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Case Study – Propane School Bus Fleets

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This report summarizes the use of propane gas in school buses deployed by five school districts that, in some cases, were funded in part by the American Recovery and Reinvestment Act of 2009. The fleets discussed in this case study provided critical assistance in information collection, as did the local Clean Cities coordinators who worked closely with these fleets to implement these projects. On behalf of the U.S. Department of Energy's (DOE's) Clean Cities program, this report was developed for Argonne National Laboratory by Energetics, Inc.

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Contents

Case Study – Propane School Bus Fleets

Background

> **MAJOR FINDINGS**
>
> - Cost Savings – Some of the school districts in this study save nearly 50% on a cost per mile basis for fuel and maintenance relative to diesel.
> - Payback Period – The incremental cost of the propane buses and fueling infrastructure can be recouped in 3–8 years.
> - Improved Efficiency – The newest propane engine technologies are more efficient than older technologies still in use.
> - Typical Usage – Propane buses in this case study traveled around 14,700 miles per year on average and achieved fuel economy of 7.2 miles per diesel gallon equivalent (DGE).
> - Energy & Environmental Impact – The total petroleum displacement was 212,000 DGE per year for these 110 buses, while greenhouse gas (GHG) reductions were approximately 770 tons per year.

Propane is a promising alternative fuel for school buses because it is widely available, even in rural areas, and it can cost less than diesel or gasoline. Propane is generically known as liquefied petroleum gas (LPG), and is sometimes marketed as propane "autogas" when used for vehicle applications. This case study highlights five school districts that used propane-fueled school buses successfully. Four of the districts are in Texas: *Alvin Independent School District*, *Dallas County Schools*, *Northside Independent School District*; and *Ysleta Independent School District*. The fifth district, *Gloucester County Schools*, is in Virginia. This case study compiles information from these five Texas and Virginia school districts and broadly discusses their experiences, lessons learned, and considerations for deployment in other fleets.

The Texas fleets were funded in part by Federal grants under the American Recovery and Reinvestment Act (Recovery Act) of 2009. The Department of Energy's Vehicle Technologies Office received almost $300 million in Recovery Act funding to support 25 Clean Cities projects to reduce petroleum consumption and emissions through the deployment of alternative fuel and advanced technology vehicles and fueling stations across the United States. These buses were deployed as part of the Texas Propane Fleet Pilot Program, a $45.2 million Recovery Act project run by the Railroad Commission of Texas that included more than 600 propane vehicles and 30 propane fueling stations. Similarly, the Virginia fleet received funding as part of the Clean School Bus USA Middle Peninsula Project, a U.S. Environmental Protection Agency (EPA)/Virginia Department of Environmental Quality program. The Mid-Atlantic Regional Air Management Association also supported the purchase of the propane school buses with a leveraged funding contribution.

Propane has been used as an alternative fuel in school bus applications for many years, particularly in areas of the country with relatively low-cost propane. In the early 2000s, the only original equipment manufacturer (OEM) propane vehicle available in the school bus market was discontinued because production ceased for the engine and chassis upon which it was based, and suitable replacements were not immediately available. As a result, school bus fleets were unable to maintain or expand their propane bus purchases. The recent introduction of new school bus product lines with improved engine technologies has revitalized interest in propane as a low-cost option for school bus fleets. These new buses incorporate more advanced fuel injection systems that are more efficient and more reliable than their predecessors. The new generation of buses was first introduced in 2008 and was quickly adopted by several school bus fleets, as described below.

In Texas, *Alvin Independent School District (ISD)* is located in the Houston area (northern Brazoria County). It began purchasing propane buses in 1980. *Dallas County Schools* is an intermediate educational agency in the Dallas metropolitan area that serves the 14 independent school districts in Dallas County. The *Dallas County Schools* bus fleet is one of the largest in the nation and is the largest propane school bus fleet in Texas. *Northside ISD* serves a portion of the San Antonio metropolitan area and has the second-largest propane school bus fleet in Texas. At one point, the majority of the *Northside ISD* bus fleet was propane-powered (garnering it a Clean Cities National Partner Award in 2001). However, the lack of propane school bus products caused Northside to purchase conventional school bus technologies for a number of years. *Northside ISD* maintained its interest in propane during this time, and it was the first school district in the nation to purchase the Blue Bird Vision propane bus when it was made available in 2008. The Blue Bird Vision bus engine uses a newly developed liquid propane injection (LPI) system that improves engine performance relative to previous propane technologies. *Ysleta ISD* serves a portion of the El Paso metropolitan area and had not operated any propane buses prior to receiving Recovery Act funding.

Figure 1. Alvin ISD propane school bus and bus depot. *Alvin ISD.*

Figure 2. Gloucester County officials with Bluebird Vision propane bus. *Virginia Clean Cities.*

In Virginia, *Gloucester County Schools* serves the Hampton Roads area (Williamsburg/Newport News). It was the first school district in the state to implement propane in its school bus fleet. Table 1 summarizes the major characteristics of each school district, including the total number of propane buses and fueling stations.

Table 1. Basic Characteristics of School Districts in Case Study.

School District	Area Served (square miles)	Students Served	Total Bus Fleet	Propane Bus Fleet	Yearly Fleet Miles Traveled (millions)	Yearly Fleet Fuel Use (thousands of gallons)	Year Fleet First Used Propane	Number of Onsite Propane Stations
Alvin (TX)	250	18,200	192	112	2	500	1980	1
Dallas (TX)	908	425,000	1,597	560	20	2,700	1994	7
Northside (TX)	355	100,000	831	355	9	1,700	1980	5
Ysleta (TX)	60	44,000	200	30	2	300	2010	1
Gloucester (VA)	200	5,500	90	5	1	240	2009	1

Motivation for Adopting Propane

All of the school districts chose propane for financial reasons. Fleets are able to secure advantageous fuel prices for propane to achieve significant operating cost savings. These districts also mentioned the importance of emission reductions with propane, but emission reductions were secondary to cost reductions as a motivator.

Financial Benefits

As will be described in more detail later in this case study, these fleets have seen financial benefits as a result of using propane buses. These fleets have saved between $400 and $3,000 per propane bus per year, with the range of savings dependent on the fuel prices and the maintenance cost savings realized. Maintenance cost savings for propane engines can potentially come from several areas, including less-frequent oil changes and less-complicated emission control systems that do not use diesel exhaust fluid.

Alvin ISD representatives noted the low fuel cost and lower maintenance costs as considerations for its propane school bus use. The school district estimated its annual fuel cost savings with propane to be about $330,000, or just under $3,000 per propane bus per year. *Alvin ISD* noted that the maintenance costs for the propane buses were lower overall than for the diesel buses. In an examination of its vehicle maintenance data for January through December 2010, *Alvin ISD* found that maintenance costs of its 2010 propane buses were significantly lower than its 2006 diesel buses, as shown in Figure 3. This can partially be attributed to the age discrepancy between the buses, but it can also be attributed to the lower maintenance requirements for the propane buses. *Alvin ISD* is seeing extended oil change intervals of 10,000 miles for the propane buses, relative to the 6,000–7,000-mile interval for the diesel buses. Anecdotally, *Alvin ISD* observed lower tire wear on the front steer axle and noted that the lower weight of the propane engine might make this another potential area for maintenance cost savings.

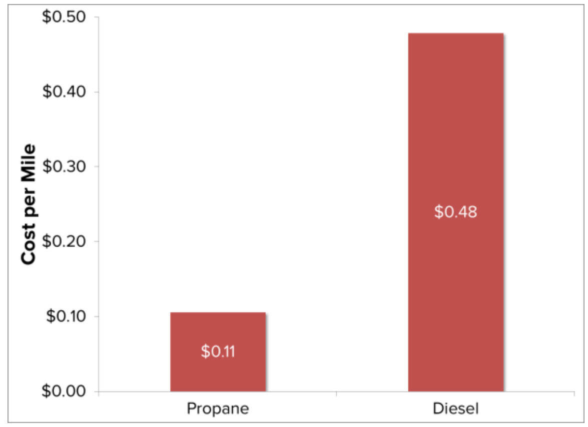

Figure 3. Maintenance costs per mile for Alvin propane and diesel buses.

Dallas County Schools noted the fuel cost savings available to fleets using propane school buses, observing a historical price differential of 30% for propane relative to gasoline. The school district estimated it is saving about $1.5 million in fuel costs annually through the use of propane, or just under $3,000 per propane bus per year. Its transportation director, Tim Jones, stated, "The OEM LPG bus and new retrofit LPG systems are very exciting for DCS to renew our LPG lower emission fleet."

Northside ISD is also seeing financial benefits from its propane use, estimating an annual fuel cost savings of about $320,000. This translates to a savings of just under $1,000 per propane bus per year. *Northside ISD* also noted that propane use has significantly reduced its maintenance costs. One maintenance cost reduction is related to oil change intervals: using oil analysis, *Northside ISD* has been able to lengthen the oil change intervals for its propane buses.

Ysleta ISD's Transportation Supervisor, Frances Yepez, indicated that the school district is interested in using propane for its environmental benefits, as well as its financial benefits. The district is still developing an internal financial analysis to assess the financial benefits.

Gloucester County Schools began investigating propane in 2008 as petroleum fuel prices increased rapidly. "We've been looking for ways to save money," stated Roger Kelly, Director of Transportation for *Gloucester County Schools*. When the five propane buses in this study were compared with five diesel buses of similar vintage in the school district's fleet for the first year of the propane bus operations, Gloucester calculated a savings of over $2,000 for fuel and maintenance costs, or around $400 per propane bus per year. In a sample of maintenance data *Gloucester* collected between October 2009 and December 2010, the school district found that it was saving roughly 6 cents per mile in maintenance costs. In this case, the *Gloucester* diesel buses were 2009 models and its propane buses were 2010 models; this made for a reasonable comparison of maintenance costs for buses of similar age but differing technology, as Figure 4 shows. Less-frequent oil changes were among the maintenance cost benefits *Gloucester* observed.

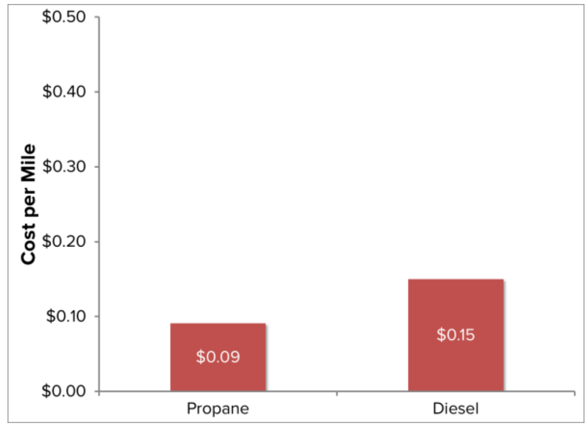

Figure 4. Maintenance costs per mile for Gloucester propane and diesel buses.

Environmental and Energy Benefits

The use of propane in vehicle applications can reduce GHG emissions while also reducing dependence on petroleum. The Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool developed by Argonne National Laboratory for the Clean Cities program estimates that a propane vehicle can reduce lifecycle GHG emissions by 15% if it has the same fuel economy as a diesel vehicle (less if the fuel economy for propane is lower) and can reduce lifecycle petroleum use by 99% when that propane is derived from natural gas processing. Currently, 70% of propane production is from natural gas, while the remaining 30% is produced through petroleum refining. Relative to model year 2010 and newer diesel buses, new propane buses do not offer significant air quality benefits, but replacement of older diesel buses with these propane buses can reduce air pollutant emissions considerably.

Alvin ISD identified the environmental impacts of the propane buses as a benefit. The Houston area (where *Alvin ISD* is located) is in non-attainment for ozone, so the use of new propane buses as compared to the older diesel buses is beneficial. *Northside ISD* also noted the environmental benefits of propane as a positive aspect of its alternative fuel program. The school district specifically cited the reduction of hydrocarbon emissions compared to older buses as a particular benefit. Similarly, *Ysleta ISD's* Transportation Supervisor indicated that the school district is interested in using propane for its environmental benefits, and *Gloucester County Schools* cited the lower GHG emissions and domestic sourcing of propane as major benefits.

Project-Specific Activities

Vehicles Deployed

In total, the five school bus fleets in this case study purchased 110 propane school buses with support from Recovery Act or other federal funds. All fleets purchased the Blue Bird Vision bus, because it was the primary OEM propane bus product on the market at the time.[i] (1) The specific number of buses purchased by each school district is listed below:

- *Alvin ISD*: 28 buses
- *Dallas County Schools*: 10 buses
- *Northside ISD*: 59 buses
- *Ysleta ISD*: 8 buses
- *Gloucester County Schools*: 5 buses

Figure 5. Blue Bird Vision propane bus in Gloucester County. *Virginia Clean Cities.*

Figure 6. Refueling of Alvin ISD propane bus with propane tank in background. *Texas Railroad Commission.*

Infrastructure Deployed

All of the school districts in this project have onsite fueling available for their propane bus fleets. Several of the school districts received Recovery Act funding for propane infrastructure. *Northside ISD* and *Ysleta ISD* constructed fueling stations, while *Alvin ISD* used its Recovery Act funding to upgrade its existing station. *Alvin ISD* has one onsite fueling station, which was upgraded with a higher-volume pump and dispenser to save time and money in refueling the buses. Juan Mejias, *Alvin ISD's* fleet maintenance manager, stated that the upgraded facility "allowed us to refuel more buses at once and practically cut fueling time in half."

Dallas County Schools has eight propane fueling stations onsite at various depots, while *Northside ISD* has propane fueling stations at five of its locations. *Ysleta ISD* has one onsite propane fueling station. *Ysleta ISD* recommends that other fleets invest in dedicated onsite fueling, because the fuel supplier provides a good price for the fuel and because the fleet has lower labor costs when drivers do not have to wait in line at a public fueling station to fuel the buses. A local propane supplier furnished the equipment for an onsite 1,000-gallon capacity fueling station for *Gloucester County Schools* to use for its propane buses. The school system only paid for the concrete slab on which the station equipment was mounted, which made adoption of the propane buses more cost effective.[ii]

Training for Drivers and Technicians

Fleets in this case study conducted training for technicians and drivers to improve the level of success for the vehicle deployments. Several of the Texas fleets were already experienced with using propane as a fuel for their buses, which facilitated the rapid deployment of these vehicles.

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[1] These endnotes indicate the availability of supplemental information at the end of the document to provide additional perspective or more technical explanations.

The Texas Railroad Commission offered an extensive training program as part of the overall propane deployment project, providing information about propane vehicles to drivers, mechanics, and local emergency responders.[iii] The Railroad Commission and the Propane Education and Research Council have also developed safety, technical, and diagnostic online training modules for propane fuel systems to supplement the other training efforts, which both *Alvin ISD* and *Northside ISD* said were useful. In addition, *Alvin ISD* noted that shop technician training for operation and maintenance of propane buses is readily available from the bus manufacturers. The videos and other material for the training programs ("Fuel Saving Tips for Propane School Buses" and "Safely Refueling Propane-Powered School Buses") are available online from the Texas Railroad Commission. *Gloucester County Schools* provided education to its mechanics partly to overcome their fear of the new propane technology. This effort was successful in educating the technicians about the safety of propane vehicles, particularly with regards to propane tanks.

Data Analysis Results

The five fleets operating the 110 school buses described in this case study provided data sets on vehicle operation during 2010, 2011, and 2012.[iv] This information was analyzed to provide some insight into the performance of these vehicles (fuel economy, fuel cost per mile, and environmental performance). In general, the propane buses were used in much the same way as the conventional diesel buses were used, achieved generally similar fuel economy performance (on an energy equivalent basis), and provided notable petroleum displacement and GHG emission reductions. Most importantly, the fuel cost savings available to these fleets can produce reasonable payback of the upfront capital costs for the propane vehicles, depending on the price differential between propane and diesel.

Summary of Vehicle Operational Data

Figure 7 summarizes the basic operational data for the 110 propane school buses considered in this case study on a per-bus basis. In addition, Figure 7 shows the seasonal trends in

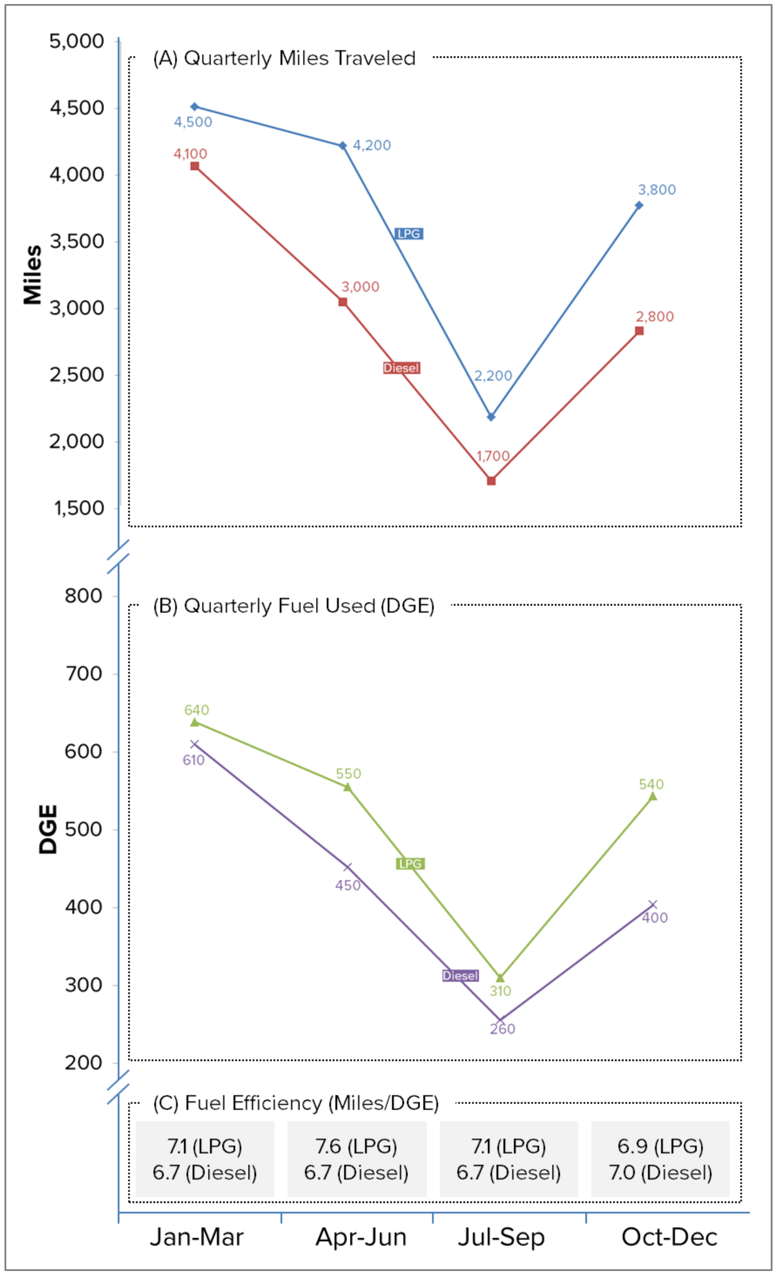

Figure 7. Summary of quarterly operational data (miles, fuel use, fuel economy) per bus.

mileage accumulation that might be expected with school buses, particularly the low vehicle usage over the summer months because school is not in session and the buses are used only occasionally. This results in low miles traveled and fuel used during this period (July through September in the figure). Diesel bus use trends (vehicle miles traveled [VMT] and fuel use) generally exhibit similar seasonal patterns to propane bus use. Because several higher mileage fleets did not provide information on their diesel buses, there was some differential between the propane and diesel bus annual VMT. Specifically, the propane buses traveled around 14,700 miles per year, while the comparable diesel buses that reported data traveled about 11,700 miles per year.[v] The propane buses used around 2,000 DGE of propane per year, and the diesel buses used around 1,700 DGE per year.[vi] The fuel economy information is also shown in Figure 7, which shows that the propane buses achieved around 7.2 miles per DGE, and the diesel buses achieved around 6.8 miles per diesel gallon.[vii]

Environmental and Energy Impact Data

Petroleum displacement and GHG reductions are important benefits of propane vehicles. The operational data were used in the AFLEET Tool to estimate the reductions in petroleum use and GHG emissions for these propane vehicles. Figure 8 summarizes the total petroleum displacement and GHG reductions of the 110 propane vehicles.[viii] The total petroleum displacement was 212,000 DGE per year for these vehicles, while GHG reductions were approximately 770 tons per year.[ix]

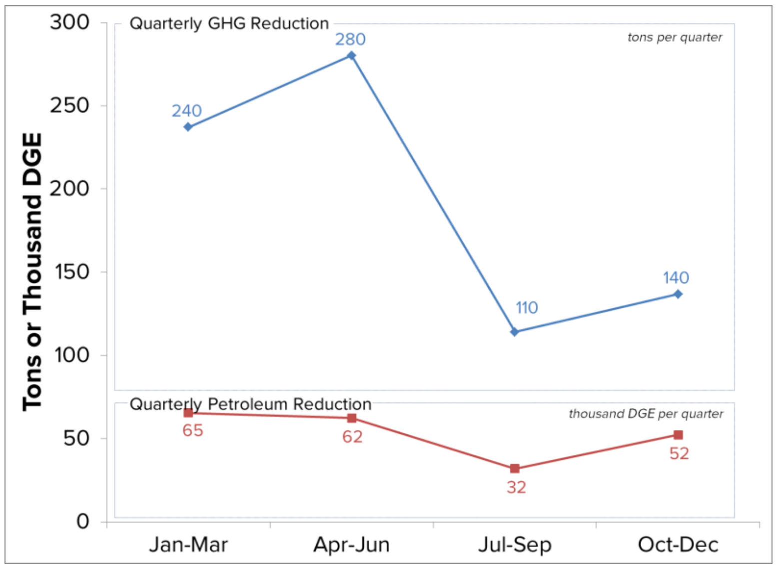

Figure 8. Summary of total petroleum displacement and GHG reductions (110 buses).

Business Case Data

Unlike light-duty vehicles that are often purchased for personal reasons, heavy-duty vehicles (such as these school buses) are purchased by fleets to do a job. This means that investments in new technologies, such as propane, must pay for themselves over time to be a viable choice. Lower fuel prices and lower maintenance costs for propane relative to diesel provide this payback opportunity and save the fleets considerable amounts of money after the capital costs for the vehicles and fueling stations are recouped.[x] In some cases, fuel suppliers may install propane fueling stations at no cost to the fleet if fuel purchase commitments are made, which improves the cost savings potential even further. The fleets in this case study provided information that allows some assessment of the cost savings potential for these school buses.

Figure 9 presents the average cost per mile for these school bus fleets, demonstrating the magnitude of fuel cost savings possible with lower propane prices. The April 2013 issue of the *Clean Cities Alternative Fuel Price Report* shows that propane at private stations averages $1.85 per gallon ($2.85 per DGE), and diesel at private stations costs $3.94 per gallon. As Figure 9 illustrates, the average cost differential between propane and diesel for these fleets at these fuel price levels was around $0.18 per mile.[xi]

The major capital costs of implementing propane school buses are the incremental cost of the bus and the cost of the fueling station. The fleets profiled received outside funding to pay for much of the incremental vehicle and fueling station costs.

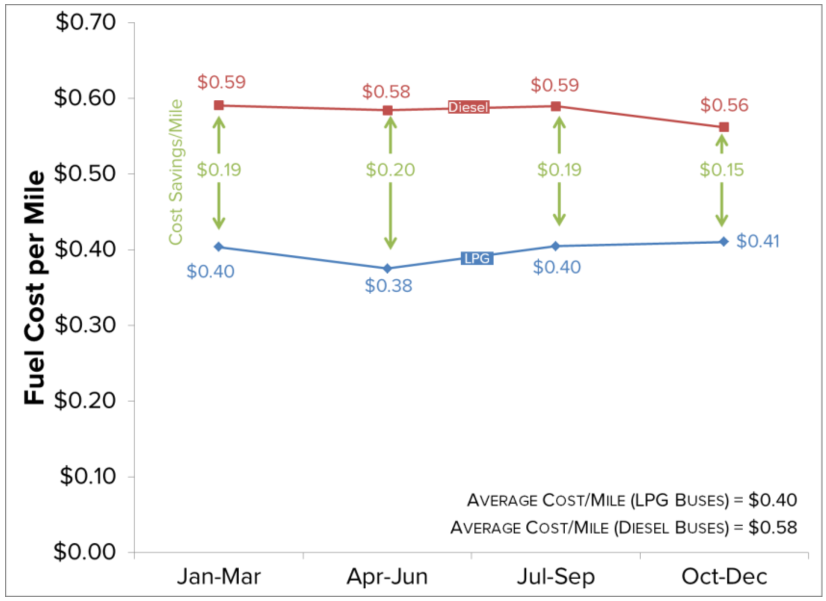

Figure 9. Fuel cost per mile for propane and diesel school buses.

Based on information from the fleets in this study, the incremental cost of each bus purchased by the Texas fleets was $16,300, while the incremental cost for the Virginia buses was $15,900.

- *Alvin ISD*: total of $456,400 in award funding for incremental vehicle costs; $16,300 per bus
- *Dallas County Schools*: total of $163,000 in award funding for incremental vehicle costs; $16,300 per bus
- *Northside ISD*: total of $961,700 in award funding for incremental vehicle costs; $16,300 per bus
- *Ysleta ISD*: total of $130,400 in award funding for incremental vehicle costs; $16,300 per bus
- *Gloucester County Schools*: total of $79,500 in award funding for incremental vehicle costs; $15,900 per bus

In addition, *Alvin ISD*, *Northside ISD*, and *Ysleta ISD* each built a propane station and received Recovery Act funding in the range of $90,000 to $220,000 for each one. In the overall Texas Railroad Commission project, fueling station costs for the school districts involved ranged from $55,000 to $250,000. The variance in cost can be attributed to several factors, including the choice of upgrading a facility versus constructing a new one and the characteristics of the fueling facility (number of dispensers, size of storage tanks, and other features). Stations with more storage capacity and additional features (such as public access card readers) will have higher costs overall. As noted above, it is possible to obtain fueling facilities from a local propane distributor at no upfront cost: this can be done if the fleet is able to enter into a long-term contract for fuel with that distributor.

Table 2. Example Business Case Analysis – Six Scenarios (dollars in thousands).

Parameter	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Propane fleet size	10	10	10	10	60	60
Number of fueling stations	0	0	1	1	1	1
VMT Level (average or high)	Average	High	Average	High	Average	High
Cost per station	N/A	N/A	$55	$55	$250	$250
Total vehicle incremental cost	$163	$163	$163	$163	$978	$978
Total fueling station cost	N/A	N/A	$55	$55	$250	$250
Total capital cost	$163	$163	$218	$218	$1,228	$1,228
Fuel cost savings per vehicle	$3	$4	$3	$4	$3	$4
Yearly fuel savings with propane versus diesel	$27	$45	$27	$45	$163	$269
Simple payback (years)	**6.0**	**3.6**	**8.0**	**4.9**	**7.6**	**4.6**

At a minimum, a favorable business case for a propane bus project would require yearly fuel and maintenance cost savings that are sufficient to repay the initial capital costs of the vehicles and stations in a timeframe acceptable to the bus fleet without outside funding.[xii] This can be difficult for school bus fleets because of their limited budgets and low annual fuel use (relative to other more favorable alternative fuel applications, such as refuse haulers, which use significantly more fuel and can generate much higher annual cost savings). Propane can be a good option for some school bus fleets because of the large incremental cost savings per gallon of fuel, which enables more rapid payback at the fuel use rates typical of school bus operation. Table 2 explores the simple payback results of several business case scenarios, using the parameters for capital cost, fuel cost savings, and maintenance cost savings from fleet averages in this case study.[xiii]

In this table, two different fuel cost savings figures were used to provide boundaries on the possible payback periods. Cases 1, 3, and 5 used the annual propane bus VMT and fuel economy averaged across the fleets in the case study, while Cases 2, 4, and 6 used the annual propane VMT from the highest VMT fleet in this study with the average propane bus fuel economy. In both situations, these values are compared to diesel fuel use, which was calculated by using the average or high propane bus VMT and the average diesel bus fuel economy from the case study.[xiv] In both cases, fuel costs were calculated by using publically available information from the April 2013 Alternative Fuel Price Report on propane and diesel fuel prices at private stations. Because diesel fuel prices have risen as compared to when the fleets reported, while propane prices remained stable, this incremental fuel price savings has increased, resulting in more favorable economics.

In the simplest business case scenarios (Cases 1 and 2 in Table 2), a fleet would purchase propane buses and use existing or shared fueling infrastructure. In this case, only vehicle incremental costs would need to be recouped from fuel cost savings. Here, a simple payback at the average VMT is around 6 years. At the high VMT level, a payback of 4 years can be achieved.[xv]

If the fleet constructs a new fueling station, the business case analysis becomes more complex. Two fueling station capital costs were considered: the lowest-cost ($55,000) and highest-cost ($250,000) stations purchased with Recovery Act funds in this deployment project. Two fleet sizes were also considered: a small fleet of 10 propane buses and a larger fleet of 60 propane buses. These variations in capital cost and fleet size were combined with the low- and high-fuel-use cases to calculate the potential payback opportunities in a variety of scenarios.

In Cases 3 through 6, payback periods for capital costs of the buses and fueling stations under these assumptions range from 5–8 years. These are within the useful lifetime of the average school bus of around 12–15 years, so fleets have an opportunity to achieve further cost savings once the capital costs have been repaid, if the fleet keeps the buses for their full useful life.[xvi]

Table 3. Example Business Case Analysis – Six Scenarios including Vehicle Maintenance Savings (dollars in thousands).

Parameter	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Propane fleet size	10	10	10	10	60	60
Number of fueling stations	0	0	1	1	1	1
VMT Level (average or high)	Average	High	Average	High	Average	High
Cost per station	N/A	N/A	$55	$55	$250	$250
Total vehicle incremental cost	$163	$163	$163	$163	$978	$978
Total fueling station cost	N/A	N/A	$55	$55	$250	$250
Total capital cost	$163	$163	$218	$218	$1,228	$1,228
Fuel and maintenance cost savings per vehicle	$4	$6	$4	$6	$4	$6
Yearly fuel savings with propane versus diesel	$36	$59	$36	$59	$215	$355
Simple payback (years)	**4.6**	**2.8**	**6.1**	**3.7**	**5.7**	**3.5**

As noted from the fleet feedback discussed earlier, propane buses can have lower maintenance costs per mile than diesel buses. The amount of savings may vary depending on the maintenance practices of the particular fleet and the characteristics of the buses being used (recommended maintenance intervals). To examine the impact of maintenance cost savings on total cost payback, the maintenance cost per mile for the *Gloucester County* LPI propane buses ($0.09/mile) and diesel buses ($0.15/mile) was incorporated in the fuel cost savings presented in Table 2.[xvii] With these maintenance costs incorporated as shown in Table 3, payback periods are shorter, at around 3–6 years (versus the 4–8 years in Table 2 for the fuel cost savings only).

Lessons Learned and Future Plans

All of the fleets included in this case study are interested in continuing their use of propane school buses, chiefly because of the cost savings available to the school districts.

Alvin ISD

Alvin ISD plans to continue to expand its propane fleet to take advantage of the favorable economics. Mr. Mejias referred to propane as the "perfect fuel to use for a school bus" because of its performance, cost, and maintenance characteristics. Drivers for *Alvin ISD* have expressed a preference for using the propane buses rather than the conventional diesel ones. "When we take the [propane] buses out of rotation for routine maintenance and drivers use the spare diesel buses, they come back and ask us how soon they can get their propane bus back," stated Mr. Mejias.

Dallas County Schools

Dallas County Schools characterizes propane as a "fuel of choice" for its operations. The school district plans to continue with propane school bus deployments, because propane offers lower costs and comparable performance to conventional bus technologies.

Tim Jones, Transportation Director for *Dallas County Schools*, stated, "The decision to convert additional buses to propane autogas was an easy one. We have the infrastructure in place, making it a simple transition. It's hard to argue with not investing in more (propane) autogas transportation for our schools."

Northside ISD

Northside ISD Vehicle Maintenance Manager Roy McClure observed in an interview with the Texas Railroad Commission that propane has been a "good decision" for the district and the public, because of the benefits of reduced emissions, lower fuel cost, and lower maintenance costs. School Superintendent John Folks echoed these points in addressing the public at a bus dedication ceremony, stating "These buses allow us to reduce air pollutants by using cleaner, Texas-produced fuel, while also saving our taxpayers' money."

Ysleta ISD

Frances Yepez, Transportation Supervisor, stated that *Ysleta ISD* has not had any negative comments from drivers to date, and that the buses have been reliable with no maintenance issues.

Gloucester County Schools

Chelsea Jenkins, former coordinator for the Virginia Clean Cities coalition, noted that one of the major lessons learned for the *Gloucester County Schools* program is that it is valuable to have a passionate champion within the organization to keep a project like this moving. In this case, Ms. Jenkins observed that Gloucester's Transportation Director, Roger Kelly, was the champion for the project.

Gloucester County's School Board Chairperson, Ann Burruss, stated "The positive impact on cost savings, morale of both drivers and students, the benefits realized from a safety standpoint are major pluses in our purchase of the propane buses last year. As a School Board member, it was and continues to be a source of great pride in being first in the Commonwealth of Virginia for these vehicles to be in a school bus fleet." Superintendent Ben Kiser added, "We've had really good success with these propane buses."

Gloucester County Schools has found that the propane buses take somewhat longer to fuel than diesel buses (15–20 minutes to refill the propane tank, versus 10–12 minutes for a diesel bus). This is because the propane tank filler neck size appears to restrict the rate at which fuel enters the tank. The propane vehicles also must be fueled more frequently (every 2–3 days) than the diesel vehicles (every 3–4 days). The district also needed to do some public education as well to make parents aware of the new buses. *Gloucester County Schools* also highlighted the reduced noise from propane buses, a positive for both drivers and student riders. "The only complaint I've had was from one parent whose daughter is missing the bus because she can't hear it rumbling down the street like she used to," Mr. Kelly observed.

General Observations

The Texas Railroad Commission established a blog specific to the Texas propane fleet project that included articles about each of the propane bus fleets. The blog provides a forum for fleets to share information about their experiences with each other and the general public. Each of the more than 900 blog posts written as part of this project was also shared on the Texas Alternative Fuel Fleet Pilot Program Facebook page to reach additional audiences. The Pilot Program also has a YouTube channel and a Flickr photo sharing page to distribute photos and videos about the project. A number of these were reposted to other forums and shared via e-mail by the viewers who subscribed to the RSS feed or "liked" the Facebook page.

Lastly, Roush CleanTech, producer of the propane system for the Blue Bird Vision propane buses in this project, summarized the effectiveness of the project for the Texas Railroad Commission's final report:

> *Prior to commencement of this project, most of the propane school buses in Texas were aftermarket conversions done in the 1990s. Blue Bird introduced an OEM ultra-low emission propane school bus in 2008, but school districts nationwide were unwilling to pay the higher incremental cost ($16,316 versus the $2,500 they had paid in the 1990s for an aftermarket conversion). By removing the initial cost barrier, funding onsite refueling, and providing training for mechanics and drivers, this project was able to jumpstart adoption of the EPA-certified OEM system, initially in Texas and now nationwide. Propane buses are now mainstream, and represent the nation's fastest growing transportation fuel. Texas (1,324) still leads in the number of new ultralow emission propane school buses, but California (754), Nebraska (435), Oregon (260), New York (222), Pennsylvania (155), Wisconsin (139), and Florida (129) are also significant and growing markets. As a result of the market growth brought about through this project, the incremental cost has dropped 45 percent, to $9,000, and a second bus manufacturer, Thomas, has entered the market.*

Conclusion

With the aid of the Recovery Act and other funding sources, school districts in Texas and Virginia have successfully deployed propane school buses. This study considered five of those fleets. The buses have been generally well received by the fleets in this study, which continue to consider propane for considerable fuel cost savings.

Overall fuel economy for the propane vehicles is close to that of comparable diesel vehicles, on an energy-equivalent basis. In total, these fleet vehicles are annually displacing around 212,000 DGE of petroleum and around 770 tons of GHG emissions. Data in this case study showed that propane school buses exhibited a smaller fuel efficiency penalty relative to diesel buses than typically expected. Data submitted by the fleets show the potential for fuel cost and maintenance cost savings, depending on the price spread between propane and diesel. Favorable business cases can be demonstrated through the information gathered from these fleets.

New propane engine technology is showing potential efficiency improvements over older engines. The fleets included in this study have not encountered any significant technical or management hurdles associated with the deployment of propane buses, and most of them are exploring ways to expand their use of propane in the future.

Supplemental Information

i. The Blue Bird Vision bus has been offered with two different propane engines: an 8.1-liter V-8 dedicated propane engine based on a General Motors (GM) engine (available between 2008 and 2011), and a 6.8-liter V-10 dedicated propane engine based on a Ford Motor Company engine (available beginning in 2012). Both engines use liquid propane injection technology and are included in this case study.

   In the past, propane vehicles commonly used a vapor pressure system that was somewhat similar to a carburetion system, where propane would be vaporized and mixed with combustion air in the intake manifold of the engine. This leads to lower breathing efficiency as more air, rather than fuel, is inducted into the cylinder for combustion. A newer LPI system has become available that injects propane directly into the cylinder, resulting in improved breathing efficiency and no mixing penalty because air is not diluted with the gaseous fuel in the intake manifold.

ii. If a fleet signs a long-term contract with a propane supplier for fuel, the supplier will often provide the fleet with on-site fueling equipment for the duration of the contract (see http://www.johnray.com/index/propane-5/commercial-propane-services-26.html for one example).

iii. Clean Cities also funded the National Alternative Fuels Training Consortium to produce first responder safety training as part of their Clean Cities Learning Program; this resource is accessible through the Consortium's Clean Cities Learning Program Website at http://www.naftc.wvu.edu/cleancitieslearningprogram.

iv. This case study analysis aggregates information collected from the fleets to provide an overall view of propane school bus performance in real-world operation. The performance data were reported quarterly to DOE throughout 2011 and 2012 for the Texas fleets. Similar performance data were provided (in a different format) by the Virginia fleet for 2010, 2011, and 2012. The fleets provided data for 3 months to 1 year of operation over slightly different timeframes. The information was also aggregated by calendar quarter data to capture seasonal trends wherever possible. For fleets with less than 1 year of data, existing performance trends were extrapolated to fill out one calendar year of service.

v. On average, the Texas fleets travel more miles per year (15,200) than the Virginia fleets (11,900), which can be explained by the larger geographic areas typically covered by the Texas buses.

vi. Trends in quarterly fuel use track with quarterly VMT, as do differences in fuel use between the Texas fleets (2,000 DGE/year) and Virginia fleets (1,800 DGE/year). Diesel fuel use is generally lower than propane use in terms of volume (gallons), both because of the previously noted limitations on the diesel vehicles included in the data and slight differences in energy-equivalent fuel economy between the propane and diesel buses.

vii. The fuel economy for the propane buses is fairly constant over the course of the year, and fuel economy was relatively consistent between the Texas propane bus fleets (7.3 miles per DGE) and Virginia bus fleets (6.7 miles per DGE). The close agreement of the diesel and propane bus fuel efficiencies (on an energy-equivalent basis) is also notable. Propane buses often achieve slightly lower fuel economy than diesel buses on an energy basis, because they use spark-ignition engines that can be less efficient than compression-ignition diesel engines. Given the limited information available from these fleets and the small number of diesel buses included in the analysis, it is difficult to draw any larger conclusions about the comparison of propane and diesel buses. Some key factors to consider when comparing in-use fuel economy include route type, driving behavior, engine performance, and engine vintage. These factors were not necessarily the same between the propane and diesel buses in the case study fleets, so differences in fuel economy are not solely a function of vehicle technology.

- Route type: Some of the fleets in this case study used their propane and diesel buses on similar route types while others did not. This can play an important role in interpreting fuel economy results, as routes with stop-and-go operation will result in higher fuel consumption than routes with more steady speeds.
- Driver behavior: In addition, driver behavior will affect fuel economy. Aggressive driving will increase fuel consumption when compared to driving behavior with gentler accelerations and decelerations.
- Engine type: While some fleets noticed improved acceleration of their propane vehicles, in general, engine performance and vintage (year of manufacture) were not always equal to those of vehicles in this case study and would thus not be strictly comparable. However, it is clear that the LPI systems used in the newest buses have improved performance relative to older vapor pressure injection systems.

viii. Both petroleum displacement and GHG reductions for the propane vehicles were calculated on a quarterly basis relative to comparable diesel vehicles traveling the same annual mileage (annual vehicle miles traveled were normalized to the propane vehicles).

ix. In this calculation, "tons" refers to the short ton (2,000 pounds).

x. Propane vehicle repair facilities do not require any special equipment beyond what is required for gasoline and diesel vehicle repair and maintenance, so no incremental costs for garage modifications are needed.

xi. The cost per mile analysis for the propane vehicles was performed on a quarterly basis relative to comparable diesel vehicles driving the same annual mileage (annual vehicle miles traveled [VMT] was normalized to the compressed natural gas [CNG] vehicles). The average fuel cost per mile was derived by using regional fuel prices for CNG and diesel published in the *Alternative Fuel Price Report* and the normalized fuel use/VMT reported by the fleets.

xii. This is commonly known as simple payback, which excludes the time value of money.

xiii. A rigorous business case analysis is difficult to complete with the data provided by these fleets; a limited amount of diesel vehicle information was provided and the information available shows generally lower annual VMT for the diesel buses, so it is possible that the comparisons between fuels are not representative. The small fuel cost savings per mile reported by these fleets is likely attributable to the low diesel price cited by the fleets, creating a small per-gallon fuel price increment for propane that is offset by the lower volumetric fuel economy of the propane vehicles. It is possible, however, to combine the operational information for the propane vehicles in this study with other publicly available information to make some general business case conclusions about the benefits of propane operation. To do this most effectively, the diesel vehicle VMT was normalized to the propane VMT as described in the section on environmental impacts.

xiv. As described elsewhere in this document, the average propane school bus in these fleets traveled approximately 14,700 miles per year. The highest mileage fleet in the case study (*Alvin ISD*) traveled around 24,000 miles per propane bus. Average fuel economy for the propane buses was around 7.2 miles per DGE, while the average fuel economy for the diesel buses was 6.8 miles per DGE.

xv. Note that these calculations are for 10 buses as an example, but the payback period would be the same for any number of buses because there are no fueling station costs.

xvi. The 15-year life is an estimate from the National Association of State Directors of Pupil Transportation Services, in an information report on school bus replacement considerations based on information from South Carolina (http://www.nasdpts.org/Documents/Paper-BusReplacement.pdf). A 2004 National Renewable Energy Laboratory (NREL) report indicates a turnover of around 12 years (http://www.nrel.gov/docs/fy04osti/35765.pdf).

xvi. These maintenance cost savings figures were chosen because the propane and diesel vehicles represented by these figures are relatively close in age (2009–2010), making a comparison more reasonable. The diesel buses provided by Alvin were older buses with higher maintenance costs; the increment of $0.06 per mile between the Gloucester propane and diesel buses was used, because discrepancies in bus vintage would artificially increase the maintenance cost savings (old diesel buses versus new propane buses).

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