

Alternative Fuel Tool Kit

How to Implement: Compressed Natural Gas

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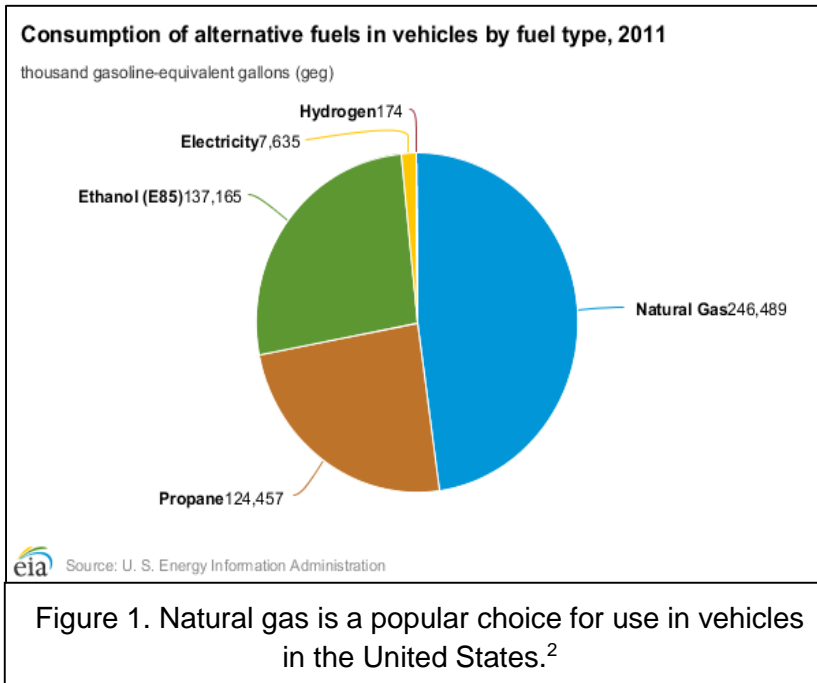
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Introduction to Compressed Natural Gas (CNG)

What is Compressed Natural Gas?

Compressed natural gas (CNG) is a clean-burning alternative to gasoline or diesel used in transportation. Made of predominantly methane (CH₄), natural gas is the most commonly used alternative vehicle fuel in the United States.¹ It is drawn from wells or extracted during crude oil production. While some petroleum is used in the production of natural gas, using it as a transportation fuel reduces petroleum consumption by more than 90% compared to gasoline.² In transportation, natural gas is used either as CNG or as liquefied natural gas (LNG).



Benefits of this fuel include cost savings, reduced emissions, ease of vehicle maintenance, and increased energy security.

Because natural gas has a lower energy density than liquid petroleum fuels, it is either compressed or liquefied to store more energy for increased vehicle range. Therefore, to use natural gas, vehicles must have a CNG- or LNG-specific fuel storage and delivery system installed. The installation can be done on a vehicle after it has been manufactured (i.e., CNG aftermarket retrofit) or at the vehicle factory as part of its original equipment. In the medium and heavy duty market, there are engine options that are designed to run exclusively on natural gas, as well as conversion options. In the light duty market, there are a few 'direct from the manufacturer' CNG options available. There is also a gaseous prep package option for the

standard gasoline engine, which costs around \$300 and includes hardened valves and valve seats. It is recommended that engines that will use natural gas have hardened valves and valve seats, because as a dry fuel, natural gas does not have the cooling effect and lubricity of liquid injected petroleum fuels. A "prepped" vehicle is then ready to be sent to a qualified system retrofitter to be up-fitted with a CNG system, with no engine modifications required and no impact on the manufacturer's powertrain warranty.

On CNG vehicles, natural gas must be compressed before being stored on the vehicle. This compression takes place at the fueling site, using specialized equipment. Because natural gas currently is not as widely available as conventional fuels, vehicles that regularly return to a fleet yard are ideal for natural gas fueling.

¹ <http://www.eia.gov/renewable/afv/?src=Renewable-b5>

² http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html. The prices are compiled and reported quarterly by region and then averaged over each year.

Benefits of Using Compressed Natural Gas

Cost savings:

One advantage of compressed natural gas is that it costs less than gasoline or diesel. While the cost can vary by year, in 2012 the average cost per gasoline gallon equivalent (GGE) of CNG was about \$1.50 less than gasoline or diesel fuels.³

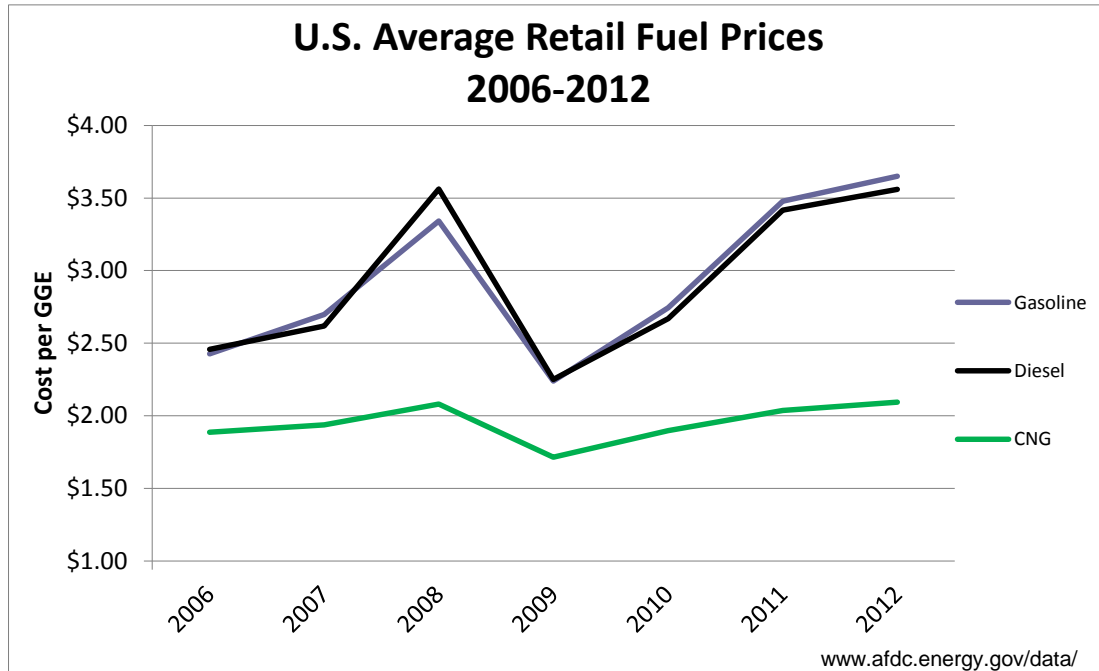


Figure 2. 2006-2012 US Average Retail Fuel Prices⁴

A number of factors influence natural gas prices, including the amount being produced, stored, imported and exported at any given time.⁵ Transportation fuel prices change often, sometimes dramatically, so while the graphics in Figures 1 and 2 can provide some insight into longer term fuel price trends, it is best to contact natural gas providers and local CNG retailers directly for the most current prices in your area.

Energy Security:

According to the U.S. Energy Information Administration, about 40% of the petroleum consumed in the United States in 2012 was imported from other countries.⁶ In the same year, only 6% of the natural gas consumed in the United States was imported from other countries, most of it from Canada.⁷

Vehicle Maintenance:

CNG vehicles can generally be operated longer between oil changes because natural gas produces less soot and combustion by-products.⁸ The ideal interval can be determined by sending oil samples to a laboratory (e.g. Wear Check in Cary NC) to be tested. Gaseous fuels also do not “wash” the lubrication from the cylinder walls, so cylinder and ring wear are significantly reduced. This increases the engine overhaul interval – some CNG

⁴ Ibid.

⁵ http://www.eia.gov/energyexplained/index.cfm?page=natural_gas_factors_affecting_prices

⁶ <http://www.eia.gov/tools/faqs/faq.cfm?id=32&t=6>

⁷ http://www.eia.gov/energyexplained/index.cfm?page=natural_gas_imports

⁸ http://www.afdc.energy.gov/vehicles/natural_gas_maintenance_safety.html

users have reported engine overhaul intervals two to three times greater than gasoline vehicles running similar duty cycles.

Emissions Reductions:

Although currently unregulated, natural gas fuel reduces greenhouse gas (GHG) emissions by about 6% - 11% when compared to gasoline.⁹ The United States Environmental Protection Agency regulates emissions for all vehicles. In recent years, the emissions benefits of natural gas fueling have been reduced because all vehicles are held to higher standards. Using natural gas may reduce some regulated emissions, including hydrocarbons, oxides of nitrogen, and carbon monoxide. These reductions differ based on the type of vehicle and its duty cycle. The greatest benefit is achieved when replacing diesel vehicles older than 2007 as emission standards were significantly tightened for diesel vehicles in 2007 and again in 2010.

Various Applications, Available Vehicles, Vendors in the NC Market

CNG Fleet Applications in North Carolina

- Transit/Paratransit
- Waste & Recycle Haulers
- Delivery & Work Vans
- Pickup Trucks
- Utility Trucks
- Sedans & SUVs

There are now a number of natural gas vehicle (NGV) options for fleets to consider. Major automakers are adding NGVs to their production lines, and there are a number of conversion options for most light and medium duty vehicles.

NGVs can be categorized as either compressed natural gas (CNG) or liquefied natural gas (LNG) vehicles. CNG is made by compressing natural gas to less than 1% of the volume it occupies at standard atmospheric pressure. It is stored and distributed in hard containers at a pressure of 200–248 bar (2,900–3,600 psi), usually in cylindrical or spherical shapes. LNG is natural gas that has been converted to liquid form for ease of storage or transport, and takes up about 1/600th the volume of natural gas in the gaseous state. LNG is principally used for transporting natural gas to markets, where it is regasified and distributed as pipeline natural gas. LNG

can be used in natural gas vehicles, although it is more common to design vehicles to use CNG. This document focuses primarily on CNG as a vehicle fuel, since that is currently the predominant type of NGV used in North Carolina.

CNG Vehicle types and availability

Compressed natural gas can be used in most light-, medium-, or heavy-duty applications. **Dedicated vehicles** operate only on CNG. **Bi-fuel vehicles** may operate on CNG or gasoline. A bi-fuel vehicle will have 2 fueling ports and one or more CNG tanks in addition to a gasoline tank. **Dual-fuel vehicles** use mix of natural gas and diesel, with diesel injected near the top of the compression stroke as an ignition source. A dual fuel engine can operate on 100% diesel or a mixture of natural gas and diesel (maximum of 90% natural gas¹⁰). In general, dedicated CNG vehicles demonstrate better performance and have lower emissions than bi-fuel vehicles because their engines are better optimized for CNG fuel.

The U.S. Department of Energy's Alternative Fuel Data Center annually compiles a list of available [light duty bi-fuel natural gas vehicles](#)¹¹, [light duty dedicated natural gas vehicles](#)¹², and [medium/heavy duty natural gas vehicles and engines](#).¹³ The North Carolina Clean Energy Technology Center also maintains a [listing of CNG vehicle options](#).

⁹ http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html

¹⁰ <http://www.cleanairpower.com/dual-fuel.html>

¹¹ <http://1.usa.gov/1d8MXm5>

¹² <http://1.usa.gov/1j8q4e8>

¹³ <http://1.usa.gov/1gNAJlL>

North Carolina is fortunate to have two companies involved with the manufacturing or up-fitting of natural gas engines. CNG upfit company [Altech Eco](#)¹⁴ in the Asheville area is a Qualified System Retrofitter for Ford. [Cummins Westport](#)¹⁵ in Rocky Mount manufactures the ISL G 8.9L engine for medium- and heavy-duty applications.

Any state agency and local government, as well as some non-profit service agencies, can procure vehicles from the NC Department of Administration Purchasing and Contracting Division contract. Please refer to the [current state bid calendar](#),¹⁶ which includes available vehicles, bid and contract dates. Currently, Nuovo Energy Solutions, LLC is listed as the company for natural gas conversions. Fleets may also purchase CNG vehicles from Honda, Ford, Ram, and GMC/Chevy dealers, as excerpted below from the North Carolina Clean Energy Technology Center's "[Clean Transportation Technology Industry Directory](#)" (pages 5- 10). In addition to light and medium duty options below the Directory also includes information on heavy duty CNG and refueling infrastructure providers that serve the North Carolina market.¹⁷

- Honda Civic Natural Gas: <http://automobiles.honda.com/tools/dealer-locator/?type=gxc>
- Ford: <http://www.ford.com/dealerships>
- Ram: http://www.ramtrucks.com/en/#ram_1500
- GMC/Chevy: <http://www.gmfleet.com/specialty-vehicles/fuel-efficiency.html>

Selecting CNG Vehicles

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

1. Purchase new, dedicated CNG vehicles. These 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 CNG stations convenient to your driving routes. Heavy-duty applications do not currently offer an option for bi-fuel, so it is necessary to carefully analyze fuel needs and infrastructure location.
2. Purchase new, bi-fuel CNG vehicles. These vehicles may best be used if fueling infrastructure is less convenient to the fleet location or driving route. When CNG is not available, an on-board computer system can switch the fuel to gasoline.
3. Convert existing vehicles to a bi-fuel, dual-fuel or dedicated CNG system. Bi-fuel CNG systems run on either gasoline or CNG. Dual-fuel CNG systems for long haul trucks, such as Detroit diesel engine conversions, run simultaneously on CNG and diesel.¹⁸ In the medium duty and heavy duty market, there are companies that will do a diesel engine to natural gas engine conversion, such as NVG Motori, Omnitek, NVG Repower and Power Solutions International. More gasoline vehicles are becoming available every year that may be converted to a bi-fuel CNG system. NGV America maintains a [database of engines and vehicles](#)¹⁹ eligible for conversion.

Additional Considerations: The Three “C’s”

Fleet managers should consider the following when making purchasing decisions:

1. Cost. Natural gas vehicles (NGVs) cost more than gasoline or diesel vehicles, whether factory made or converted after market. This is largely due to the greater expense of high-pressure fuel tanks, which are necessary to store CNG onboard the vehicle.²⁰ However, natural gas fuel is significantly less expensive than gasoline in North Carolina (about \$1.50 cheaper in 2012²¹). Maintenance requirements for natural gas vehicles are different from gas and diesel, costing less for some things and more for others. Differences in routine maintenance

CNG Vehicles can cost an additional \$6,000-15,000 for light-duty vehicles, or \$40,000-\$60,000 for heavy-duty vehicles compared to traditional gasoline or diesel vehicles.

¹⁴ <http://www.transeoenergy.com/>

¹⁵ <http://www.cumminswestport.com/models/isl-g>

¹⁶ https://docs.google.com/a/ncsu.edu/file/d/0B1L_uScUZTktmMmd0V2ZvLU9aV2c/edit?pli=1

¹⁷ <http://nccleantech.ncsu.edu/wp-content/uploads/Clean-Transportation-Technology-Industry-Directory.pdf>

¹⁸ <http://www.landiusa.com/epa-approval-of-dual-fuel-cng-system-for-detroit-diesel-12-7l-s60-engine.html>

¹⁹ <http://www.ngvamerica.org/vehicles/vehicle-availability/>

²⁰ <http://www.ngvamerica.org/vehicles/consumers/>

²¹ <http://www.afdc.energy.gov/fuels/prices.html>. The prices are compiled and reported quarterly by region and then averaged over each year.

requirements between CNG and diesel are cost-neutral.

2. **Certification.** The U.S. Environmental Protection Agency (EPA) requires proof that conversion systems meet emissions and on-board vehicle diagnostics standards. To meet these requirements, use only certified manufacturers when choosing a conversion system. The database provided by NGV America is a comprehensive list of certified conversions (see above). The U.S. Environmental Protection Agency (EPA) also maintains a [database of certification documents](#)²², which is updated periodically. Users may search for a specific vehicle converter and fuel type.
3. **Cylinders.** Unlike gasoline tanks, CNG cylinders are only certified for a limited period of time before they expire. Due to improved technology in manufacturing techniques, the NGV industry's most recent standards for cylinder life are 20 years, with labeling requirements setting a "Do not use after" date.²³

The National Highway Traffic Safety Administration (NHTSA) mandated notices be affixed to all CNG cylinders for vehicles produced after Dec. 2, 1996. The notices state the cylinders should be inspected for damage or deterioration every 36 months or 36,000 miles, whichever comes first, or after a fire or accident.²⁴

Fuel & Infrastructure Providers

Fueling options and availability

There are a number of publicly accessible CNG dispensers in North Carolina, as shown in Table 1. Many fleets using natural gas depend on these publicly available stations for their operation. Much like a typical gasoline or diesel station, the driver pulls up to the dispenser and uses a credit card or fuel card to purchase fuel. Filling the vehicle's tank is comparable to filling with a petroleum fuel. No prior scheduling is required, although some stations are only open during regular business hours.

One advantage of using publicly available stations is 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. The table below shows the CNG stations in North Carolina as of February 2014.



Figure 3. Public Station in Durham

City	Station Name	Street Address	Station Phone
Arden	NC – CNG	2618 Hendersonville Rd	828-654-8300
Asheville	City of Asheville	45 McCormick Pl	828-259-5700
Asheville	PSNC Energy	15 Overland Industrial Blvd	877-776-2427
Charlotte	Piedmont Natural Gas	112 Verbena St	919-235-6006
Dudley	Piedmont Natural Gas	250 Five Points Rd	919-235-6006

²² <http://iaspub.epa.gov/otagpub/>

²³ Older CNG cylinders manufactured in the early 1990's expired after 15 years.

²⁴ <http://www.government-fleet.com/channel/green-fleet/article/story/2010/05/what-happens-when-your-cng-tanks-expire.aspx?prestitial=1>

Durham	PSNC Energy	2541 Whilden Dr	877-776-2427
Fayetteville	Piedmont Natural Gas	1069 Wilkes Rd	919-235-6006
Gastonia	PSNC Energy	800 Gaston Rd	704-810-3282
Greensboro	Piedmont Natural Gas	2611 Greengate Dr	919-235-6006
Hendersonville	Henderson County	320 Williams St	828-697-4809
Hickory	City of Hickory	1441 9th Ave NE	828-323-7573
High Point	Piedmont Natural Gas	2623 Uwharrie Rd	919-235-6006
Lexington	Davidson County	925 N Main St	336-242-2250
Raleigh	PSNC Energy	2712 Discovery Dr	877-776-2427
Raleigh	City of Raleigh	4120 New Bern Ave	919-996-2733
Raleigh	PSNC Energy	4211 Global St	919-836-2428
Troutman	PSNC Energy	121 Houston Rd	877-776-2427
Winston-Salem	Piedmont Natural Gas	2300 Lowery St	919-235-6006

Table 1. Listing of Publicly Available Fuel Stations in North Carolina.

For current NC CNG refueling/station availability, the Alternative Fuels Data Center has a nationwide [alternative fueling station search tool](#).²⁵ This tool will display the hours of each station, as well as options for payment.

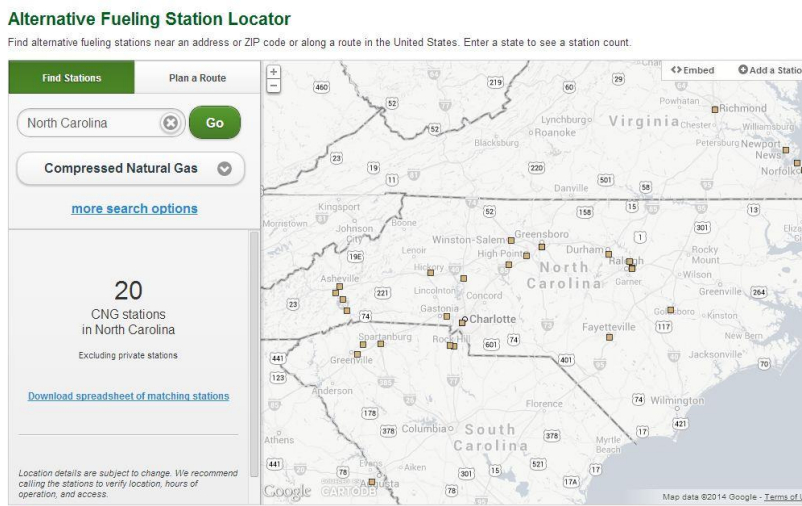


Figure 4. Alternative Fueling Station Locator²⁶.

The National Renewable Energy Lab has developed an iPhone application for users to locate the 20 closest alternative fueling stations within a 30-mile radius of any specified address. The app is available for free download at [Apple's App Store](#) and can be found by searching "Alternative Fueling Station Locator."

Establishing a CNG fuel dispensing facility 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 CNG fueling infrastructure. The Alternative Fuels Implementation Team has created a guide to installing natural gas fueling stations in North Carolina, called the [Natural Gas Station Installation Guide](#). This guide includes information on site selection, permitting, working with the fire marshal, and other valuable information.

²⁵ http://www.afdc.energy.gov/locator/stations/#results?utf8=%E2%9C%93&location=North+Carolina&filtered=true&fuel=E85&owner=all&payment=all&ev_level1=true&ev_level2=true&ev_dc_fast=true&radius_miles=5

²⁶ Image links to <http://www.afdc.energy.gov/locator/stations/>



Figure 5. Public Station in Goldsboro

There are two types of dispensers: time-fill and fast-fill. The following sections provide more information on these types of dispensers. The cost of installing a fueling station will vary based on the amount of fuel to be dispensed, the amount of compression required, storage needs, and other factors. Installation of a natural gas fueling station is an investment with a wide cost range depending on needs and circumstances – small, time-fill stations average \$10,000, while fast-fill stations could cost from \$400,000 to \$2 million depending on size and other factors.²⁷ The lower price of natural gas compared to conventional fuels (along with reduced maintenance costs) will allow the fleet to recoup money on their investment in infrastructure. Fleets that use a significant amount of fuel will see a faster rate of return than fleets that use less fuel.

Time-Fill Dispensers

Vehicles that return to a central location with long periods of down time can utilize a time-fill dispenser. Time-fill dispensers allow the use of smaller compressor systems compared to a fast-fill system, and deliver the fuel directly from the compressor to the tank on each vehicle. As a result, this type of fueling infrastructure is typically less expensive to install than fast-fill stations. Therefore, this is a good fueling strategy for vehicles with large tanks that return to a central location and remain there for several hours. For example, a refuse vehicle fleet usually returns to a lot at the end of the day, when vehicles can be filled overnight.

Fast-Fill Dispensers

Fast-fill dispensers operate more like a traditional gasoline or diesel dispenser. A vehicle can be fueled in minutes while the driver waits. This is possible because the natural gas is compressed ahead of time, then stored on-site. Because of the storage capabilities, this type of infrastructure is more expensive than time-fill stations.

This type of fueling infrastructure is ideal for vehicles that can regularly access the fueling location, but that might not return to the same location overnight. “Hot-seat” duty cycles, where the vehicle is used continuously through day and evening shifts are also a good fit. All publicly accessible CNG stations in North Carolina use fast-fill dispensers, for the convenience of their customers.

Barrier Busters – Infrastructure

- Refer to map of existing and planned natural gas stations that are available for public use, or private stations which may provide an opportunity to form a fueling partnership
- Inquire about infrastructure-supplier agreements, wherein fuel provider pays for the fueling station in exchange for long-term fuel purchase contracts
- Consider partnership with nearby ‘anchor’ fleets to share infrastructure costs
- Carefully scrutinize fueling needs (current and future) to avoid overspending on compressor size, on a more expensive “fast fill” station when “time fill” station may be adequate

²⁷ http://www.afdc.energy.gov/fuels/natural_gas_infrastructure.html

Manufacturers and Options

There are many vendor options for designing and installing natural gas fueling systems. The North Carolina Clean Energy Technology Center maintains a list of technology providers in the [Clean Transportation Technology Industry Directory](#).²⁸ The natural gas infrastructure options can be found on page 8.

Crunch the numbers – Vehicle cost calculators

Another helpful tool for selecting a natural gas vehicle is the Vehicle and Infrastructure Cash-Flow Evaluation Model, or “VICE.” It can be accessed from the [Alternative Fuel Data Center](#).²⁹ This tool will determine the payback period of natural gas projects, as well as the petroleum displacement and greenhouse gas savings.

The North Carolina Clean Energy Technology Center (NCCETC) also offers a [Vehicle Cost 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 cost of capital rate), cumulative savings, return on investment, and payback period.

Barrier Busters – Vehicle Costs

- Utilize available cost calculators to select best vehicle options to match operational needs
- Ensure adequate CNG 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 CNG vehicles

Using this NCCETC vehicle calculator for a hypothetical fleet, the following is a summary comparison of five new 2014 pickups running on CNG versus gasoline. The assumptions and inputs for this scenario used include:

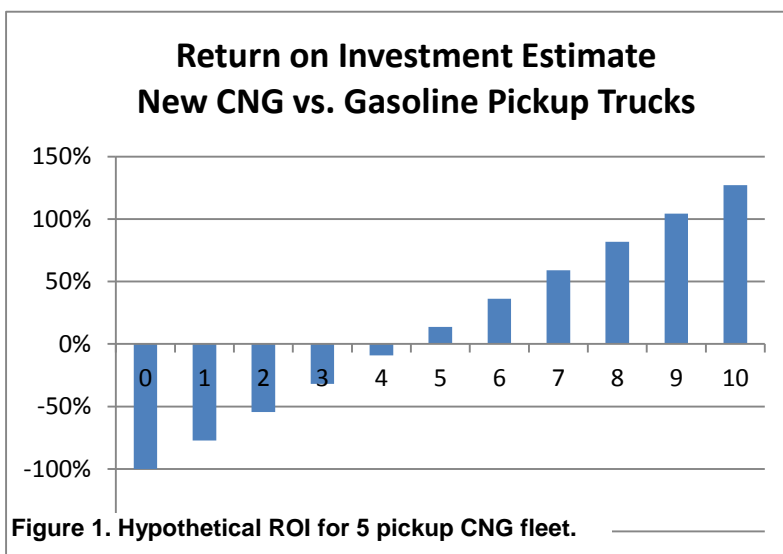
- Public fleet using public fueling infrastructure for gasoline and CNG (no infrastructure costs were included, no rebates or tax incentives were applied).
- Average public fuel prices in Raleigh NC March 2014 (\$3.39/gallon for gasoline, \$1.71/gge for CNG)
- Average of 15,000 miles driven per year
- Average fuel efficiency of gasoline pickups of 12 miles per gallon
- CNG conversion cost of \$8,000 per vehicle
- Technician/driver training cost of \$1,000

²⁸ <http://nccleantech.ncsu.edu/wp-content/uploads/Clean-Transportation-Technology-Industry-Directory.pdf>

²⁹ http://www.afdc.energy.gov/fuels/natural_gas_infrastructure.html

Vehicle Cost Calculator Results for Hypothetical 5-truck Fleet

- Payback period: 5 years
- Annual fuel savings: \$9,313 (\$1,862 per vehicle)
- 10-year cumulative savings: \$52,125
- 10-year ROI: 127% (see Figure 1)



North Carolina CNG Case Study

There are a number of fleets successfully using compressed natural gas throughout North Carolina. Details regarding motivation, factors tied to the decision, lessons learned and the overall experience for select fleets can be found at [“CNG Case Study”](#). Additionally, the [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 natural gas. A few North Carolina fleets that use natural gas and are in the Database include:

- BuildSense in Durham, NC
- City of Charlotte Solid Waste Services
- FL Transportation in Charlotte, NC
- Waste Industries across NC
- Public Service North Carolina-Asheville

Trends Looking Ahead

Heavy-Duty Vehicle Fleets

North Carolina’s biggest trend in natural gas vehicles is the adoption of this fuel in heavy-duty fleets. Refuse haulers in particular have been popular natural gas applications. This is due to the large amount of fuel used in these vehicles, offering opportunities for excellent cost savings. A single refuse truck traveling 10,000 miles a year, for example, could save about \$9,000 on fuel in that time assuming a fuel efficiency of 2.5 miles per gasoline gallon equivalent using CNG. Refuse haulers also return to a central location each night, making them ideal for [usually less costly] time-fill infrastructure. Public and private refuse fleets alike have adopted natural gas for some or all of their vehicles. The Cities of Charlotte, Greensboro, and Hendersonville, and the Town of Rocky Mount all deployed natural gas refuse vehicles through the Carolina Blue Skies and Green Jobs Initiative.³⁰ Waste Industries of Durham and Waste Management in Gastonia are examples of private heavy-duty fleets adopting natural gas.³¹

Hydraulic Fracturing

Natural gas reserves in the United States are expanding supply in the United States.³² These reserves can be extracted using horizontal drilling and hydraulic fracturing, a process also known as “fracking.” At time of publication, the effects of hydraulic fracturing on the environment and public health are unknown. The U.S.

³⁰ Carolina Blue Skies Program: <http://carolinablueskies.net/>

³¹ <http://www.wasteindustries.com/News/CNGStationLaunch.pdf>

³² <http://www.eia.gov/pressroom/releases/press375.cfm>

Environmental Protection Agency is conducting a study on these effects and anticipates its release in 2014.³³ The concerns around hydraulic fracturing include the large amount of water used in the fracking process, as well as the effects of hazardous chemicals mixed near the wells and injected into the fracking water. Currently, federal regulation exempts hydraulic fracturing chemicals from regulation in the Safe Water Drinking Act and the Clean Water Act. Another concern with natural gas production is methane leaks during the extraction and distribution process. Methane is a greenhouse gas 30 times more potent than carbon dioxide and is currently not a regulated emission under federal law.

Biogas

Renewable natural gas, also called biogas, is captured from the decomposition of organic matter.³⁴ Wastewater treatment, solid waste, and agricultural facilities produce this gas as a byproduct during normal operation. In order for this gas to be used as a vehicle fuel, it must first be purified and then distributed. The recaptured gas can be used to generate electricity, heat homes, or fuel vehicles. Examples of landfill gas to CNG include the Sanitation Districts of Los Angeles County, and a facility in DeKalb County Georgia.^{35, 36} In DeKalb County Georgia a U.S. Department of Energy County grant helped install a CNG station fueled by biogas produced at the county landfill that is expected to save \$3 million dollars in fuel costs over several years. In North Carolina, refuse facilities such as landfills could capture methane and use it to fuel vehicles. Additionally, as the second-largest hog farm producer in the United States, North Carolina could produce 169 million gasoline gallons equivalent of CNG from hog farms alone.³⁷

³³ <http://www2.epa.gov/hydraulicfracturing>

³⁴ http://www.afdc.energy.gov/fuels/emerging_biogas.html

³⁵ <http://www.lacsd.org/solidwaste/swpp/energyrecovery/default.asp>

³⁶ <http://www.co.dekalb.ga.us/greenfocus/energy.html>

³⁷ http://fuelsfix.com/eazines/FuelsFix_Fall13-Final.pdf, page 28, "Feces to Fuel"