/9/2013 through 9/23/2013 – Propane Bus #1001 ran in place of bus #309

b. Comparative Results

i. 2012-13 Route #325 – Bus #1001 (Propane) / Bus #325 (2009 Thomas ISB 6.7L)

Only 3 fuelings covering 300 total miles.

	Miles	Gallons	MPG
Propane	300	74.5	4.027
Diesel	1502	196.9	7.628

The propane bus used 89.43% more fuel per mile. Because this sample was small this percentage was excluded from the average.

ii. 2012-13 Route #333 – Bus #1001 (Propane) / Bus #333 (2010 Thomas ISB 6.7L)

Only two fuelings covering 98 total miles.

	Miles	Gallons	MPG
Propane	98	27.6	3.564
Diesel	1337	204.0	6.554

The propane bus used 83.91% more fuel per mile. Because this sample was small this percentage was excluded from the average.

iii. 2013-14 Route #309 – Bus #1001 (Propane) / Bus #309 (2008 IC VT365E)

	Miles	Gallons	MPG
Propane	645	169.0	3.817
Diesel	3106	453.8	6.844

The propane bus used 79.33% more fuel per mile.

Test #3 – Chapel Hill – Carrboro City Schools Bus Number #1000

c. Time Periods

11/1/2013 through 11/19/2013 – Propane Bus ran in place of bus #65

11/25/2013 through 12/20/2013 – Propane Bus ran in place of bus #55. Bus #65 returned to its regular route.

d. Results

i. 2013-14 Route #65 – Bus #1000 (Propane) / Bus #65 (2014 Blue Bird ISB 6.7L)

	Miles	Gallons	MPG
Propane	932	244.5	3.812
Diesel	1854	263.6	7.033

The propane bus used 84.51% more fuel per mile.

ii. 2013-14 Route #55 – Bus #1000 (Propane) / Bus #55 (2013 Thomas ISB 6.7L)

	Miles	Gallons	MPG
Propane	1066	321.7	3.314
Diesel	2611	422.5	6.180

The propane bus used 86.50% more fuel per mile.

C. Test #3 – Nash County Bus Number #1001

a. Time Periods

10/10/2013 – 12/11/2013 Propane bus #1001 ran in place of Bus #68

b. Results

i. 2013-14 Route #68 – Bus 1000 (Propane) / Bus #68 (2013 Thomas ISB 6.7L)

	Miles	Gallons	MPG
Propane	3011.2	839.8	3.586
Diesel	1845	304.7	6.055

The propane bus used 68.87% more fuel per mile. This is the lowest in the test. Interestingly, in this driver's statement he noted that you need to drive conservatively in the propane bus to reduce fuel expenditures. (NOTE: The largest impacts to fuel economy outside engine are route and driver. Any vehicle driven more conservatively will show better fuel economy than otherwise.)

Appendix B - Propane Bus Test Protocol

Things you will need:
2 routes with two current E2 status route buses

Preferably these two buses should be newer model buses with ISB 6.7L engines (preferably with 2010+ emissions AKA has DEF fluid).

The routes should be based from wherever the propane refueling will occur, which should also be where diesel refueling of the existing bus occurs. Everything possible should be done to assure this, as refueling at an alternate location would alter the mileage and route characteristics.

2 drivers

The routes and the drivers should be stable going forward and backward in time (if possible). The routes do not need to have anything in common.

The Start of Each Route Test:

1. Fill the propane bus to full and get a correct mileage. This mileage will be the starting odometer reading for the test.
2. Take the first diesel bus off the road, refill it with fuel and record the correct mileage.
3. The propane bus should now take over the first route with the original driver of that route.

NOTE: The drivers will always drive their normal route. At no point should the driver change the route they are driving as it introduces too much variability.

During the Route Test:

4. The propane bus can be refilled as necessary. Every refueling the bus should be filled to full and a correct mileage and quantity of fuel entered into BSIP. Please note for logistical purposes how the refueling goes. Speed of refill, ease of use, etc.

At the End of Each Route Test:

5. The propane bus should be filled to full and correct mileage recorded.
6. The first diesel bus should return to its original route with its original driver.
7. The second diesel bus should be taken off the road refilled with fuel and correct mileage entered.
8. The propane bus should now take over the second route. The original driver of the second route should now be using the propane bus.
9. Switch dates should be recorded for reporting to DPI at the end of the test.

If you run into problems such as either of the drivers being sick or absent, or any of the buses involved having mechanical or other work done, that information needs to be noted so that it can be assessed for relevance by DPI. If either of the routes selected needs to be altered in any substantial way, please contact DPI to discuss how best to proceed with the test.

APPENDIX C - Information Sources

1. Propane Education and Research Council: http://www.propanecouncil.org/

www.propanecouncil.org/uploadedFiles/Council/Industry_Resources/PERC_MarketOutlook_2013.pdf

2. Propane Education and Research Council: http://www.propanecouncil.org/

www.propanecouncil.org/uploadedFiles/REP_15964%20Propane%20Reduces%20GHG%20Emissions%202009.pdf

3. U.S. Environmental Protection Agency: http://epa.gov

http://epa.gov/otaq/cert/eng-cert/on-hwy/on-hwy-2013b.xls

4. Ferrell Autogas: http://ferrellautogas.com

http://ferrellautogas.com/Resource_/PageResource/PricingAdvantages/Autogas_FAQ.pdf

5. Index Mundi: http://www.indexmundi.com

www.indexmundi.com/commodities/?commodity=propane

http://www.indexmundi.com/commodities/?commodity=diesel

Source data from: http://www.eia.gov

6. U.S. Energy Information Administration: http://www.eia.gov/

http://www.eia.gov/dnav/pet/pet_pri_wfr_dcus_snc_w.htm

7. New York State Energy Research and Development Authority: http://www.nyserda.ny.gov/

http://www.nyserda.ny.gov/Energy-Data-and-Prices-Planning-and-Policy/Energy-Prices-Data-and-Reports/Energy-Prices/Propane/Average-Propane-Prices.aspx

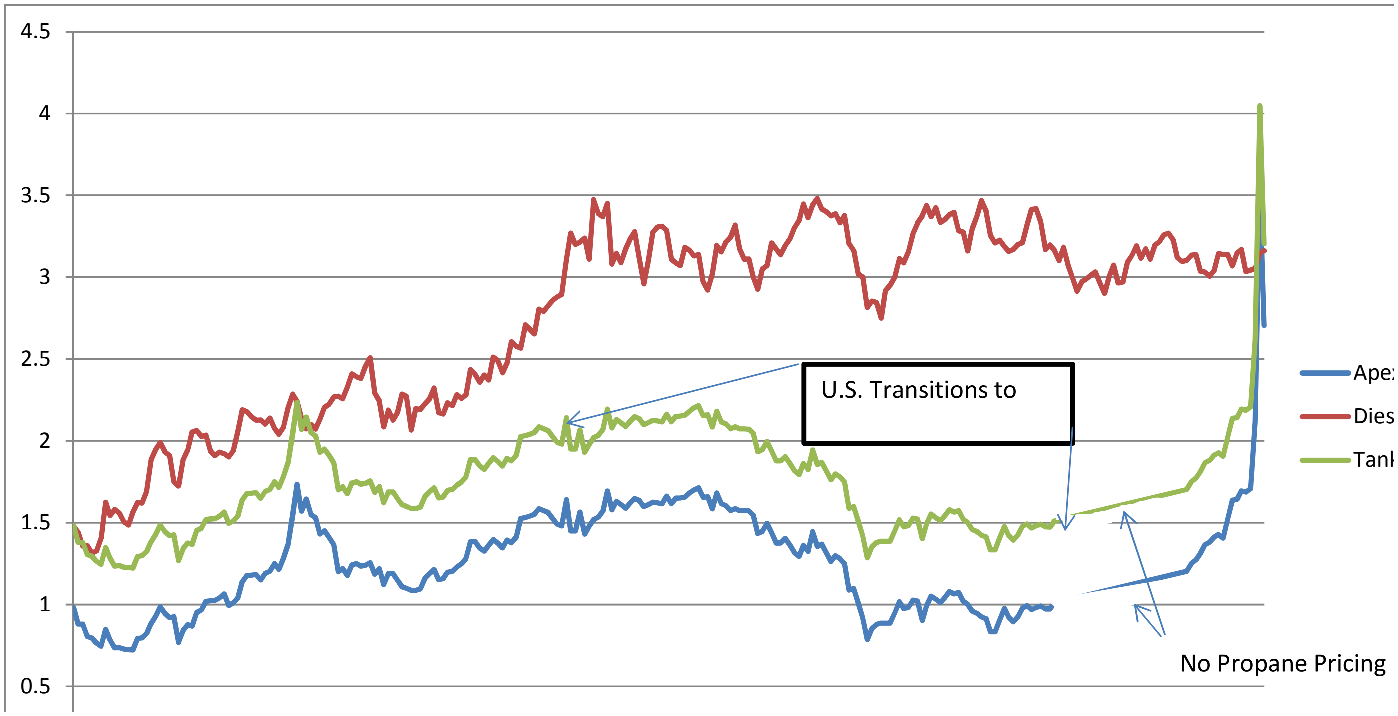
8. Roush Clean Tech: http://www.roushcleantech.com

http://www.roushcleantech.com/sites/all/themes/roushcleantech/pdf/ROUSHcleantech_BB_TrainingPowerpoint.pdf

9. Argonne National Laboratory: http://www.anl.gov/

http://greet.es.anl.gov/afleet

Appendix D – History of Diesel and Propane Prices



Note: Tank wagon delivery pricing provided by Energy United. Diesel state contract is for tanker loads, assuming infrastructure to store 7500 gallons.