

# Alternative Fuel Tool Kit

## How to Implement: Propane

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## Introduction to Propane (LPG) for Transportation

### What is Liquefied Petroleum Gas?

Liquefied petroleum gas (LPG) is commonly referred to as propane or autogas when used in transportation. Propane is a cleaner-burning alternative to gasoline or diesel that has been used for decades to power light-, medium-, and heavy-duty vehicles. It is an odorless, colorless gas that is a byproduct of natural gas production and crude oil refining. Propane autogas is a mixture of propane with smaller amounts of other gases. It has a high octane rating and excellent properties for spark-ignited internal combustion engines.<sup>1</sup> Propane autogas is today the most widely used alternative fuel in the automotive sector with more than 23 million vehicles operating worldwide.



Figure 1: Iredell County Propane fueling station. Source: NC Clean Energy Technology Center.

To maximize energy storage, propane is stored as a liquid in a pressurized tank onboard the vehicle, typically at 100-150 pounds per square inch. The tank pressure will vary based on temperature.<sup>2</sup> As the pressure is released, the liquid propane vaporizes and turns into gas that is used in a combustion engine. Propane has a lower Btu rating than gasoline – it takes about 1.33 gallons of propane to equal the energy content in one gallon of gasoline – which means that it takes slightly more fuel to drive the same distance.<sup>3,4</sup> However, it also has a higher octane rating than gasoline (104-112, compared to

According to the Gas Processors Association's HD-5 specifications, propane autogas must consist of at least 90% propane, and no more than 5% propylene, and 5% other gases (primarily butane and butylene).

87-92 for gasoline), so a properly tuned LPG system achieves a volumetric fuel economy of 85-90% compared to operating on gasoline.<sup>5</sup> It should be noted that propane is sold by the liquid gallon, not gasoline gallon equivalent (GGE) with regards to energy content. Propane vehicles are being used in fleet applications, such as law enforcement vehicles, school buses, and transit vans. While some medium- and heavy-duty propane vehicles are purpose built, most light-duty vehicles are converted to use propane as a fuel source.

## Benefits of Using Propane (LPG) for Transportation

As an alternative transportation fuel, the benefits of propane include:

- Same horsepower, torque, and payload capacity of traditionally fueled vehicles.
- EPA and California Air Resources Board certification.
- Potential increased maintenance intervals.
- Reduced operating costs.
- A viable pathway for complying with federal alternative fuel vehicle requirements for fleets.
- Cost-effective development of on-site refueling infrastructure.
- Purchase or conversion rebates and incentives offered by federal and state organizations.
- Potential emissions reductions.
- Supports the use of domestically produced fuel, decreasing reliance on imports.

<sup>1</sup> [http://www.afdc.energy.gov/fuels/propane\\_basics.html](http://www.afdc.energy.gov/fuels/propane_basics.html). (Alternative Fuels Data Center, 2013). Accessed March 24, 2014.

<sup>2</sup> <http://www.propanecarbs.com/propane.html>

<sup>3</sup> [http://www.afdc.energy.gov/fuels/propane\\_benefits.html](http://www.afdc.energy.gov/fuels/propane_benefits.html). (Alternative Fuels Data Center, 2013) Accessed March 24, 2014.

<sup>4</sup> (National Alternative Fuels Training Consortium, 2012)

<sup>5</sup> Per discussions with David Finder of Alliance Autogas and Monte McLeod of Palmetto Gas (May 2014).

### Cost Savings:

Propane is a domestic product with high-energy density and relative low cost. Propane is one of the most accessible alternative fuels to the general public. It typically cost less than gasoline and diesel and offers a comparable driving range. Seasonal variations in price do occur with typical propane price increases during winter months, due to increased demand for propane in home heating applications. Propane is a popular choice for high-mileage vehicles. Propane's high octane, low-carbon, and low oil-contamination characteristics result in longer engine life than conventional petroleum engines.<sup>6</sup> According to the Battelle Memorial Institute, propane is the most economical alternative fuel for fleets (on a per mile basis) once infrastructure, ownership, and operational cost are considered.<sup>7</sup>

### Vehicle and Infrastructure Availability:

A number of propane vehicle models are available through original equipment manufacturers (OEMs) and select dealerships. In addition to OEM models, fleets and consumers have the option of converting existing gasoline vehicles for propane operation using qualified system retrofitters.

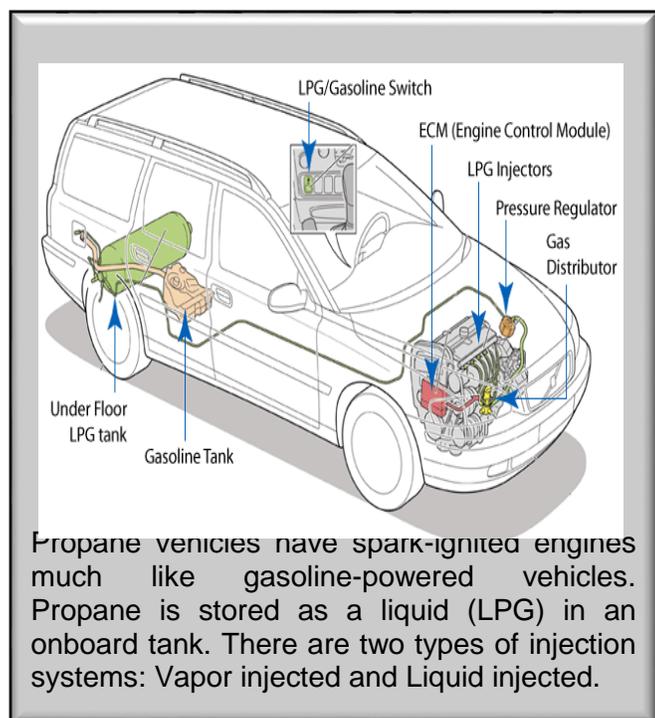


Figure 2: Bi-fuel Volvo LPG vehicle. Source: AFDC

comparing new vehicles, more stringent emission regulations have driven engineering improvements in engine and vehicle emission control systems that have made conventional petroleum fueled vehicles comparable to LPG fueled vehicles.

### Emissions Reductions:

Due to its low carbon content, propane is fundamentally one of the cleanest burning fossil fuels. When used as a transportation fuel, it offers a 10% reduction in lifecycle emissions of greenhouse gases over petroleum based fuels, depending on vehicle type and load conditions.<sup>8</sup>

Compared to older vehicles, propane shows significant reduction of regulated emissions versus petroleum based fuels, as shown in Figure 4. Therefore, if you are replacing an older petroleum fueled vehicle with a new propane vehicle, in addition the benefits listed above, you will also be achieving emissions reductions. However, in

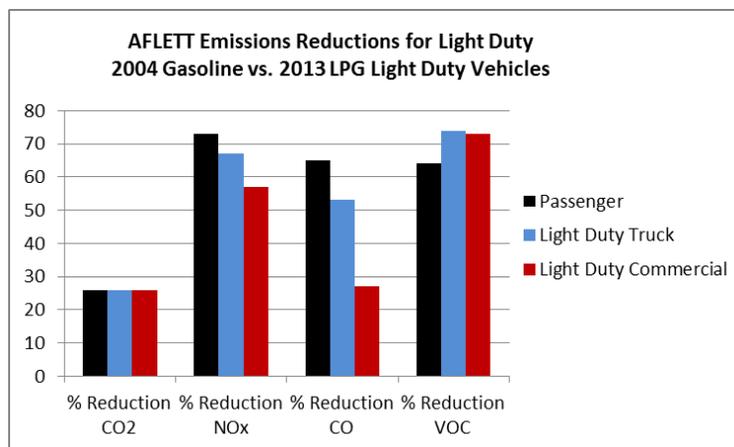


Figure 4: 2004 Gasoline vs. 2013 LPG Vehicle Emissions from Argonne National Lab AFLETT Tool

<sup>6</sup> [http://www.afdc.energy.gov/fuels/propane\\_benefits.html](http://www.afdc.energy.gov/fuels/propane_benefits.html). (Alternative Fuels Data Center, 2013). Accessed March 24, 2014.

<sup>7</sup> [http://www.naftconline.org/ccfptoolbox/\\_prt/propane/Propane\\_Awareness\\_Booklet.pdf](http://www.naftconline.org/ccfptoolbox/_prt/propane/Propane_Awareness_Booklet.pdf)

<sup>8</sup> [http://www.afdc.energy.gov/vehicles/propane\\_emissions.html](http://www.afdc.energy.gov/vehicles/propane_emissions.html)

## Various Applications, Available Vehicles, Vendors in the NC Market

There are a number of propane options for fleets and consumers to consider. Major automakers are adding propane vehicles to their production lines, and there are a number of conversion options for most light and medium duty vehicles. Propane vehicles perform similar to conventional fuel vehicles with regard to power, acceleration and cruising speeds.

### Propane Vehicles types and availability

Propane autogas can be used in most light-, medium-, or heavy-duty applications. **Dedicated vehicles** operate only on LPG. **Bi-fuel vehicles** may operate on LPG or gasoline. A bi-fuel vehicle will have two fueling ports and one or more LPG tanks in addition to a gasoline tank. The driving range for dedicated and bi-fuel vehicles is comparable, extra storage tanks can increase driving range, but the additional weight and space requirements affect payload capacity.

The U.S. Department of Energy's Alternative Fuel Data Center (AFDC) annually compiles a list of available light-duty, and medium/heavy duty bi-fuel and dedicated propane vehicles. The vehicle data search tools are searchable by fuel and duty type at the AFDC website available at <http://www.afdc.energy.gov/tools>.

### Selecting Propane Vehicles

There are three main ways to utilize propane vehicles in fleet applications:

1. Purchase new, dedicated LPG vehicles. An increasing number of dedicated propane autogas powered cargo and passenger vans are now available for purchase, offering reduced greenhouse gas emissions and lower fuel costs without sacrificing performance and reliability. Companies including General Motors, Ford, Freightliner and ROUSH CleanTech are leading the way in North Carolina, producing dedicated propane autogas fuel systems that are EPA and CARB certified.

Dedicated vehicles may best be used if fueling infrastructure is plentiful and convenient; e.g., if you plan to install fueling infrastructure on-site, and/or you can find propane stations convenient to your driving routes. Certain light-duty vehicles can be ordered from a dealer with a gaseous fuel prep-package and converted to use propane. For example, many Ford vehicles are available with the factory LPG gaseous engine prep package and can be converted to dedicated or bi-fuel vehicles through certified up fitters. Qualified dealers (such as Capital Ford in Raleigh: Ron Wilson 919-713-5066) can work closely with customers for vehicle purchase and to arrange certified up fits on new and used vehicles.

- Search for local Ford dealer near you: <http://www.ford.com/dealerships>
- State contract: <http://www.doa.state.nc.us/PandC/070a.pdf>
- State Bid Calendar: [https://docs.google.com/spreadsheets/u/1/d/1pnnGp\\_TlcEVdHea3XOqTaij51-yai\\_XPDWeKPUzqNq0/pub?output=html](https://docs.google.com/spreadsheets/u/1/d/1pnnGp_TlcEVdHea3XOqTaij51-yai_XPDWeKPUzqNq0/pub?output=html)

New, dedicated LPG vehicles offer the following benefits:

- Have the same weight as gasoline-powered versions of the same models.
- Meet all Environmental Protection Agency emissions standards.

The following list of vehicles includes dedicated propane autogas fuel systems:

- Roush E-150/250/350 - ROUSH CleanTech dedicated propane autogas powered Ford E-series cargo and passenger vans.  
Roush E450 6.8L V10 Cutaway - ROUSH CleanTech dedicated propane autogas fuel system for the Ford E-450 is Altoona tested and offers a great alternative fuel solution for 2009 and newer Ford E-450 DRW dual rear wheel cutaways.
- Roush F-250/350 - Fuel systems are available for 2012 and newer model years Ford F-250 / F-350 trucks equipped with the 6.2-liter V8 engine.

- Roush F-450/F-550 Chassis Cab - This system offers an alternative fuel solution for 6.8L V10 2012 and newer Ford F-450 / F-550 chassis cab.
- Roush F-650 Chassis Cab - This system offers an alternative fuel solution for 6.8L V10 2013 and newer Ford F-650 chassis cab.
- Freightliner LPG S2G Commercial Chassis - The Freightliner Custom Chassis Corporation's S2G features a dedicated 8.0L LPG engine from a General Motors long block provided by PowerTrain Integration and a Liquid Propane Injection (LPI) system manufactured by Clean Fuel USA. The S2G is rated at 350 hp and 500 lb/ft of torque and touts a carbon monoxide rating of 60 percent below and a nitrogen oxide rating of 20 percent below EPA set standards for heavy duty vehicles.



Figure 5: Thomas Built Dedicated LPG Bus  
Source: Triangle Clean Cities

There are several Roush CleanTech dealers in NC located in Raleigh, Garner, Kannapolis, Shelby, and Midland. See: [www.roushcleantech.com](http://www.roushcleantech.com).<sup>9</sup>

**School buses** fueled by dedicated propane autogas are available from leading school bus manufacturers, including Blue Bird Corporation, Thomas Built Bus, and Collins Bus Corporation.

2. Purchase new, bi-fuel LPG vehicles. Bi-fuel systems run on either gasoline or propane. These vehicles may be best used if fueling infrastructure is less convenient to the fleet location or driving route and/or fleets that would benefit from the extended range that two fuels offer. When propane is not available, an on-board computer system can switch the fuel to gasoline. In addition to the automatic switch over between fuels, there is also a manual switch that allows the user to select the fuel to be used.

GM Fleet has several vehicle models that have CNG- or LPG-powered versions and they're the industry's only CNG/LPG vehicles that are fully integrated at the factory, crash tested, and backed by GM's 100,000 mile/5-year transferable Powertrain Limited Warranty. Available CNG vehicles are: 2014 Chevrolet Silverado 2500HD/3500HD (bi-fuel), 2015 GMC Sierra 2500HD/3500 HD (bi-fuel), 2014 Chevrolet Express Passenger/2500 Cargo/3500 Cargo, 2014 GMC Savana Passenger/2500 Cargo/3500 Cargo. Available LPG vehicles are: 2014 Chevrolet Express 4500 and 2014 GMC Savana 4500. These models are expected to be offered for MY 2015, as well. For additional information: <http://www.gmfleet.com/overview/alternative-fuel-vehicles.html>.

**Law enforcement** agencies in many areas have selected propane for their patrol and support vehicles. Reasons cited include affordability, and vehicle power, performance, and reliability. Their fleet operations are also conducive to centralized propane refueling.

Production of the Ford Crown Victoria, an extremely popular law enforcement vehicle and LPG conversion candidate, ended in 2011. Agencies are still running these vehicles and converting them to propane. In addition, there are conversion packages available for some of the recent and current model OEM police packages such as the Chevrolet Impala, Caprice and Tahoe Police Packages, the Ford Explorer and Taurus Interceptors, and the Dodge Charger Police Package.<sup>10</sup>



Figure 6: Raleigh Police Bi-Fuel LPG Patrol Car  
Source: NC Clean Energy Technology Center

<sup>9</sup> <http://cleantransportationbuyersbook.weebly.com/> (Clean Transportation Buyers Book)

<sup>10</sup> Per discussions by Rick Sapienza with Charles Gregory of Force911, David Finder of Blossom Gas, and Dan Kelly of the Texas Rail Road Commission (July 2014).

Propane-fueled law enforcement vehicles offer the following benefits:

- Promote environmentally friendly transportation throughout the community because of their high visibility.
- Ensure the reliable operation of essential emergency and security vehicles.

3. Convert existing vehicles to a bi-fuel or dedicated LPG system. A qualified system retrofitter (QSR) should perform propane vehicle conversions. Conversions must meet OEM emissions standards for the given vehicle model year and the conversion requires U.S. EPA approval. The Propane Education & Research Council (PERC) partners with manufacturers to develop dedicated propane or bi-fuel propane systems for a wide range of light-, medium-, and heavy-duty vehicles, including trucks, vans, buses, trolleys, emergency vehicles, and fleet vehicles. These partnerships spur innovation and support successful commercialization.

The following companies in North Carolina offer certified LPG conversions and repowers:

<p>Alliance Autogas  <a href="http://www.allianceautogas.com">www.allianceautogas.com</a>            David Finder            828-251-0027  <a href="mailto:dmfinder@blossmangas.com">dmfinder@blossmangas.com</a></p>	<p>ICOM North America  <a href="http://www.icomnorthamerica.com">www.icomnorthamerica.com</a>            248-573-4934  <a href="mailto:info@icomnorthamerica.com">info@icomnorthamerica.com</a>            NC Dealers: Fontaine Modifications &amp; Rutherford Equipment</p>
<p>IMPCO Technologies  <a href="http://www.impcoweb.com">www.impcoweb.com</a>            714-656-1200  <a href="mailto:sales@impcotechnologies.com">sales@impcotechnologies.com</a></p>	<p>Trans Tech Energy, Inc.  <a href="http://www.TransTechEnergy.com">www.TransTechEnergy.com</a>            Greg Ezzell            252-557-0727</p>
<p>Baker Equipment Co.  <a href="http://www.bakerequipment.com">www.bakerequipment.com</a>            Skip Baker            919-569-0081  <a href="mailto:sbaker@bakerequipment.com">sbaker@bakerequipment.com</a></p>	<p>Landi Renzo USA / Baytech  <a href="http://www.landiusa.com">www.landiusa.com</a>            310-257-9481  <a href="mailto:info@landiusa.com">info@landiusa.com</a></p>
<p>CleanFUEL USA  <a href="http://www.cleanfuelusa.com">www.cleanfuelusa.com</a>            Ed Brand            512-864-0300  <a href="mailto:ed.brand@cleanfuelusa.com">ed.brand@cleanfuelusa.com</a></p>	<p>ROUSH CleanTech  <a href="http://www.roushcleantech.com">www.roushcleantech.com</a>            Chelsea Jenkins            864-923-5000  <a href="mailto:Chelsea.Jenkins@roush.com">Chelsea.Jenkins@roush.com</a></p>

Download a complete list of 2013 EPA or CARB certified conversion kit manufacturers (updated April 10, 2014) from the Propane Education & Research Council: [www.autogasusa.org](http://www.autogasusa.org).<sup>11</sup>

**Transit agencies** can choose to retrofit their vehicles with or purchase new propane-fueled bus engines. Note that Thomas Built Buses manufactures LPG school buses at their plant in High Point NC.

<sup>11</sup>[http://www.propane.com/uploadedFiles/Propane/On\\_Road\\_Fleets/Propane\\_Conversions/April\\_2014\\_OTR\\_Manufacturer\\_Listing\\_Public\\_View.pdf](http://www.propane.com/uploadedFiles/Propane/On_Road_Fleets/Propane_Conversions/April_2014_OTR_Manufacturer_Listing_Public_View.pdf)

## Fuel Providers & Refueling Equipment Vendors

### Fueling Options and Availability

There are a number of publicly accessible propane (LPG) stations in North Carolina. Anyone dispensing propane is required to be properly trained. Training is available from local propane providers, the Propane Education & Research Council (PERC) or the National Fire Prevention Association (NFPA). In most cases, an onsite attendant will fill the tank. No prior scheduling is required, although some stations are only open during regular business hours.

One advantage of using publicly available stations is the cost savings. The fleet does not need to install and maintain its own dispensing equipment. On the other hand, the fleet may be inconvenienced if the dispenser goes down for service, if there is a high demand and wait time, or if there are other accessibility issues. Some fleet managers negotiate a bulk price for fuel when they operate their own stations, but are unable to do so when using a public station. Therefore, there can be a fuel price benefit to owning your own station.

For current North Carolina propane (LPG) refueling station availability, the Alternative Fuels Data Center has a nationwide [alternative fueling station search tool](#).<sup>12</sup> The alternative fueling station locator will display information on each station including the hours and payment options.



Figure 7: LPG Ford Transit Connect Taxi  
Source: Ford Media

### Alternative Fueling Station Locator

Find alternative fueling stations near an address or ZIP code or along a route in the United States. Enter a state to see a station count.

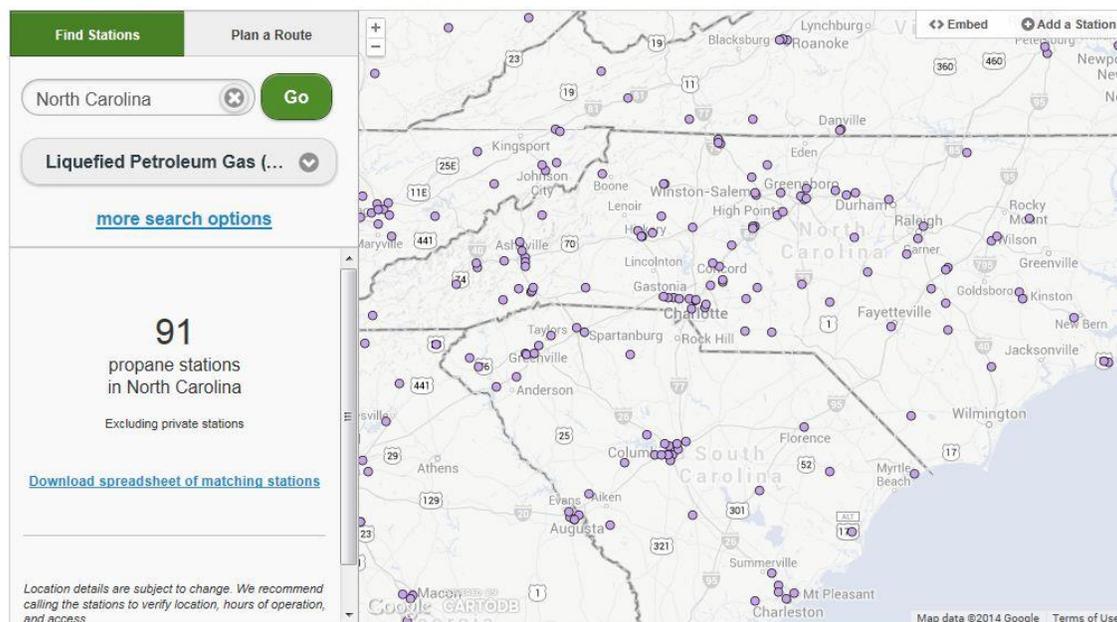


Figure 8: Alternative Fuel Data Center station locator, using North Carolina as the geographic search entry and LPG as the fuel type.

### Establishing a Propane (LPG) fuel dispensing station in North Carolina

If you are a fleet that currently operates or wants to manage your own fueling, there are a number of considerations regarding propane (LPG) fueling infrastructure.

<sup>12</sup> <http://www.afdc.energy.gov/locator/stations/>

The propane fueling infrastructure is very similar to gasoline and diesel refueling equipment. Propane is delivered to the station by a transport truck and dispensed into an onsite storage tank. Traditionally, the tank is located above ground.<sup>13</sup> The main difference between conventional fuels and propane is that the propane is delivered under pressure to the vehicle so that it remains a liquid. Establishing a propane fueling station for vehicle refueling requires the build-out of dispensing equipment, the simplest of which includes a storage tank and a pump with a simple meter. For easier fuel use monitoring, a card reader and dispenser can also be added (Figure 9.). A majority of propane suppliers offer an inexpensive lease of the equipment in return for a multi-year fuel supply contract. This arrangement can make the upfront cost of the propane station very affordable for fleets. The average cost of a private station including the purchase and installation of all necessary equipment is \$45,000, but varies depending on the situation and need, with electrical and crash protection considerations being the most common influences on additional costs.<sup>14</sup>

There are safety guidelines that should be considered when developing fueling infrastructure. The design and installation requirements of the station must meet the National Fire Prevention Association’s NFPA 58 Vehicular Liquefied Petroleum Gas Code. In addition, there may be other state and local codes and ordinances that apply. Your local fire marshal, planning and zoning staff can help you as well as your local propane supplier.

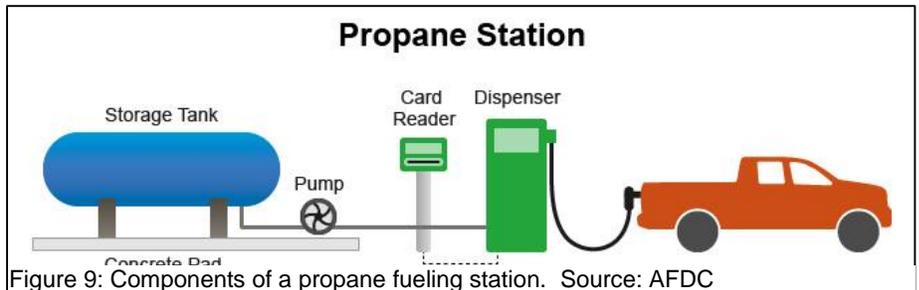


Figure 9: Components of a propane fueling station. Source: AFDC

The following companies in North Carolina offer LPG station installer / refueling equipment:

<p>Alliance Autogas  <a href="http://www.allianceautogas.com">www.allianceautogas.com</a>          David Finder          828-251-0027  <a href="mailto:dmfinder@blossmangas.com">dmfinder@blossmangas.com</a></p>	<p>CleanFUEL USA  <a href="http://www.cleanfuelusa.com">www.cleanfuelusa.com</a>          Mike Merwarth          512-864-0300  <a href="mailto:michael.merwarth@cleanfuelusa.com">michael.merwarth@cleanfuelusa.com</a></p>
<p>Amerigas LPG refueling  <a href="http://www.amerigas.com">www.amerigas.com</a>          Milo Arnold          252-362-9599  <a href="mailto:milo.arnold@amerigas.com">milo.arnold@amerigas.com</a></p>	<p>Jones and Frank  <a href="http://www.jones-frank.com">www.jones-frank.com</a>          Steve Bernstein          704-393-8542 ext. 3913  <a href="mailto:SBernstein@jones-frank.com">SBernstein@jones-frank.com</a></p>

## North Carolina Case Studies

There are an ever-increasing number of fleets successfully using propane (LPG) throughout North Carolina. Details regarding motivation, factors tied to the decision, lessons learned, and the overall experience for select fleets can be found at “[Propane Case Studies](#)”.<sup>15</sup> Additionally, the North Carolina [Alternative Fuels User Database](#) includes an online, searchable map that allows website visitors to learn more about some fleets that are already using alternative fuels, including propane. A few North Carolina fleets that use propane and are in the Database include:



Figure 10: Rowan County Bi-Fuel LPG Transit Van Source: Centralina

[the\\_infrastructure.html](#)  
 Alliance Autogas (July 2014).  
[uploads/Propane-Case-Study1.pdf](#)

- [Rowan County Transit System](#)
- Raleigh Police Department, City of Raleigh
- [Iredell County Sheriff](#)
- Steven's Sausage

## Crunch the numbers – Vehicle cost calculators

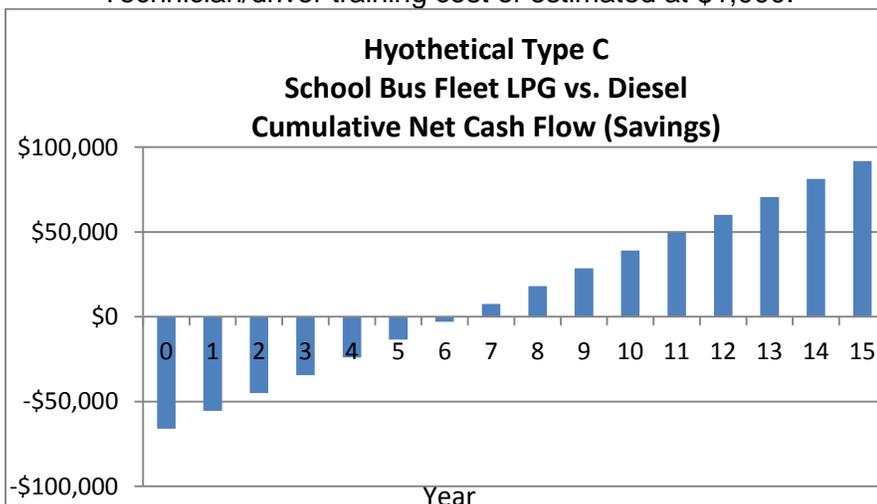
The North Carolina Clean Energy Technology Center (NCCETC) offers a vehicle calculator that can be used to compare a baseline fleet to a potential alternative fuel replacement fleet. Inputs include average vehicle miles per gallon, fuel costs, vehicle costs, infrastructure costs, and training costs. It also offers the option to include vehicle and/or infrastructure financing. This calculator returns fuel cost per mile, net present value (based on input discount rate), cumulative savings, return on investment, and simple payback period. See [NC Clean Energy Technology Center Vehicle Calculator Example](#) and [NC Clean Energy Technology Center Vehicle Calculator](#).

Using the NCCETC vehicle calculator for a hypothetical fleet, the following is a summary comparison of five new type C school buses running on LPG versus diesel. The assumptions and inputs for this scenario used include:

- Public fleet using onsite fueling (no rebates or tax incentives were applied).
- Onsite fueling station was completed via a partnership with an LPG provider where the provider supplied the equipment free of charge and the organization paid for site prep and fuel monitoring system. Cost was estimated at \$15,000 using information from Palmetto Gas.
- Average NC state contract prices for LPG 07/08/2014-07/14/2014 was \$1.23/gallon.
- Average NC state contract price for diesel 07/11/2014 was \$3.01/gallon.
- Average of school bus vehicle miles traveled per year from ADFC VICE is 12,000 miles.
- Average diesel school bus fuel economy from ADFC VICE is 7 mpg.
- Average gasoline school bus fuel economy 10% less than diesel, per Mesa Public Schools.
- Plus cost for LPG vehicle over diesel \$10,000 from Thomas Built.
- Technician/driver training cost of estimated at \$1,000.

**Barrier Buster – Vehicle Costs**

- Utilize available cost calculators to select best vehicle options to match operational needs
- Ensure adequate LPG vehicle tank size or consider using bi-fuel systems to accommodate range needs
- Upgrade maintenance facility and train staff mechanics to enable in-house work on LPG vehicles



### **Vehicle Cost Calculator Results for Hypothetical 5-Truck Fleet**

- Payback period: 7 years
- Annual fuel savings: \$10,516 (\$2,103 per vehicle)
- 15-year cumulative savings: \$91,743 (See figure 11.)
- 15-year ROI: 143%

## **Trends Looking Ahead**

Propane has been used in transportation for decades. It is the most commonly used alternative motor fuel in the world and its prices are typically more stable than those of gasoline. According to the Propane Education and Research Council (PERC), there were more than 270,000 on-road propane vehicles in the U.S. at the beginning of 2012. This number includes private businesses and municipal government agencies vehicles.

As of October 2013, the fuel is available at more than 2,700 stations throughout the country. These numbers are likely to grow significantly over the coming years.

The future of propane used as a transportation fuel in North Carolina may include propane produced in the state. Currently, the U.S. produces nearly 90% of the propane it uses with the majority of this being a byproduct of domestically produced natural gas. With natural gas reserves under consideration for development in North Carolina, LPG may become more readily available as production of natural gas takes place.

Increased use of domestic resources aids North Carolina's economy and energy security by decreasing dependence on imported oil. In fact, according to the Propane Education and Research Council (PERC), propane has grown to become a \$49 billion domestic industry. With economic, environmental, energy security and public health benefits, the advantages that propane vehicles have to offer will continue to increase the number of LPG vehicles on North Carolina's roadways.